

Microsoft

Introduction to Programming

Through Game Development

Using Microsoft® XNA® Game Studio

Rob Miles

ACADEMIC EDITION

PUBLISHED BY

Microsoft Press
A Division of Microsoft Corporation
One Microsoft Way
Redmond, Washington 98052-6399

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Library of Congress Control Number: 2009932322

A CIP catalogue record for this book is available from the British Library.

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Cover: Tom Draper Design

Body Part No. X16-03277

To Mary, David, and Jenny.

Table of Contents

| | |
|------------------------|------|
| Acknowledgements | xv |
| Introduction | xvii |

Part I **Getting Started**

| | |
|--|-----------|
| 1 Computers, C#, XNA, and You | 3 |
| Introduction | 3 |
| Learning to Program | 3 |
| Becoming a Great Programmer | 4 |
| How the Book Works | 4 |
| C# and XNA | 5 |
| Getting Started | 6 |
| Installing the Development Environment and the XNA Framework | 6 |
| Setting Up a PC to Run XNA Games | 7 |
| Setting Up an Xbox 360 to Run XNA Games | 7 |
| Writing Your First Program | 10 |
| Creating Your First Project | 10 |
| Running Your First Program | 12 |
| Stopping a Program | 14 |
| Storing Games on the Xbox 360 or Zune | 15 |
| Running the Same XNA Game on Different Devices | 15 |
| Conclusion | 18 |
| Chapter Review Questions | 19 |
| 2 Programs, Data, and Pretty Colors | 21 |
| Introduction | 21 |
| Making a Game Program | 22 |
| Statements in the <i>Draw</i> Method | 23 |
| Working with Colors | 24 |
| Storing Color Values | 24 |
| Setting a Color Value | 25 |
| Controlling Color | 27 |
| Games and Classes | 27 |
| Classes as Offices | 29 |
| Game World Data | 30 |
| Storing Data in Computer Memory | 31 |
| Drawing by Using Our Color Intensity Variables | 32 |

Updating Our Colors 33
Memory Overflow and Data Values 35
Making a Proper Mood Light 36
Making Decisions in Your Program 37
The Completed Mood Light 40
Finding Program Bugs 42
Conclusion 43
Chapter Review Questions 44

3 Getting Player Input 45

Introduction 45
Reading a Gamepad 46
 Gamepads and Classes 46
 Finding a Gamepad 48
 Testing the Gamepad Status 49
 Zune Buttons 51
Using the Keyboard 52
 Stopping the Game with the Escape Key 53
 Using a Gamepad and a Keyboard
 at the Same Time 53
Adding Vibration 54
 Controlling the Vibration of a Gamepad 55
 Testing Intensity Values 55
Program Bugs 59
Conclusion 61
Chapter Review Questions 62

Part II Images, Sound, and Text

4 Displaying Images 65

Introduction 65
Resources and Content 66
 Getting Some Pictures 66
 Content Management Using XNA 67
 Working with Content Using XNA Game Studio 68
 XNA Game Studio Solutions and Projects 68
 Adding Resources to a Project 70
Using Resources in a Game 73
 Loading XNA Textures 73
 Positioning Your Game Sprite on the Screen 76

| | |
|---|------------|
| Sprite Drawing with <i>SpriteBatch</i> | 79 |
| Filling the Screen | 81 |
| Conclusion | 84 |
| Chapter Review Questions | 84 |
| 5 Writing Text | 85 |
| Introduction | 85 |
| Text and Computers | 85 |
| Text as a Resource | 85 |
| Creating the XNA Clock Project | 86 |
| Adding a Font Resource | 86 |
| Loading a Font | 89 |
| Drawing with a Font | 89 |
| Changing the Font Properties | 92 |
| Getting the Date and Time | 93 |
| Making a Prettier Clock with 3-D Text | 95 |
| Drawing Multiple Text Strings | 95 |
| Repeating Statements with a <i>for</i> Loop | 97 |
| Other Loop Constructions | 99 |
| Fun with <i>for</i> Loops | 99 |
| Creating Fake 3-D | 101 |
| Creating Shadows Using Transparent Colors | 101 |
| Drawing Images with Transparency | 103 |
| Conclusion | 104 |
| Chapter Review Questions | 104 |
| 6 Creating a Multi-Player Game | 105 |
| Introduction | 105 |
| Creating the Button-Bash Game | 105 |
| Level and Edge Detectors | 109 |
| Constructing the Complete Game | 109 |
| Adding Test Code | 112 |
| Conclusion | 114 |
| Chapter Review Questions | 114 |
| 7 Playing Sounds | 115 |
| Adding Sound | 115 |
| Creating the Drum Pad Project | 115 |
| Capturing Sounds with Audacity | 115 |
| Storing Sounds in Your Project | 117 |

| | |
|--|------------|
| Using Sounds in an XNA Program | 119 |
| Playing Background Music | 121 |
| Conclusion | 126 |
| Chapter Review Questions | 126 |
| 8 Creating a Timer | 127 |
| Making Another Game | 127 |
| Reaction Timer Bug | 130 |
| Finding Winners Using Arrays | 132 |
| Creating an Array | 132 |
| Using Data in an Array | 133 |
| Scanning an Array | 134 |
| Using an Array as a Lookup Table | 136 |
| Displaying the Winner | 137 |
| Conclusion | 138 |
| Chapter Review Questions | 139 |
| 9 Reading Text Input | 141 |
| Using the Keyboard in XNA | 141 |
| Creating the Message Board Project | 141 |
| Registering Key Presses | 142 |
| The Keys Type | 143 |
| Enumerated Types | 144 |
| Working with Arrays, Objects, and References | 144 |
| Values and References | 145 |
| Arrays as Offices | 145 |
| Say Hello to the Garbage Collector | 147 |
| Using References and Values | 147 |
| Why Do We Have References and Values? | 149 |
| References and <i>GetPressedKeys</i> | 149 |
| Displaying Keys | 149 |
| Detecting Key Presses | 151 |
| Decoding Key Characters | 155 |
| Using the Shift Keys | 156 |
| Editing the Text | 157 |
| Conclusion | 159 |
| Chapter Review Questions | 159 |

Part III Writing Proper Games

| | | |
|-----------|--|------------|
| 10 | Using C# Methods to Solve Problems | 163 |
| | Introduction | 163 |
| | Playing with Images | 163 |
| | Zooming In on an Image | 163 |
| | Creating a Zoom-Out | 165 |
| | Updating the Drawing Rectangle | 166 |
| | Creating a Method to Calculate Percentages | 169 |
| | Returning Nothing Using <i>void</i> | 171 |
| | Debugging C# Programs | 175 |
| | Hitting a Breakpoint | 176 |
| | Using Floating-Point Numbers in C# | 179 |
| | The Compiler and C# Types | 180 |
| | Compilers and Casting | 181 |
| | Expression Types | 182 |
| | Stopping the Zoom | 184 |
| | Zooming from the Center | 184 |
| | Conclusion | 187 |
| | Chapter Review Questions | 188 |
| 11 | A Game as a C# Program | 189 |
| | Introduction | 189 |
| | Creating Game Graphics | 190 |
| | Projects, Resources, and Classes | 191 |
| | XNA Game Studio Solutions and Projects | 191 |
| | The Program.cs File | 194 |
| | Renaming the <i>Game1</i> Class | 199 |
| | Creating Game Objects | 201 |
| | Sprites in Games | 201 |
| | Managing the Size of Game Sprites | 201 |
| | Moving Sprites | 204 |
| | Bouncing the Cheese | 206 |
| | Dealing with Display Overscan | 206 |
| | Conclusion | 208 |
| | Chapter Review Questions | 209 |

| | | |
|-----------|---|------------|
| 12 | Games, Objects, and State | 211 |
| | Introduction | 211 |
| | Adding Bread to Your Game | 211 |
| | Using a Structure to Hold Sprite Information | 212 |
| | Using the Gamepad Thumbsticks to Control Movement | 214 |
| | Improving Programs Using Methods | 215 |
| | Handling Collisions | 218 |
| | Making the Cheese Bounce off the Bat | 218 |
| | Strange Bounce Behavior | 219 |
| | Strange Edge Behavior | 220 |
| | Adding Tomato Targets | 223 |
| | Tomato Collisions | 225 |
| | Conclusion | 228 |
| | Chapter Review Questions | 228 |
| 13 | Making a Complete Game | 229 |
| | Introduction | 229 |
| | Making a Finished Game | 229 |
| | Adding Scores to a Game | 229 |
| | Adding Survival | 231 |
| | Adding Progression | 232 |
| | Improving Code Design | 235 |
| | Refactoring by Creating Methods from Code | 236 |
| | Refactoring by Changing Identifiers | 237 |
| | Creating Code Regions | 240 |
| | Creating Useful Comments | 241 |
| | Adding a Background | 242 |
| | Adding a Title Screen | 243 |
| | Games and State | 244 |
| | Using the State Values | 244 |
| | Building a State Machine | 245 |
| | Conclusion | 248 |
| | Chapter Review Questions | 248 |
| 14 | Classes, Objects, and Games | 249 |
| | Introduction | 249 |
| | Design with Objects | 249 |
| | An Object Refresher Course | 250 |
| | Cohesion and Objects | 250 |
| | Coupling Between Objects | 253 |

| | |
|---|------------|
| Designing Object Interactions | 256 |
| Container Objects | 257 |
| Background and Title Screen Objects | 259 |
| Classes and Structures | 260 |
| Creating and Using a Structure | 260 |
| Creating and Using an Instance of a Class | 261 |
| References | 263 |
| Multiple References to an Instance | 263 |
| No References to an Instance | 264 |
| Why Bother with References? | 264 |
| Value and Reference Types | 265 |
| Should Our Game Objects Be Classes or Structures? | 265 |
| Creating a Sprite Class Hierarchy | 267 |
| The <i>BaseSprite</i> Class | 267 |
| Extending the <i>BaseSprite</i> to Produce a <i>TitleSprite</i> | 268 |
| Building a Class Hierarchy | 269 |
| Adding a Deadly Pepper | 270 |
| Creating a <i>DeadlySprite</i> Class | 271 |
| Conclusion | 275 |
| Chapter Review Questions | 275 |
| 15 Creating Game Components | 277 |
| Introduction | 277 |
| Objects and Abstraction | 277 |
| Creating an Abstract Class in C# | 278 |
| Extending an Abstract Class | 278 |
| Designing with Abstract Classes | 280 |
| References to Abstract Parent Classes | 280 |
| Constructing Class Instances | 281 |
| Constructors in Structures | 283 |
| Constructors in Class Hierarchies | 284 |
| Adding 100 Killer Tangerines | 285 |
| Creating a <i>KillerSprite</i> Class | 286 |
| Positioning the <i>KillerSprites</i> Using Random Numbers | 286 |
| Using Lists of References | 289 |
| Adding Artificial Intelligence | 293 |
| Chasing the Bread Bat | 293 |
| Adding Game Sounds | 298 |

| | |
|---|------------|
| From Objects to Components | 300 |
| C# Interfaces | 301 |
| Creating an Interface | 302 |
| Implementing an Interface | 303 |
| References to Interfaces | 303 |
| Linking Bread, Cheese, and Tomatoes | 304 |
| Designing with Interfaces | 304 |
| Conclusion | 305 |
| Chapter Review Questions | 305 |
| 16 Creating Multi-Player Networked Games | 307 |
| Introduction | 307 |
| Networks and Computers | 307 |
| Starting with the Signal | 307 |
| Building Up to Packets | 308 |
| Addressing Messages | 308 |
| Routing | 309 |
| Calls and Datagrams | 309 |
| Networks and Protocols | 310 |
| Xbox Live | 311 |
| Gamertags and Xbox Live | 311 |
| System Link and XNA | 311 |
| Bread and Cheese Pong | 312 |
| Managing Gamer Profiles in XNA | 313 |
| Ensuring a Gamer Is Signed In for Network Play | 317 |
| Zunes and Gamer Profiles | 318 |
| Creating a Game Lobby | 319 |
| Network Games and State | 319 |
| Playing the Game | 326 |
| The Completed Game | 330 |
| Zune Network Games | 331 |
| Conclusion | 331 |
| Making Games for Fun | 331 |
| <i>verysillygames.com</i> | 332 |
| Chapter Review Questions | 332 |
| Answers | 335 |
| Glossary | 351 |
| Index | 371 |

Acknowledgments

I'm not sure if you are meant to have fun writing books, but I do. Thanks to Devon Musgrave, Ben Ryan, and Valerie Woolley at Microsoft Press for making everything fit so well together, and to Kurt Meyer, the technical reviewer, for making sure it all makes sense. I must also mention the Microsoft XNA team, who keep making a great thing better, year on year.

Introduction

There has never been a better time to learn how to program. Modern programming languages, coupled with powerful and widely available development environments, provide an excellent place to work. A wide range of operating environments, including mobile devices, cloud computing, robotics, embedded devices, and games, means that you can apply your programming-acquired skills in a huge range of different areas.

Programming lets you bring your ideas to life, and with C# and XNA expertise you can learn a lot about how games work and even create totally new ones of your own.

This book teaches you programming from first principles. It shows you how to use the C# language to solve problems and how C# is used within the Microsoft XNA Framework to create computer games. The games that you write can run on a Microsoft Windows PC, an Xbox 360, or a Zune device. Along the way you will also gain an insight into how software is created, and what makes an effective programmer.

C# is a massively popular programming language used by many thousands of software developers all over the world. The C# skills that you pick up in this book can also be used as the basis of a career in programming should you find that you really enjoy writing programs. And because the design of the C# language is very similar to C, C++, and Java you will find that your skills can be used with them too.

XNA is a framework which allows games to be written in C#. It provides all the “heavy lifting” concerned with making a game work. It drives the display, manages content, and provides an easy to use way of interacting with gamepads and other controllers. It also provides a common platform so that XNA games can run on a variety of different devices, and XNA games can also be distributed to Xbox users around the world using the Xbox Live service.

The book also provides a working introduction to the Microsoft Visual Studio development environment used in many thousands of software houses throughout the world. This tool is the means by which programs are created, tested, and deployed.

Who This Book Is For

This book teaches programming in a gaming context. However, the programming principles that are explained can be used in any application area. If you want to learn the C# language and the fundamentals of object-oriented programming using a modern and popular programming language then this book is for you.

The book is tightly coupled to an instructional course which also contains practical sessions, project ideas, and even tests so that you can find out how well you are learning. By the end of it you will have acquired a grasp of programming fundamentals, an insight into the inner workings of computer games, and hopefully had some fun too.

The book is structured into 16 chapters, starting with the simplest possible XNA program and moving on to show you how to use the Xbox and Zune gamepad, the keyboard, sounds, graphics, and network in your games. In the course of learning how to use C# and XNA, you create some very silly games, including Color Nerve, Mind Reader, Gamepad Racer, Bread and Cheese, and Button Bash.

System Requirements

You need the following hardware and software to build and run the code samples for this book. Chapter 1, “Computers, C#, XNA, and You,” explains how to set up your environment.

- A Windows PC with 3-D graphics acceleration if you want to run your XNA games on your PC.
- Microsoft Windows XP SP2 or Windows Vista.
- Microsoft Visual Studio 2008 C# Express edition, Visual Studio 2008 Standard edition, Visual Studio 2008 Professional edition, or Visual Studio 2008 Team Suite.
- XNA Game Studio 3.0.
- To test your games on a console, you need an Xbox 360 fitted with a hard disk. Your Xbox 360 must be connected to Xbox Live, and you need to join the XNA Creators Club. You will find out how to do this in Chapter 1.
- If you have a Zune media player, you can run XNA games on that as well. Any Zune device, from the original 30-gigabyte (GB) device to the latest 4 GB device, can be connected to your PC you can load your XNA games into it.

Code Samples

All the code samples discussed in this book are accessible through the class instructor.

There are also code samples and games at <http://www.verbsillygames.com>.

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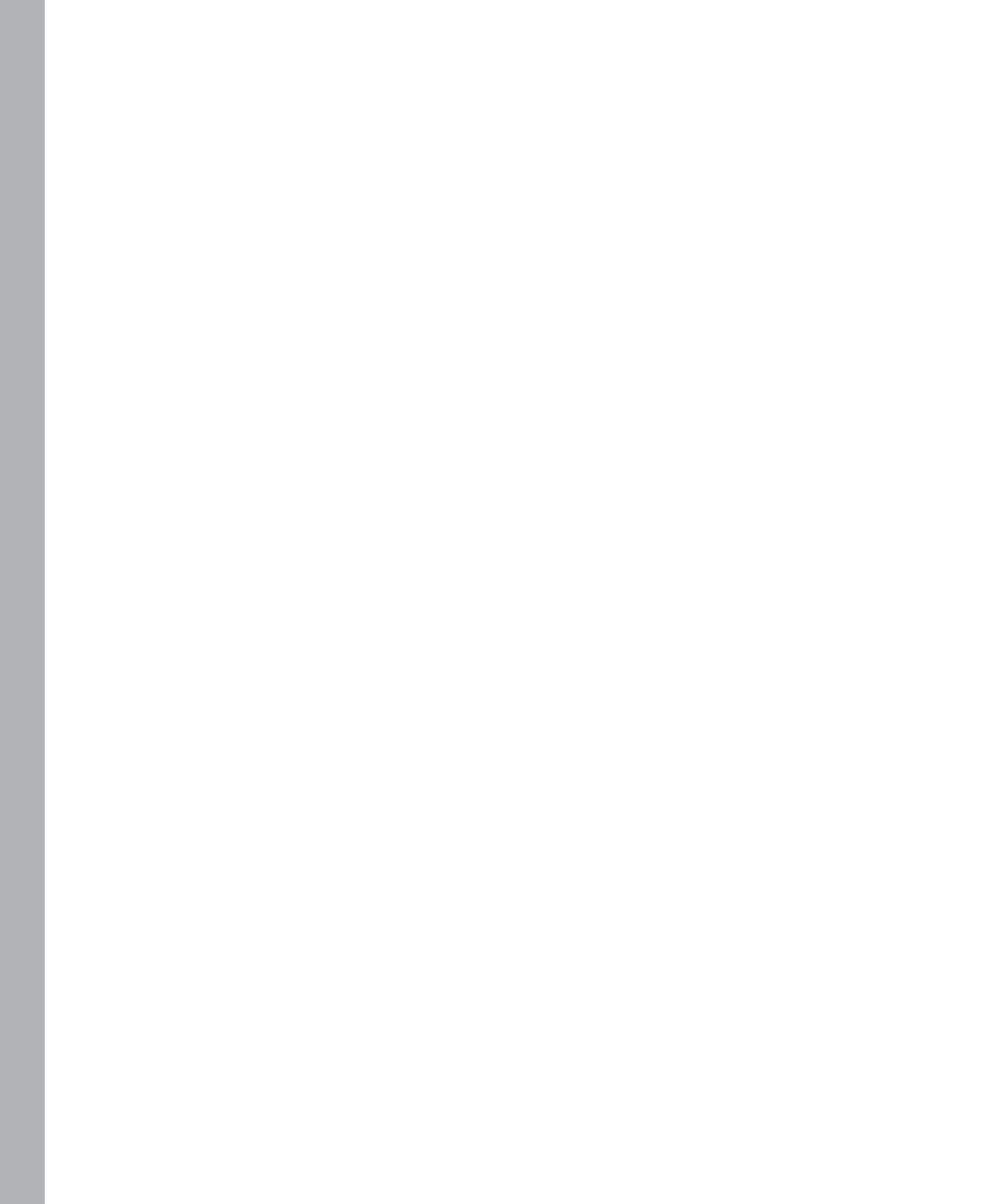
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Part I

Getting Started

In this part:

| | |
|---|----|
| Chapter 1: Computers, C#, XNA, and You..... | 3 |
| Chapter 2: Programs, Data, and Pretty Colors..... | 21 |
| Chapter 3: Getting Player Input..... | 45 |



Chapter 1

Computers, C#, XNA, and You

In this chapter, you will

- Discover what makes a good programmer and what makes a great one.
- See what computers are all about.
- Find out why C# is a language you can love and Microsoft XNA is a framework you can adore.
- Get your system set up so that you can write code.
- Run your first XNA program.

Introduction

Welcome to the wonderful world of Rob Miles—a world of bad jokes, puns, and programming. In this book, I'm going to give you an introduction to the C# programming language and show you how to use C# to create XNA games. If you have programmed before, I'd be grateful if you'd still read all the text. It's worth it just for the jokes, and you may actually learn something as you're laughing.

Learning to Program

If you haven't programmed before, don't worry. Programming is not rocket science. It is, well, programming, and there are many more people in the world who have learned programming than rocket science. The bad news about learning to program is that you have lots of different things to learn when you start, and this can be confusing. But the keys to learning programming are simple:

- **Practice** Do a lot of programming and force yourself to think about things from a problem-solving point of view.
- **Study** Look at programs written by other people. You can learn a lot from studying code that others have created. Figuring out how somebody else did the job is a great starting point for your solution. And remember that in many cases, there is no best solution—just solutions that are better in a particular context. (In other words, sometimes you need an approach that is the fastest or the smallest or the easiest to use, and so on.)
- **Persistence** Writing programs is hard work. And you have to work hard at it. The main reason most folks don't make it as programmers is that they give up, not because

they are stupid. However, don't get too persistent. If you haven't solved a programming problem in 30 minutes, you should call a timeout and seek help or, at least, walk away from the problem and come back to it. Staying up all night trying to sort out a problem is not a good plan. It just makes you irritable in the morning. If you go to bed, have a nice sleep, and then go back to the problem in the morning, you will be amazed how often you can fix it in just a few minutes. (Later in this book, we'll cover what else you can do if a problem is being stubborn.)

Becoming a Great Programmer

You might think that great programmers can type a thousand words a second, have a mega-sized brain, and are fitted with a socket that lets them connect directly to a computer. This is not true. Especially the socket bit. In my experience, the best programmers are the ones who are the most fun to be with. The ones who you enjoy talking to. The ones who don't get upset when you find a mistake in their programs and who sometimes agree that your solution is better than the one that they invented. I'd much rather work with someone like that than someone who can write a hundred lines of code a minute but who refuses to speak to me if I dare to suggest that one of those lines might be wrong.

Great programmers take care to find out that what they are doing is the right thing. If they are working for a customer, they make sure that the customer gets what the customer wants. They do not assume that they know the best way to do it and just do it their way. They make sure that what they produce is tested and comes with helpful documentation. They work in the team, make coffee when it is their turn, and do whatever it takes to make sure that the project has a happy ending. Of course, they might also fill your office with beach balls, superglue your keyboard to the desk, or cover your chair with aluminum foil, but these are all done in a friendly spirit.

I have secured the services of a great programmer who will be adding Programmer's Points to our text. These are truly words of wisdom, so make sure to take note when you see them.

How the Book Works

Great scientists like Sir Isaac Newton and Benjamin Franklin performed experiments to discover how the world works. Then people like Thomas Edison came along and again experimented with what science and engineering could do to make things that everybody wants. You are going to take a similar experimental approach to learning about programming. By playing with XNA and writing tiny games, you are going to investigate how a computer works and how you can invent new kinds of computer games.

As you go through the text, you should never be more than a page or so away from making something happen with a program, so it helps if you have a computer system and an Xbox

360 or Zune nearby so that you can try things out. However, you don't have to have ready access to hardware when you read the text because all the programs in the book are laid out and explained in detail.

Don't be afraid to experiment and try things out yourself. At certain points in the text, I suggest ideas you might find fun to explore. Remember that learning by doing is one of the best ways to pick things up, so feel free to try stuff. One of the great things about creating game programs is that even the code that you get a bit wrong can produce cool-looking results. You might even end up creating an entirely new type of game by mistake!

Remember that the great scientists did not always find it easy to understand immediately what was going on inside their experiments, and the same is true about programming. Some of the things that you do when you write programs do not seem to make much sense at first, so be prepared to have to work to understand what is going on inside the program.



Note Throughout the chapters, words appearing in *italics* are explained more fully in the Glossary at the end of this book.

C# and XNA

Before you go any farther, it is important that you consider exactly what this book is for. You are going to learn about the *programming language C#* and the *XNA Software Development Kit*. Understanding the difference between the two is key. You are familiar with the idea of a computer program. At the moment, I'm using a word processor to create this text. I started the word processing program, and it is telling my computer to take the text that I type and add it to the document I am writing. The program is the set of instructions that tells the computer what to do with the information it receives from the keyboard.

The C# programming language is a way of expressing that set of instructions. When you create your games, you write lines of C# to tell the computer how to make each game work. You can use C# to create programs that do many other tasks; you can even use it to create your own word processor.

A Software Development Kit (SDK) is a set of prebuilt program components that you can use as part of other programs. The XNA SDK provides program code that will draw things on the screen, play sounds, read the Xbox 360 gamepad, and do lots of other useful things. When you create games, the C# code you write uses these prebuilt features of XNA. Part of becoming a successful programmer is learning how to best use the features provided by an SDK. Experience with the XNA SDK makes it much easier for you to understand how to use other SDKs. A particular SDK has an overall architecture that contains all the features that the SDK provides. This is often called a *framework*.

Getting Started

You are going to create programs on the PC and then either run them on the PC or send them into an Xbox 360 or Zune for execution. Either way, you need to install some tools on your PC.

Installing the Development Environment and the XNA Framework

When developers wanted to write a program on the very first computers, they had to take the back off and actually change the wires in the machine. Fortunately, things have moved on, and now you can use an *Integrated Development Environment* (IDE) to create your code. An IDE gets its name because it provides a single place where you can perform the entire creative process of code development. In an IDE, you can write a program by using the built-in text editor, you can run the program and see what it does, and you can also *debug* the program, which means you stop it and try to find out why it is not doing what you want it to. The IDE you are going to use is one of the Microsoft Visual Studio 2008 Express Editions, specifically the Microsoft Visual C# 2008 Express Edition. This is a version of the hugely powerful Visual Studio product, which is used by professional developers all over the world. At this point, I'm assuming that you have already installed Visual C# 2008 Express Edition and have it running on your machine. You can download Express editions of Microsoft software for free from <http://www.microsoft.com/Express/>. The setup procedure is quite straightforward, and at the end of the process you are asked to register your copy. Registration does not cost you any money and actually gives you access to even more free resources. There are a number of other Express products that you can install. You can use these in addition to XNA Game Studio 3.0, but they are not required to create XNA games.



Note If you have other versions of Visual Studio on your machine, you can also use these to write XNA games so long as they include the C# development environment. However, you must make sure that your version of Visual Studio has the latest version of the service packs installed. The XNA Creators Club Web site, <http://creators.xna.com>, has up-to-date information on service packs and Visual Studio versions.

Once you have got your development environment working, you need to install the XNA Framework. This binds itself to Visual Studio and provides it with all the extra libraries needed to create and deploy games. You can download the XNA Framework software from <http://creators.xna.com>. The installation is straightforward.



Note Once you install XNA on your system, you will find a link to Visual Studio in a folder called Microsoft XNA Game Studio 3.0 in the All Programs folder displayed under the Start menu. For the purpose of this text, every time I refer to "XNA Game Studio" from now on, I really mean the customized version of Visual C# 2008 Express Edition.

Setting Up a PC to Run XNA Games

Once you have installed XNA on your PC, you can use this to create and run games. If you just want to write games on the PC and run them on an Xbox 360 or Zune, you don't need a very powerful machine. So long as it supports the minimum requirements for Visual Studio, you can create game software. The games you are going to create in this book do not require particularly advanced hardware but you will need a machine with reasonable graphical ability to run some of the more advanced examples. You can find the detailed hardware and driver requirements for XNA at <http://msdn.microsoft.com/en-us/library/bb203925.aspx>.

XNA games can be controlled by the PC keyboard. If you have a wired Xbox gamepad, you can plug it into a Universal Serial Bus (USB) port on your computer and after the New Hardware Wizard runs, it just works. Windows Vista and Windows XP have the drivers for the gamepad already loaded. You can also obtain a special adapter that lets your PC communicate with wireless Xbox gamepads.

Setting Up an Xbox 360 to Run XNA Games

If you want the full game developer experience, there is no substitute for actually using a genuine console. In this section, you're going to find out how to set up an Xbox 360 and make it ready to receive the games that you are going to write.

To deploy games on your Xbox 360, it must be fitted with a hard disk. This is where the XNA Game Studio Connect application and the programs that you create are stored. Your console must also be connected to the Internet and you must be signed up for a Silver Xbox Live subscription or better. You must also be a Premium- or Trial-level member of the XNA Creators Club.

XNA Creators Club

If you want to deploy games to your Xbox 360 you must be a member of the XNA Creators Club. There are a number of different membership levels:

- **Visitor** A visitor to the Creators Club site can download XNA Game Studio and educational content. If all you want to do is create and run XNA games on your Windows PC you can just visit the Creators Club Web site to download software, find resources, and view the forums.
- **Registered** Registered members can create a profile on the Creators Club Web site and post questions on the forums. There is no charge to become a registered member.
- **Trial** A trial member of the Creators Club can download XNA Game Studio and educational content. They can also deploy XNA games to an Xbox 360. Trial membership is available from a variety of sources including MSDN Academic Alliance (<http://msdn.microsoft.com/academic/default.aspx>), Microsoft Faculty Connection (<http://www.microsoft.com/education/FacultyConnection>), Microsoft DreamSpark

(<http://www.dreamspark.com>), and the Dream-Build-Play contest (<http://www.dreambuildplay.com>). If you are a student on a course of study, ask at your institution to see if it has signed up for any of these initiatives.

- **Premium** A premium member of the Creators Club has all of the abilities of a trial member, and is also able to download additional sample content. Premium members can submit their games for distribution on the Xbox Live Marketplace and can also review Community Games submitted by other premium members. Premium membership presently costs \$99 a year or \$49 for three months.

Creators Club membership is linked to your Windows Live ID. Premium and Trial Creators Club memberships are also linked to your Xbox Live Gamer Tag. You can find membership details at <http://creators.xna.com/membership>.

You buy your Premium membership from the XNA Creators Club pages on Xbox Live using your Xbox 360. Find these pages by signing in to your Xbox 360 with your gamertag and then navigating to Game Marketplace|All Games and browsing down to X in the alphabetic list of game titles, where you will find the "XNA Creators Club" entry. This is also where you can download the XNA Game Studio Connect application that you must run to connect your Xbox to XNA Game Studio.

XNA Game Studio Connect

The XNA Game Studio Connect program provides the link between your Xbox 360 and the XNA Game Studio application that you use to write games on your Windows PC. When you want to send a program from your Windows PC to the Xbox 360 you must run this program on the Xbox 360. You download the program from Xbox Live and it is stored in your games library on your Xbox. You'll need to start it before each game development session in which you want to test your game on the Xbox.

You don't need this program to run XNA programs that have been downloaded onto your Xbox, these are placed in your game library on your Xbox and you can just run them as you would any other locally stored game.

XNA Game Studio Device Center

Before you can send a game from your Windows PC to your Xbox 360 (or Zune) the two systems must be connected together. Connections between XNA Game Studio and Xbox and Zune devices are managed by the XNA Game Studio Device Center application. You can find this on your Start menu, as shown in Figure 1-1. It manages all the devices on which you want to run games you have written.

I am presently developing programs for my Xbox 360 and my two Zune devices. My XNA Game Studio Device Center is shown in Figure 1-2. You can add an Xbox or a Zune by clicking Add Device. You will need to add a device so that you can send programs to it.

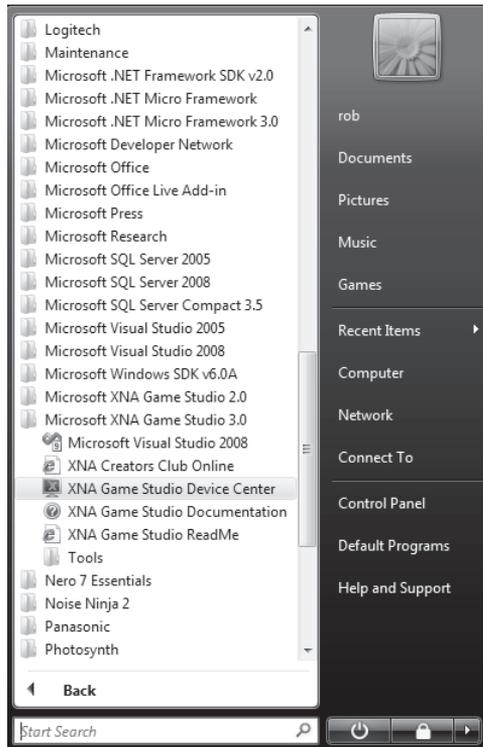


FIGURE 1-1 Starting the XNA Game Studio Device Center application

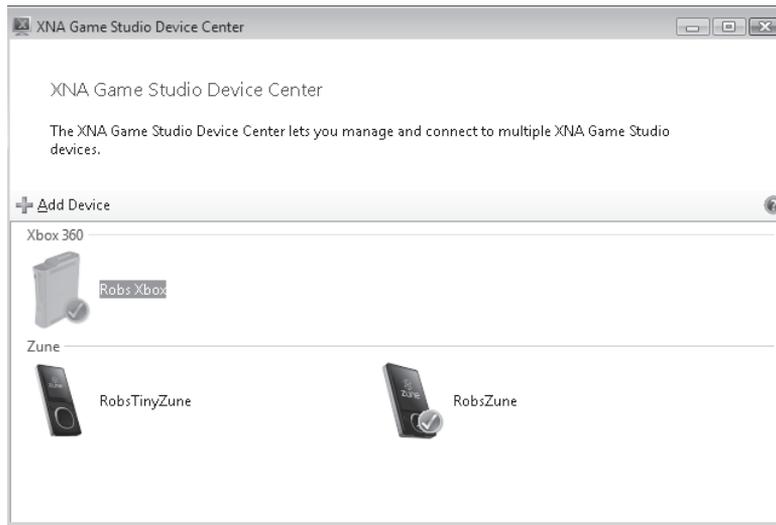


FIGURE 1-2 My XNA Game Studio Device Center

You need to use The XNA Game Studio Connect application on your Xbox and the XNA Game Studio Device Center on your Windows PC together to the first time you create a connection between your Xbox and your Windows PC. You can get detailed help with the procedure for connecting your Xbox or Zune to your PC by clicking the small blue question mark on the right side of the XNA Game Studio Device Center application.

Once you have completed the connection procedure, the PC and Xbox 360 retain the settings that you entered—when you attempt to send a program to the Xbox 360, it should just work.

Connecting a Zune to a Windows PC

The usefulness of XNA also extends to mobile devices. You can take your programming expertise and use it to create programs for your Zune music player. There are even special XNA libraries that let you access the music and pictures on your Zune so that you can write custom music players. Programs you create using XNA Game Studio can be stored on the Zune for you to use at any time. To do this you simply connect the Zune using its USB cable and deploy a Zune version of the program. But before you do that, you have to connect your Zune to Visual Studio using the XNA Game Studio Device Center. There is no Zune equivalent of the XNA Game Studio Connect program that you must run to deploy games to a Zune. The Zune will automatically accept games that are sent to it from XNA Game Studio.



Note Make sure that the Microsoft Zune application is not running when you are using your Zune device to develop games.

Writing Your First Program

You are now going to start from scratch with your first program. It won't actually do much—you won't be writing your own version of Halo just yet—but it does give you an insight into what XNA does and how you can write your own C# bits to produce a cool mood light.

Creating Your First Project

A computer game is not just a program—it is also lots of other bits and pieces that make playing the game fun and interesting. Just about every game has graphics, sounds, 3-D models of game objects, and all sorts of other items that must be created along with the code. This means that when you make a game, you have to manage all these other resources, too. The good news is that the XNA designers have thought of this, and they provide a comprehensive *content management* solution that looks after all these resources. You can just give your game resources to the Content Manager, and it makes sure that they are available to the programs that you write. Later on in the book, I'll show you how to add some content of your own so that you can use a picture of your mom or your dog as a game character.

The content management is part of the *project* mechanism provided by XNA Game Studio. What this means right now is that to create your first game program, you actually have to create an XNA Game Studio project.

To create a project, first start XNA Game Studio if it is not already running. Do this by choosing Microsoft Visual Studio from the Microsoft XNA Game Studio 3.0 folder in the Start menu shown in Figure 1-1.



Note This menu is created when XNA Game Studio is installed and contains a link to the version of Visual Studio 2008 installed on your Windows PC. If you are using a different version of Visual Studio 2008 (perhaps you installed XNA Game Studio on top your installation of Visual Studio 2008 Professional Edition) you will see a link to your version.

In XNA Game Studio, select New Project from the File menu, as shown in Figure 1-3. This automatically creates the entire project and the file into which you are going to put your code.

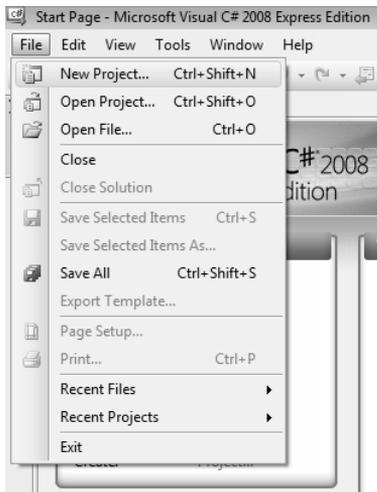


FIGURE 1-3 Opening the New Project dialog box

XNA Game Studio can make a whole range of different projects depending on what you actually want to build. The skeletons for each of these types of program are contained in project templates and Starter Kits. You can download and install other Starter Kits from the Creators Club Web site. Right now, you are going to use a template to create an empty XNA project.

Figure 1-4 shows all the possible types of projects that can be created. You need to select the project that matches the device on which you want to run the game.



Note Make sure that you create a “Game” and *NOT* a “Game Library”; otherwise, you will not be able to make your program run.

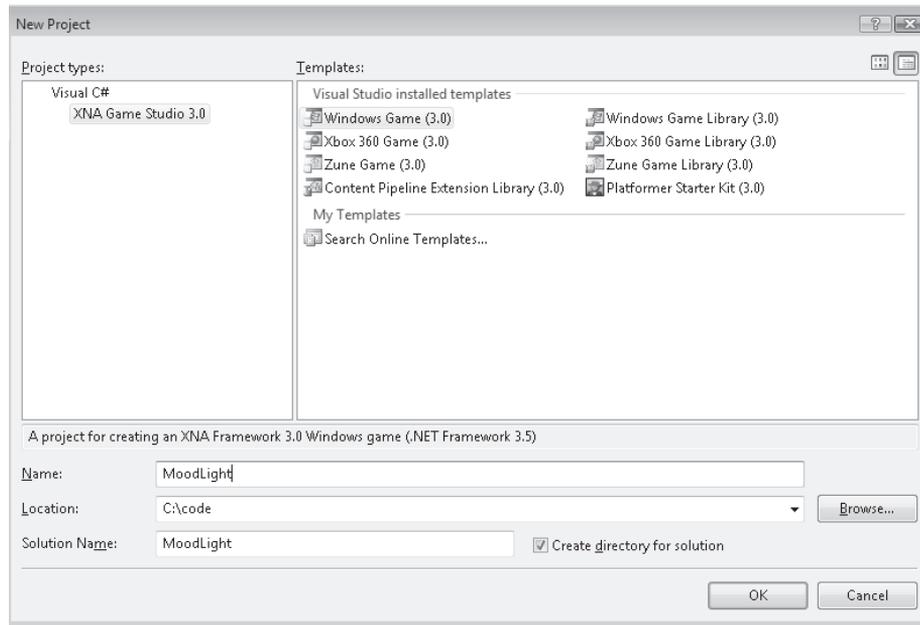


FIGURE 1-4 Creating a new project

Later in this chapter, I'll show you how you can create a workspace containing multiple projects, one for each target device. For now, you should just choose the one that you want to use; the way that the program works is identical for all. Call the project "MoodLight" because that is what we are building first. You can use the Browse button to select an appropriate destination for the project. You should ensure that the Create Directory For Solution check box is selected so that all the files for this game are held in one place. Once you have done this, click OK to get XNA Game Studio to build the project for you.

When the project has been created, you should see a screen that looks like the one in Figure 1-5. Yours might not look quite the same (it certainly won't have the big arrow pointing at the Start Debugging button), but it should look similar. There are a lot of controls that you can play with. At the moment quite a few are disabled and can't be used, but it still looks confusing the first time that you see it. The key here is not to panic. You are going to use only a few of the buttons to start with, and I'll explain the other ones as you need them.

Running Your First Program

If you are running your program on a PC, you can just click the Start Debugging button (indicated by the arrow in Figure 1-5), and the program runs. If you are sending your program to an Xbox 360, you must make sure that the XNA Game Studio Connect application is running on your Xbox 360 and that the Xbox has been connected to your Windows PC. If you are sending your program to a Zune, make sure that it is connected to your computer and that the Zune application is not running.

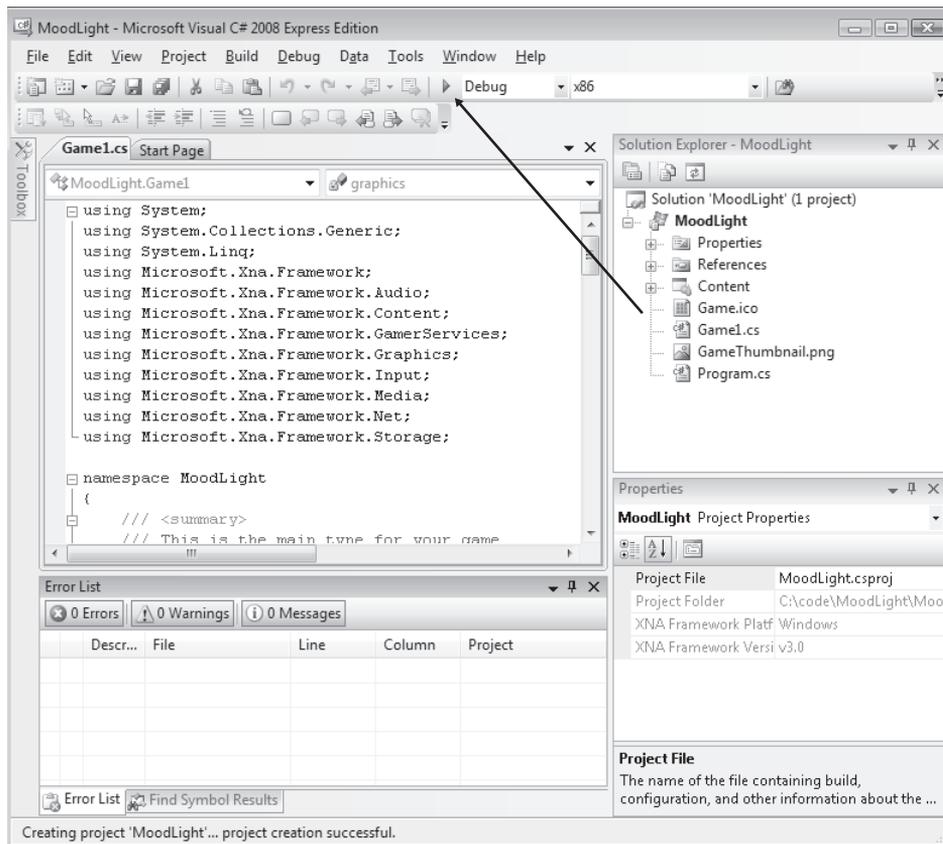


FIGURE 1-5 XNA Game Studio and MoodLight

When you click the button to run the program, a number of things happen in quick succession:

1. XNA Game Studio *compiles* the *source code* files. The source code of the program is all the lines of C# code that you and XNA Game Studio create that actually describe what you want the computer to do. A compiler is a program that takes source code and creates a set of machine instructions that can be loaded into the computer's processor to control what the computer does. The C# language has a particular specification, and the compiler knows all about the rules in the specification. The compiler rejects any program that it thinks is not correct and tells you about the *compilation errors*. You are going to have to live with the fact that you will see a lot of these errors if you decide to become a computer programmer.
2. Your project might contain a large number of different source files; each of them must be compiled. If all the program source files compile correctly, they are then combined with any resources (for example, images and sounds) that are part of the project.
3. If you are using an external device, either Xbox 360 or Zune, the compiled files are now transferred into it.

4. Finally, XNA Game Studio starts the program running. If you are using a Windows PC, the program runs in a window on the desktop. If you are using an external device, the program takes it over completely. At this point, the window or target device is under the control of your program statements.

When XNA Game Studio produces an empty project, it actually creates a program that will compile and run, so you can just click the Start Debugging button (if you haven't already) and turn the program loose.

When you run the program, the screen turns blue. That's it—nothing else. All that work to turn the screen blue? You could have done that with a can of paint in 30 seconds. The "empty" project from XNA just turns the screen blue, but in Chapter 2, "Programs, Data, and Pretty Colors," you're going to add some code to make it do much cooler things. You're going to make a light that can display millions of possible colors, an ever-changing mood lamp, and finally, the world's first-ever color-changing game.



Note One slightly irritating thing about Visual Studio is that when the program is running, the organization of the controls in Visual Studio changes. This can confuse a first-time user because menus, toolbars, and panes suddenly don't seem to be where they used to be. If you carefully compare Figure 1-5 and 1-6, you notice that a new toolbar has appeared that has buttons on it that you can use to pause or stop the program.

Stopping a Program

Before you do anything else, you need to stop the program. There are two ways to do this. You can press the Back button on an Xbox 360 gamepad or Zune to instruct the program to finish. If the program is running on a remote device, XNA Game Studio displays a message indicating that the remote connection to the device has been lost. Simply click OK on the message to dismiss it. Alternatively, you can stop the program from within XNA Game Studio by clicking the Stop button indicated by the arrow in Figure 1-6.

If you are using a PC and don't have an Xbox gamepad, you have to stop the program from XNA Game Studio.



Note You should not normally stop your program by using XNA Game Studio. This is like turning off your Xbox 360 rather than quitting a game correctly. It stops the program, but because the program is interrupted, it might not save all the game data properly before it stops. When you make your own game, you should make sure that you provide the player with instructions on how to stop it properly.

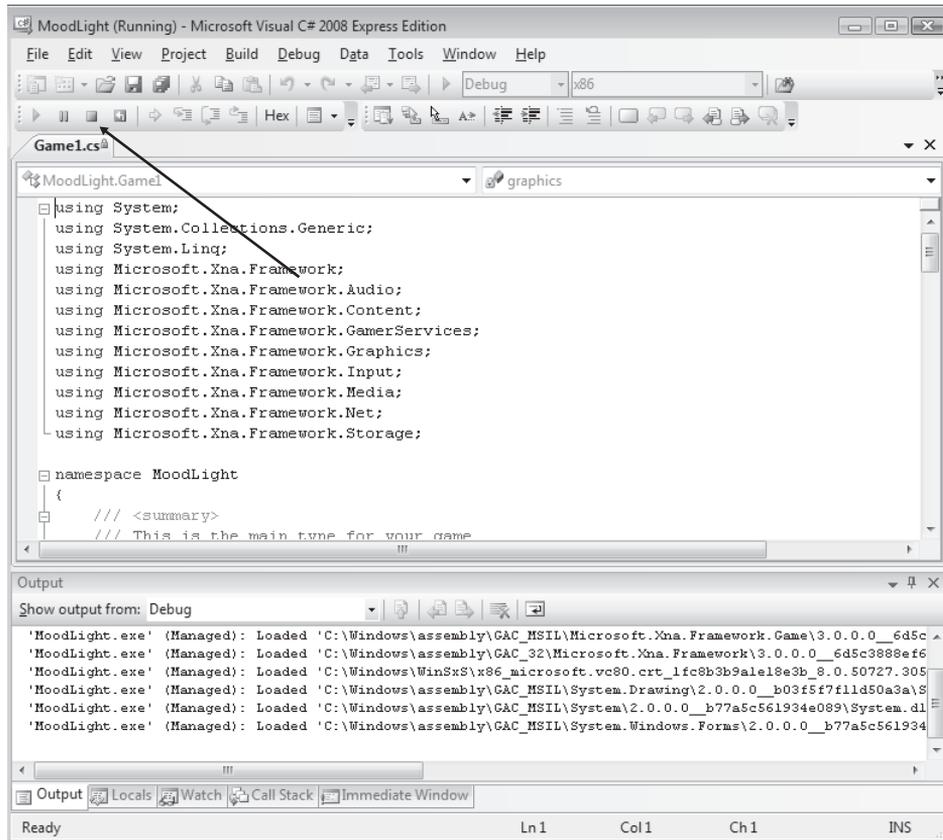


FIGURE 1-6 Stopping a running program

Storing Games on the Xbox 360 or Zune

Once you've created a game and deployed it to an Xbox 360 or Zune, the game itself remains stored inside the machine for you to load and play later, without the need for a PC to be attached. You can find the games you have created by selecting your Game Library on the Xbox 360 or entering the Games menu on the Zune.

Running the Same XNA Game on Different Devices

You can use a single XNA workspace to hold multiple projects, one for each device you want to target. You will find out more about projects and workspaces in the section "XNA Game Studio Solutions and Projects" in Chapter 4. The following example shows how a Windows PC project can be copied to produce an Xbox 360 project.

Creating a Copy of an XNA Project for Another Device

Start by clicking the MoodLight project in the Solution Explorer of XNA Game Studio so that it is selected. Then choose Create Copy Of MoodLight For Xbox 360 from the Project menu, as shown in Figure 1-7.

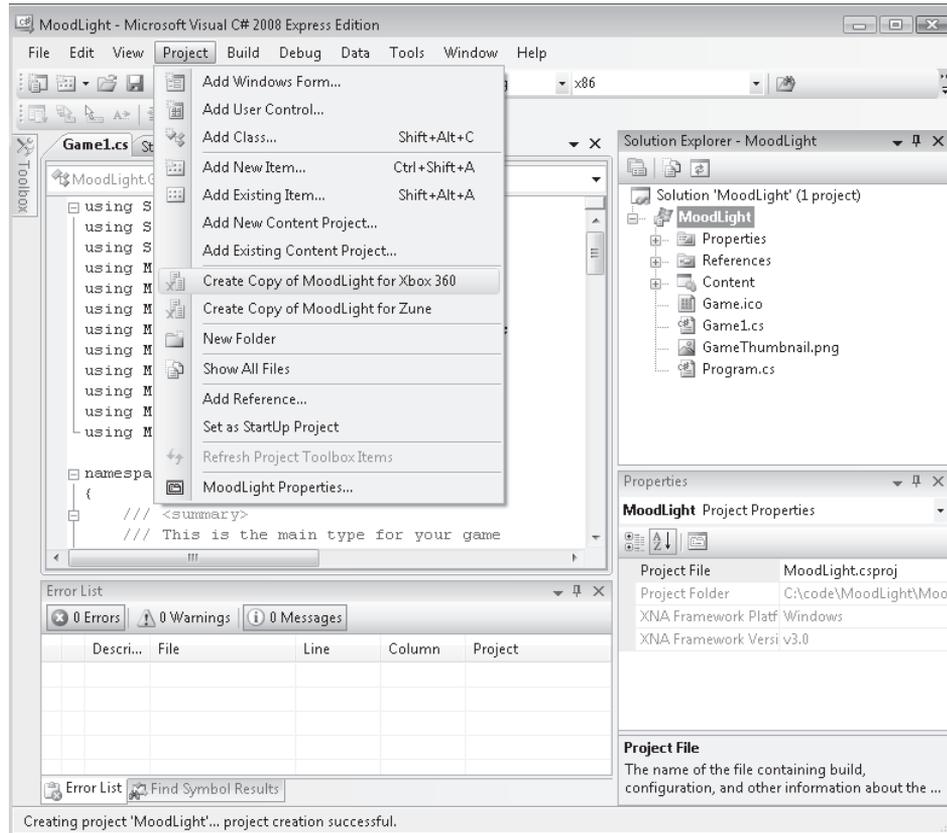


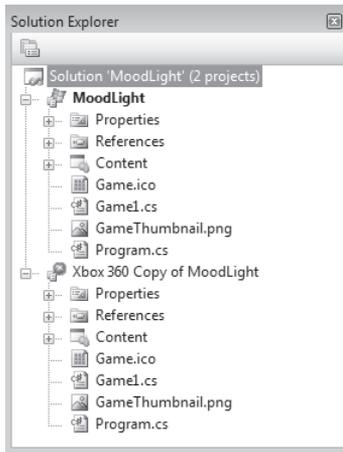
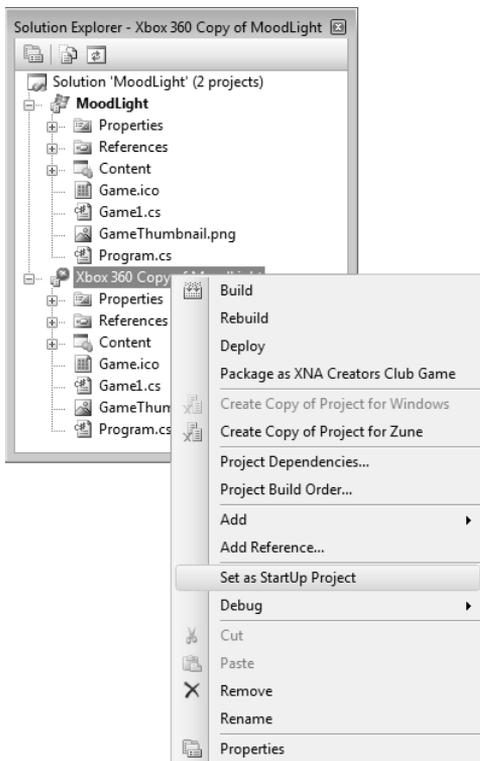
FIGURE 1-7 Copying a project

XNA Game Studio now copies the project and adds the copy to the workspace. This means that there are now two projects in the workspace, as shown in Figure 1-8.



Note It looks as if there are now two copies of everything concerned with the project. This is not actually the case. The copy uses links to the files in the original. This means that changes to the content of one project are reflected in the other.

You can select which of the projects started by setting one of the projects as the StartUp Project. If you look carefully at Figure 1-8, you see that the Windows version of MoodLight has the name of the project displayed in bold type. This means that it is the project that runs on the Windows machine. To set a project as the StartUp project, you right-click the project and choose Set As StartUp Project from the menu that appears, as shown in Figure 1-9.

**FIGURE 1-8** Multiple projects**FIGURE 1-9** Selecting the StartUp Project

When you click Start Debugging, the project that is selected as the StartUp project is the one that gets to run.

Selecting Your Deployment Targets

If your solution contains multiple projects that target different devices, XNA Game Studio attempts to send a compiled program to each of them when you try to run the program. This can be a problem, if for example you want to work on the Windows PC version of your program and don't have your Xbox 360 switched on. You can select where the compiled programs are sent by using the combobox at the top of XNA Game Studio, as shown in Figure 1-10. If you set this to Mixed Platforms, the program is sent to every device. Otherwise, pick just the target that you want. To deploy the game just to your Windows PC (both 32-bit and 64-bit versions), you need to set it to "x86."

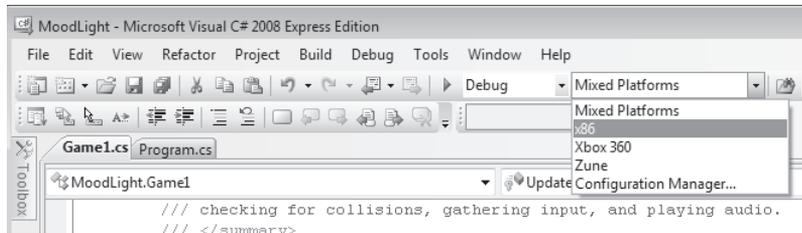


FIGURE 1-10 Selecting a deployment target

You can change this option at any time, depending on which platform you are working with.

Sample Code: Blue Screen of Life All the sample projects can be obtained from the course instructor. The sample projects in the 01 Moodlight Blue Screen folder for this chapter draw a blue screen for you. They are exactly the same as an empty project that you might create. The version supplied can be deployed to a PC, an Xbox 360, or a Zune. You can open the project by double-clicking the Visual Studio solution (.sln) file in this directory to start Visual Studio.

Conclusion

Actually, you've done quite a lot in this chapter. You've learned about computers, what makes great programmers so easy to get along with, and the difference between C# (the programming language of champions) and XNA (the game development framework of champions). You've also got all your development tools sorted out, and you are now ready to roll. And you did manage to turn the screen a nice blue color.

Chapter Review Questions

Every chapter in this book has a set of questions at the end, just to test you a little. There are no prizes, but you might find it useful to check that you know the answers to the questions in one chapter before you go on to the next. All the answers are either true or false, and you can find them by reviewing the chapter and looking in the Glossary. The list of answers for all the book's review questions are at the back of the book in Appendix A. No peeking now.

1. The most important thing about being a great programmer is having a big brain.
2. You must have an Xbox 360 to create games with C# and XNA.
3. XNA is a programming language.
4. XNA Game Studio is an IDE.
5. The C# compiler produces an XNA output file.
6. C# is a framework.
7. You need a Creators Club membership to run your XNA programs on your Xbox 360.
8. You need a Creators Club membership to run your XNA programs on your Zune.
9. The XNA Game Studio Device Center runs your programs on your Xbox 360.
10. The compiler runs your program.
11. The empty project created by XNA Game Studio draws a red screen.
12. It is not possible to use an Xbox 360 gamepad on a PC.
13. To write an XNA game for a Zune, you use a special version of XNA called Zune XNA.

Chapter 2

Programs, Data, and Pretty Colors

In this chapter, you will

- Explore how games actually work.
- See how data is stored in a program.
- Discover how colors are managed on computers.
- Find out about classes and methods.
- Write some code that controls color.
- Write some code that makes decisions.
- Create a funky color-changing mood light.

Introduction

You now know how to create a Microsoft XNA program and run it. Your program only turns the screen blue, but you could call it a start. Next, you are going to figure out how game programs are constructed. Then you'll play with colors and find out how XNA stores color information and how C# stores data.

Program Project: A Mood Light

Your first project is going to be a program that turns a display (the bigger the better) into a mood light. These are the things that they have on spaceships, where a chandelier actually would not work very well. Instead, the spaceship will have a panel on the wall that can be set to glow in different colors and brightness levels or perhaps even change color over time. This is probably not a very efficient way of lighting a building—you are using one of the most powerful game consoles ever made to replace a lamp—but it is a fun exercise and may even lead to a game idea or two along the way. You can use the same program to convert your Zune into a multicolored flashlight.

Before going any farther, you need to consider what a game program does. Computer programs in general read data, do something with it, and then send it out. This is true whether the computer is working out company wages or timing the ignition spark in a car engine. Figure 2-1 shows how this works with respect to game programs. The gamepad provides the input data to the game, and the display screen shows the output.

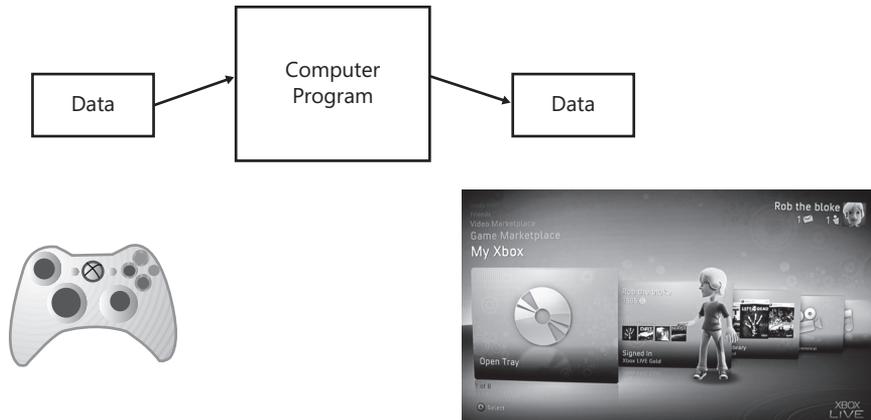


FIGURE 2-1 An Xbox game as a computer program

Later versions of games might have other inputs and outputs, too; for example, if you are playing on Xbox Live, your console is receiving information about other players in your networked game. For now, start by considering only the output from your game. In Chapter 3, “Getting Player Input,” you’ll take a look at where the input values come from.

Making a Game Program

To see how a game program can produce a display, you need to look inside one of the C# programs that XNA built. At the end of Chapter 1, “Computers, C#, XNA, and You,” you used XNA Game Studio to create a game program. Now you are going to look at this program and discover how it works.

The file that contains the game behavior is called `Game1.cs`. The name `Game1` was generated automatically when the project was created; the `.cs` part is the *file extension* for C# programs. If you want to look inside this file, start XNA Game Studio and open the file from Solution Explorer. You can find Solution Explorer, shown in Figure 2-2, in the top right corner of the XNA Game Studio screen. If you double-click the name of the file that you want to work with, the file opens in the editing window.

If you look at the content of `Game1.cs`, which drew that impressive blue screen, you can see how the program works. The program code that XNA Game Studio created when you made an empty game contains the following method:

```
protected override void Draw(GameTime gameTime)
{
    GraphicsDevice.Clear(Color.CornflowerBlue);

    // TODO: Add your drawing code here

    base.Draw(gameTime);
}
```

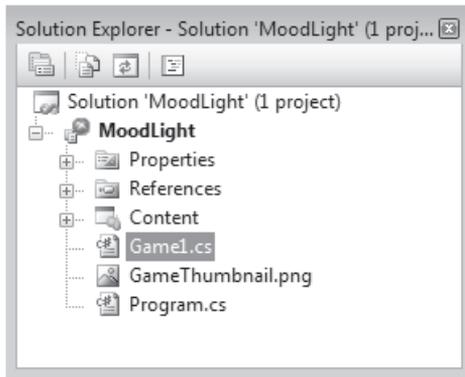


FIGURE 2-2 Solution Explorer

A *method* is a named part of a program. In this case, the method has the name `Draw` (you can ignore the protected `override void` part for now). All you need to know at the moment is that when XNA wants to draw the screen, it uses this method. You can change what gets drawn by altering the content of this method. At the moment, we just get a blue screen; if you look at the second line of the preceding code, you can see where the blue screen comes from.

Statements in the *Draw* Method

The `Draw` method contains a block of statements. `C#` programs are expressed as a series of statements that are separated by a semicolon (;). Each *statement* describes a single action that your program needs to do. There are a number of different kinds of statements; you discover new ones as you learn more about programming. The statements are organized into a single block. A *block* is a way to lump statements together. The start of a block is marked with an open curly bracket character (`{`) and the end of the block is marked with a closing curly bracket (`}`). These curly kinds of brackets are sometimes called *braces*. The `C#` compiler, which is trying to convert the program text into something that can actually run, notices and complains if you use the wrong kind of bracket.

In the preceding code, there is also a *comment*. Comments are ignored by the compiler; they let you put text into your program to describe the program or to remind you to do things. In the preceding code, the comment is a "TODO," which tells programmers that they need to do something. In this case, a programmer must add drawing statements at that position in the program file. The compiler can tell that the text is a comment because it starts with the character sequence `//`. For instance, look at the following example:

```
// This is a comment. It can be any text.
```

You can add comments anywhere in your program.

The Great Programmer Speaks: Comments Are Cool Our Great Programmer likes comments. She says that a well-written program is like a story in the way that the purpose of each part is described. She says that she will be looking at our code and making sure that we put the right kind of comments in.

From the point of view of changing the color of your screen, the statement that is most interesting is this one:

```
GraphicsDevice.Clear(Color.CornflowerBlue);
```

`Clear` is a method that is part of XNA. You will see precisely how it fits into the framework later; for now, all you need to know is that the `Clear` method is given something that describes a color, and the method clears the screen to that color. At the moment, you are sending the `Clear` method the color `CornflowerBlue`, and it is clearing the screen to be that color. If you want a different color, you just have to send a different value into `Clear`:

```
GraphicsDevice.Clear(Color.Red);
```

If you change the color as shown in the preceding line and run the program, you should see that the screen is now set to red.

Sample Code: Red Screen of Anger All the sample projects can be obtained from the course instructor. The sample project in the directory “01 MoodLight Red Screen” in the resources for this chapter draws a red screen for you. You could run this when you felt particularly angry. You can change the color that you want to display by changing the colors used in the `Draw` method; there are some comments in the code to help you with this.

You can set the background color to a range of preset ones, but you can also design colors of your own, which brings us to our first project.

Working with Colors

You have seen that XNA has a set of colors built in, including one with the strange name of `Teal` (it is actually a rather boring blue/green). However, you want to make your own colors and use these in your program.

Storing Color Values

A particular color is represented by a structure that holds the red, green, and blue intensity values. A *structure* is used to hold a number of related data items in the same way that you might write your name, address, and phone number on a piece of paper. You want to

create your own colors, and you need somewhere to store the color values you create. In programming terms, this is called *declaring a variable*. Figure 2-3 shows the anatomy of the statement that declares a variable to hold a value that represents a color.

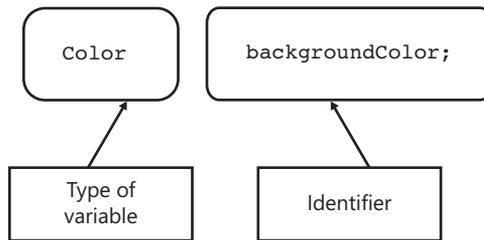


FIGURE 2-3 Declaring a `Color` variable called `backgroundColor`

The *type* of the variable is set as `Color`. This determines what you can put in your variable. Having seen this declaration, the C# compiler knows that you want to create a location with the name `backgroundCo1or` in memory, which can hold color information. In programming terms, the name of a variable is called an *identifier*. The word `backgroundCo1or` is an identifier that I've invented. When you create something to use in a C# program, you have to think up an identifier for it. An identifier is made up of numbers and letters and must start with a letter. The identifier should describe what you are going to use the thing for; in this program, you are storing the color that is going to be used for the background, so it can be given the identifier `backgroundCo1or`.



Note The C# compiler uses the type of a variable to make sure that a program never tries to do something that would be stupid. The value `Color.Red` is recognized by the compiler as being of type `Color`, and can therefore be placed in a variable of type `Color`. If the programmer wrote some code that tried to put something else in the variable `backgroundCo1or`, such as a player name, then the program would fail to compile. This is rather like real life, where an attempt to put an elephant in a camera case would be similarly unsuccessful.

The Great Programmer Speaks: Pick Useful Identifiers Our Great Programmer says that there should be a special place in hell reserved for programmers who create identifiers like `X24`, or `secretMagicCode`, or `c1unk`. She says that these tell a reader of the program code nothing about what the variable is being used for. She really likes identifiers like `CarSpeed`, `backgroundColor`, and `accountBalance`.

Setting a Color Value

You now have a variable that can hold the color of your background. At the moment, it is not set to anything useful. So next, you have to write a statement that causes the game program to put a value into this variable. You start by creating a new `Color` value that contains a

particular amount of red, blue, and green. Figure 2-4 shows the anatomy of an assignment that makes a new `Color` value and then places it in the variable.

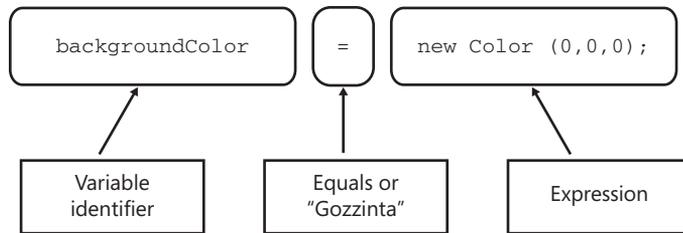


FIGURE 2-4 Assigning a new `Color` value to `backgroundColor`

The thing that is going to be assigned is on the right side of the equals sign. In this case, you are making a new `Color` value. Don't get this confused with a double-equals that might be used to compare two things. You should regard the equals sign in Figure 2-4 as being what I call a "gozzinta" operator. The value on the right of the equals sign "goes into" the variable on the left. You will investigate how to compare things later in this chapter, in the section "Making a Proper Mood Light." Now that you have your variable, you can use it in the game program:

```
GraphicsDevice.Clear(backgroundColor);
```

The preceding statement calls the `Clear` method and feeds it the value of `backgroundColor`. This causes the screen to be cleared to the new color you created. If you put these statements together, you get a game program that contains a `backgroundColor` variable that is used by the `Draw` method, which sets it to a value and then clears the screen using it:

```
protected override void Draw(GameTime gameTime)
{
    Color backgroundColor;
    backgroundColor = new Color(0,0,0);
    GraphicsDevice.Clear(backgroundColor);
    base.Draw(gameTime);
}
```

If you want to find out what color you get if you make one with no red, no green, and no blue, you can run a program that uses this `Draw` method. But I don't think I'm giving too much away when I tell you that this would produce a black screen. The actual color values are given in the order red, green, and blue, and each must be in the range 0 to 255 (you shall learn the reason for this later). By using different values when you set the `Color`, you can experiment with different displays. The color combinations obey all the rules of color combinations (for light, rather than for paint) that you would expect:

```
backgroundColor = new Color(255, 255, 0);
```

The preceding statement sets `backgroundColor` to a color value that has the red and green values at maximum, which would be displayed as yellow.

Sample Code: Yellow Screen of Peril The sample project “02 MoodLight Yellow Background” creates a yellow background color and fills the screen with it. You can change the numbers in the Draw method to make any color you like.

Controlling Color

At this point, you can see that we can add C# statements to the Draw method to change what is drawn on the screen. You also know that XNA uses a `Color` structure to lump together information that describes a particular color and that you can create your own `Color` variables in the game that contain a specific amount of red, green, and blue. Finally, you have managed to make a program that uses a color variable to set the screen to any color that you like.

Next, you want the light to change color over time, to get a nice soothing mood light effect. This sounds like hard work (and like every great programmer, I really hate hard work), but actually it turns out to be quite easy. To discover how to do this, you have to find how XNA is connected to the game programs that you write. The way this works uses C# classes.

Games and Classes

The game program is actually a *class* called `Game1`. A class is a collection of abilities (methods) and data (variables) that forms part of a program. You can put as much stuff as you like inside a single class. A class is usually constructed to look after one particular part of a system. Later in this book, in Chapter 14, “Classes Objects and Games,” you’ll use classes called things like `GameSprite`. In the commercial world, you might find classes called “Receipt,” “Invoice,” and “StockItem.”

When it created our project, XNA Game Studio gave the game class the name `Game1`. However, you can rename this if you wish; you will see how to do this later in the book in Chapter 11, “Renaming the *Game1* Class.”

Classes and Behaviors

A behavior is something that a class can be asked to do. A particular method performs a particular behavior. You have already used the `Clear` behavior of the `GraphicsDevice` class. When you use `Clear`, this causes the code in the `Clear` method to be obeyed to clear the screen. You don’t need to know how `Clear` works; you just need to know that you can feed it with information to tell it what color you want to use.

Drawing and Updating in Games

The `Game1` class provides `Update` and `Draw` behaviors (among others) so that XNA can ask `Game1` to update the state of the game and draw it on the display. `Draw` and `Update` are methods that you provide for use by XNA.

In the programs you have written up to now, you have done all the work in the Draw method. However, this is not really how games should work. The Draw method should do nothing other than draw the display, and the game should be updated by using the Update method. You might be wondering why we have this split between Draw and Update. Why can't Update do everything, including the drawing part?

The answer to this question has to do with the way that games work. It is very important that the game world is updated at constant speed. If Update is called less frequently than it should be, players would find that time in the game goes into "slow motion," which would be very frustrating for them because the game would not respond properly to their inputs to the gamepad. However, a game can usually get away with calling the Draw method less often—all that happens is that the display becomes more jerky as it is redrawn less frequently.

I've played a few games that do this, usually when there are a large number of objects on the screen at the same time. What is happening is that the display is running more slowly, but behind the scenes, the game is being updated properly, so gameplay itself is not affected. If the update and draw behaviors were not separated, it would not be possible to run them at different rates.

Sharing Game World Data Between *Draw* and *Update*

When you create a game, you must create the variables that hold the state of the game itself. In a driving game, this state would include the speed of the car the player is driving, the car position on the track, and the position and speed of the other cars. This could be called the game world data. The game world data that you are going to use in the mood light is the amount of red, green, and blue that defines the color of the light. The present version of Draw is entirely self-contained. It has a *local* variable that is set with the color that is to be drawn:

```
protected override void Draw(GameTime gameTime)
{
    Color backgroundColor;
    backgroundColor = new Color(255,255,0);
    GraphicsDevice.Clear(backgroundColor);
    base.Draw(gameTime);
}
```

Local variables are used when you just want to manipulate some data for a very short time. In this case, the program makes a color value that can be fed into the Clear method. At the moment, the value of backgroundColor is constructed from the values 255, 255, and 0, which give the amount of red, green, and blue in the color. We want to construct the color value from game data values that are set up by the Update method. To make your light work the way that XNA does, the program must store this game data in a place where both the Draw and Update methods can use it. In other words, you need to set up some game world data. Figure 2-5 shows how the Update and the Draw methods are part of the Game1 class, along with the intensity variables that make up the game world.

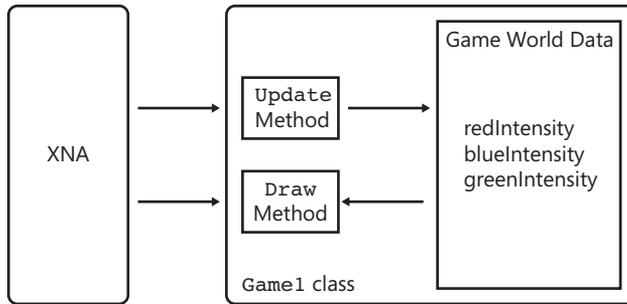


FIGURE 2-5 The Game1 class and XNA

The job of the Update method is to update the game world data in the game (that is, adjust the intensity values). The job of the Draw method is to use the game world data to draw the display (that is, create a color from these values and clear the screen with it).

The XNA system calls Draw and Update at regular intervals when the game is running. You have already used methods provided by other classes; you know that the `Clear` method can be called to clear the display to a particular color. We are going to make the Update method set the value of the color to be used, and the Draw method will just draw using that color. Values that are shared among methods in a class are called *members* of the class.

Classes as Offices

You can think of Update and Draw as two people sitting in an office called Game1. Each of them has his or her own telephone and pad of paper for taking notes (local storage). In the middle of the office is a desk (the description of the game world) with bits of paper on it.

Every now and then, Mr. Draw's phone rings, and a voice on the other end of the line tells him that a sixtieth of a second has gone by. Mr. Draw then jumps up, gets the value of the background intensities from the Game World data on the desk in the office, creates a color value on his notepad, and then uses his phone to call Ms. Clear in the GraphicsDevice office down the hall and ask her to clear the screen to that color. She has a set of paint cans and can fill the screen with any color that she is asked to use.

At a similar interval, the Update phone in the Game1 office rings, and a voice tells Mrs. Update that a sixtieth of a second has gone by. She jumps up, goes to the table in the office, and updates the Game World information on the bits of paper. You can see how this would look in Figure 2-6.

The people/methods in our office/classes perform actions for each other, and data is the information that the class stores within itself. When a class wants to use a method, it calls it.

In our first version of the Game1 class, the information on the table is the color that Mr. Draw uses to color the graphics display. You change what happens when the screen is drawn by changing what Mr. Draw does (the content of the Draw method). You change what happens when the game itself is updated by changing what Mrs. Update does (the content of the Update method).

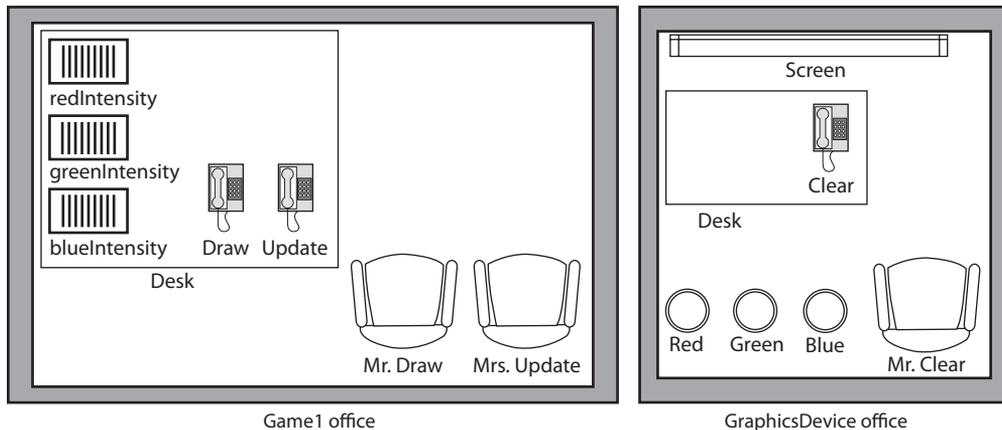


FIGURE 2-6 The `Game1` and `GraphicsDevice` classes as offices

Note that no method has to know exactly how the other methods work. Mr. Draw has no idea about cans of paint and displays, but he does know that if he asks Ms. Clear to clear with yellow paint, this results in a yellow screen being drawn. A call of a method is equivalent to calling up someone in an office and asking her or him to perform a task.

Game World Data

The Game World data must be held as part of the class so that the `Draw` and `Update` methods can make use of it. For the `MoodLight` game the data will be the brightness of the red, green, and blue components of the color of the light to be produced.

```
class Game1 {
    // The Game World - our color values
    byte redIntensity ;
    byte greenIntensity ;
    byte blueIntensity ;

    // TODO: Draw method goes here

    // TODO: Update method goes here
}
```

The preceding code declares three variables inside the `Game1` class. These are part of the class; they are often called *members* of the class and can be used by any methods that are also members of the class. They have the identifiers `redIntensity`, `greenIntensity`, and `blueIntensity`. You can think of these as separate pieces of paper on the desk in the `Game1` office. Figure 2-7 shows how a class can contain members.

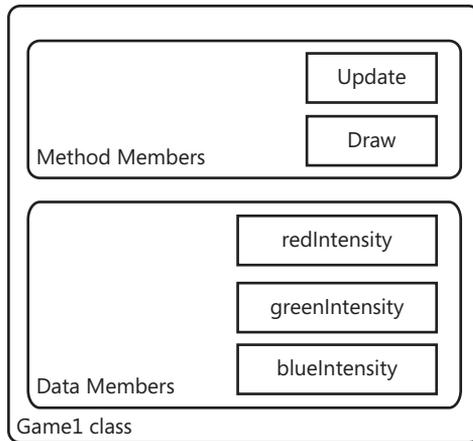


FIGURE 2-7 The `Game1` class and its members

There are two kinds of members: methods (which do something) and data (which hold information). The `Game1` class you are working on has both kinds of members; it has the `Draw` method and the `Update` method, as well as the three data members, which are going to be used to hold the color values for the changing background. The intensity data members are of type `byte`.

If you refer back to Figure 2-3, you can see that a declaration is the type of the variable, followed by the identifier. Previously you have declared variables of type `Color` that can represent a color. Now you are using another type that can represent a numeric value.

Storing Data in Computer Memory

The data for each color intensity is being held in a variable of type `byte`. The `byte` type is interesting because it uses 8 bits of computer memory to hold the value that it is trying to represent. Computer memory is actually a huge number of such locations, each of which is 1 byte in size. The Xbox 360 has 512 megabytes of memory. This means that the memory inside the console has about 512 million storage locations, each of which can hold a single byte value. The memory is addressed by number, and the compiler generates a program that uses a particular memory location when it accesses a particular variable. Figure 2-8 shows how this might work. The compiler has decided that `blueIntensity` is to be held in memory byte number 1003, `greenIntensity` in memory byte number 1004, and so on.

When the program runs, the statements that work with `redIntensity`, `blueIntensity`, and `greenIntensity` are directed to these locations in memory. Each data type uses a particular amount of computer memory; a `byte` uses a single memory location. The `Color` type uses at least 4 bytes of memory; other types can use a lot more. When the program needs to hold a `Color` value, the compiler allocates a number of adjacent memory locations.

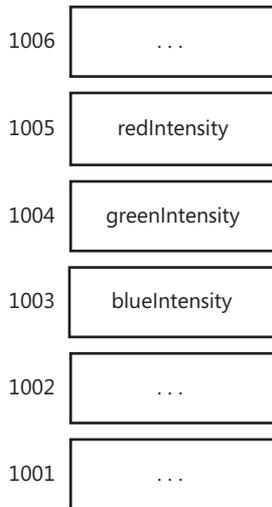


FIGURE 2-8 Storing the color intensity values in memory



Note In XNA, we never have to worry about precisely where the compiler chooses to put things. These issues are managed automatically and hidden from our programs. In fact, the way things really work is a little more complex than the explanation given, but for now, it is important for you to remember that computer data is held in memory locations of a particular size and that a particular number of memory locations is available for a program to use.

The same memory locations that store data can also be used to hold program instructions. When an Xbox game is running, it might be that half the memory space holds the game program code (the methods) and the other half holds the data that is being used (the variables). When a game is showing the dreaded “Loading” screen, the Xbox is actually transferring program code and data values from the game disk into the memory.

Drawing by Using Our Color Intensity Variables

The color intensity variables that we have created represent the amounts of red, green, and blue that the mood light has. You can use them in your Draw method to create the color to be used to clear the screen:

```
class Game1 {  
  
    // The Game World - our color values  
    byte redIntensity ;  
    byte greenIntensity ;  
    byte blueIntensity ;  
}
```

```
protected override void Draw(GameTime gameTime)
{
    Color backgroundColor;
    backgroundColor =
        new Color(redIntensity, greenIntensity, blueIntensity);
    graphics.GraphicsDevice.Clear(backgroundColor);
    base.Draw(gameTime);
}

// TODO: Update method goes here
}
```

This Draw method looks very like the previous one, except that it uses member variables to define the color that is created rather than specifying particular values. Note that the assignment to `backgroundColor` has been spread over two lines. The C# compiler is quite happy with this.

The Great Programmer Speaks: Don't Try to Fit Everything on One Line Our Great Programmer is very keen on sensible program layout. This means not letting program lines extend off the end of the page. She says if a line gets too long, you should break it at a sensible point (not in the middle of an identifier) and then continue to the next line, slightly indented. She has personally checked all the program listings in this book to make sure that the layout meets her exacting requirements.

Updating Our Colors

When the program starts, the values of byte data members are automatically set to 0 and the background color is set to black. If you run a program with the preceding Draw method, you see that the screen just goes black. What you now need to do is take control of the update process and make the colors change over time. When an empty project is created, XNA Game Studio creates a bare-bones Update method that contains a TODO reminding the programmer to add the required code:

```
protected override void Update(GameTime gameTime)
{
    // Allows the game to exit
    if (GamePad.GetState(PlayerIndex.One).Buttons.Back==ButtonState.Pressed)
        this.Exit();

    // TODO: Add your update logic here

    base.Update(gameTime);
}
```

The Update method is rather similar to Draw but has an extra couple of statements in it, one of which starts with the word `if`. This is the part of the code that decides when the game

should end. When you ran your program, you may have noticed that pressing the Back button on the gamepad stops the game. These two statements are the ones that dictate that behavior.

The first statement says, "If the Back button on the gamepad for player 1 is pressed, do the next statement," and the second statement says, "Exit the program." Put those together, and you get a behavior that means that when the Update method is called, if the Back button is pressed, the program exits. You are going to spend some time on conditions later, but for now, just remember that if you delete these two lines from your program, it is impossible to stop it via the Xbox gamepad. So don't delete them.

You may be wondering who calls Update and how often. The answers at the moment are "the XNA engine" and "60 times a second." Whenever your game is active, it needs to update the game world. This has to happen repeatedly for a game to be any fun. The XNA engine calls the Update method to give it a chance to perform. In a full-blown game, this involves reading the gamepad, moving all the objects in the game world, checking to see if any have collided, and so on. In the mood light, the Update method just changes the color values that Draw uses to draw the display.

To start with, you are just going to make a mood light that gets steadily brighter over time, so the Update method increases the value of the red, green, and blue intensities by one each time that it is called:

```
protected override void Update(GameTime gameTime)
{
    // Allows the game to exit
    if (GamePad.GetState(PlayerIndex.One).Buttons.Back==ButtonState.Pressed)
        this.Exit();

    // Make each color brighter
    redIntensity++;
    greenIntensity++;
    blueIntensity++;

    base.Update(gameTime);
}
```

The Update method works by using the *++ operator*. An operator is something in the program that tells the compiler that you want to perform an operation on a particular item. In this case, you are using the operator *++* on each of the intensity variables. The item that an operator works on is called an *operand*. Sometimes operators work by combining operands, and sometimes they work on a single operand. The *++* operator works only on a single operand. The Update method uses it on each color in turn so that each color intensity increases by one. This means that each time the Update method is called, the display should get a little bit brighter.

If you run the program with this Update method, you see that the display does get steadily brighter for about four seconds. Then it goes black again. This does not seem right. One of

the additions seems to be making the value much smaller rather than increasing it. To understand why this is, you need to take a look at how numbers are stored in computers.

Memory Overflow and Data Values

You have already seen that byte values are actually represented by 8 memory bits. Now you need to understand what this means and the problems that it can cause.

A *bit* is the smallest unit of data that you can have. A bit is either on or off; in other words, it can store just two different values. The two values are often referred to as `true` or `false`. Each value is represented by a particular voltage in the memory of the Xbox, but we don't need to worry about that in detail.

Think of a bit as a coin on a table. The coin can be either heads or tails; that is, in one of two possible states. If you put a second coin on the table, the two coins in combination now have four possible states, head-head, head-tail, tail-head, and tail-tail. Each coin that you add to the table doubles the number of possible states (that is, when you add the coin, you can have all the previous states with the new coin on heads plus all the previous states with the new coin on tails).

If you do the math with eight coins, you find that they can occupy 256 different states. So 8 data bits can hold 256 different values. One of these values is 0 (all false or all tails), which means that the largest possible integer value that a byte can hold is 255 (all true or all heads). When the `++` operator tries to increase the value of 255, it will produce the value of 256, which cannot be represented by 8 bits. The addition process would like to set the value of a ninth data bit to 1, so that it can represent the value of 256, but there is no ninth bit to set. So what happens is that the other 8 bits are cleared to zero. This causes the value to wrap around, which means that the value in the byte goes back to 0 again. The result of this is that the screen goes from maximum brightness to minimum brightness in a single step. The technical name for this is *overflow*.

One very important thing to note here is that no error messages are produced. The computer does not “know” that it has done anything wrong. Sometimes if your program does something stupid, you get an error and your program stops. However, in this case, the game does not seem to notice that you have just fallen off the end of a byte and it continues to run. Your program may well do the wrong thing, though. This means that your program has a bug in it. When you create the finished mood light code, you need to make sure that the values never “wrap around” like this.



Note Note that you have not “run out of memory.” Rather, the program has tried to put too much information in a single memory location. The Xbox can work with values much larger than 256; it does this by using multiple storage locations to hold a single item. As an example, you have seen that the information to describe a color fills at least four memory locations.

The Great Programmer Speaks: The Computer Doesn't Care Our Great Programmer finds it very amusing when people say, "The stupid computer got it wrong." She says this is not what happens. What really happened was that the person who wrote the program did a bad job. She has been known to roll around on the floor laughing when people ask her, "But why didn't the computer notice it was wrong?" She knows that the computer really doesn't know or care what a program actually does. The job of the computer is to follow the instructions that the program gives it. The job of the programmer is to write instructions that are correct in every scenario.

Sample Code: Fade from Black The sample project in the "03 MoodLight Fade Up" directory in the source code resources for this chapter performs the fade up discussed in this section. It then wraps around to black as the values in the bytes overflow.

Making a Proper Mood Light

The fade-up part of the mood light is very good, but you don't want it to suddenly change from white to black each time around. What you would like is for it to fade smoothly up and down. If you were telling Mrs. Update what to do, you would say something like this:

"Make the value of `redIntensity` bigger each time that you are called. When the value reaches 255, start making it smaller each time you are called until it reaches 0, at which point you should start making it bigger again. Do the same with blue and green."

Mrs. Update would think about this for a while and decide that she needs to keep track of two things for each color: the current intensity value (in the range 0 to 255) and something that lets her remember whether she is counting up or counting down for that color. Then, each time she is called, she can follow a sequence like this:

1. If we are counting up, increase the value of `redIntensity`.
2. If we are counting down, decrease the value of `redIntensity`.
3. If `redIntensity` is 255, change to counting down.
4. If `redIntensity` is 0, change to counting up.

This is an *algorithm*. It provides a sequence of operations that is used to solve a problem. In this case, we wanted to make the value of `redIntensity` move up to 255 and down again in steps of 1.

Of course, Mrs. Update is not a person but a C# method, so now we have to convert these steps into C#. The first thing that we need to do is work out what data we need to store.

We need the intensity value and also a way of remembering if we are counting up or down. Here's the code that declares the needed variables:

```
// The Game World - our color values
byte redIntensity = 0;
bool redCountingUp = true;
```

You have seen the `redIntensity` variable before; what you haven't seen is the way that we can set it to 0 when we declare it. The `redCountingUp` variable is new, though. It is of a new type (C# has hundreds of different types, you'll be pleased to hear). This is the `bool` type, which is special because it can hold only two possible values: `true` or `false`. It allows programs to perform what is called *Boolean algebra*, which consists of calculations involving only the values `true` and `false`. Such calculations are usually used to drive decisions along the lines of "If `itIsRaining` is `true` and `robWillBeGoingOutside` is `true`, I should call the `takeMyUmbrella` method."

In this case, the `bool` type is perfect because `redCountingUp` is either `true` or `false` and nothing else. The program uses it to make decisions in the `Update` method so that it can behave according to the data. This ability to make decisions is what makes computers truly useful, in that they can change what they do in response to their situation. To make decisions in your programs, you have to use conditional statements.

Making Decisions in Your Program

You have seen two kinds of statement so far. One calls a method to do something (you use this to call the `Clear` method), and the other changes the value of a variable (you use this to increase the intensity of your colors). Now you are going to use a conditional construction that can change what the program does depending on the particular situation.

Creating Conditional Statements

Figure 2-9 shows how a conditional construction fits together. Conditional constructions start with the word `if`. This is followed by a condition in brackets. The condition produces a Boolean result, which can be either `true` or `false`. You can use a variable of `bool` type directly here.

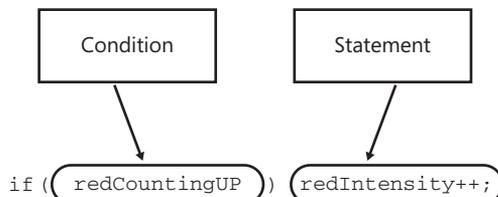


FIGURE 2-9 The `if` condition in action

If the condition is `true` (that is, the variable `redCountingUp` holds the value `true` in this case), the statement following the condition is performed. The result is that when this statement is obeyed, the value of `redIntensity` gets bigger if the program is counting up. The condition can be any value that gives a Boolean result, including this rather stupid code:

```
if (true) redIntensity++;
```

The preceding code is completely legal C# code and compiles with no problem. When the program runs, the condition is `true`, and the statement increases the red intensity value. This is very stupid code, though, as the test might as well not be there. You could also write the following:

```
if (false) redIntensity++;
```

In this code, the statement following the condition is never obeyed because the condition is always `false`. This C# code compiles all right, but if you look very closely at the Microsoft Visual Studio display, you might notice that it is trying to tell you something, as shown in Figure 2-10.

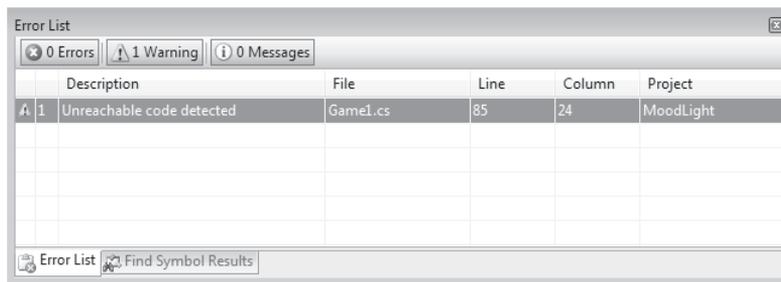


FIGURE 2-10 Compiler warnings

If the error window in Figure 2-10 is not displayed, you can open it by selecting the View menu and clicking Error List in that menu. Alternatively you can use the key combination `Ctrl+W+E`.

When the compiler has finished trying to convert your C# source code into a program that can be run on the computer, it tells you how many mistakes that it thinks it has found. There are two kinds of mistakes. An *error* is a mistake that prevents what you have written from being made into a program. Errors are really bad things like spelling identifiers wrong, using the wrong kind of brackets, and the like.

The other kind of mistake is called a *warning*. This is where the compiler thinks you might have done something wrong, but it does not prevent your program from running. Figure 2-10 shows the warning message for a program with a test for `(false)` in it.

What the compiler is telling you is that it has managed to work out that the statement after the test will never be reached. This is because it is impossible for the value `false` to be `true`. The compiler is warning you that although the code is legal C# code, what it does might actually not be what you want.

The Great Programmer Speaks: Warnings Should Always Be Heeded Our Great Programmer has very strong opinions on compiler warnings; she reckons that your code should compile with no warnings at all. Warnings usually mean that your solution is imperfect in some way, and you should always take steps to investigate and resolve them.

Adding an *Else* Part

The condition you have created is only half correct. If the program is not counting up, it must make the value of `redIntensity` smaller. You can use the `--` operator to do this, but we need to add extra code to the condition. You need to add an *else* part. Figure 2-11 shows another form of the `if` condition, with the `else` part added.

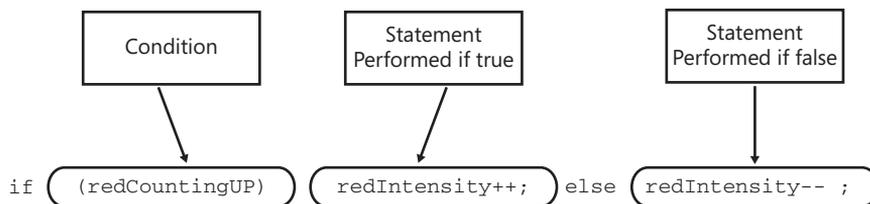


FIGURE 2-11 The *if* condition with an *else* part

The two statements are separated by a new key word, `else`. The new code means that if the program is counting up (that is, `redCountingUp` is `true`), the value gets bigger, but if the program is counting down (that is, `redCountingUp` is `false`), the value gets smaller. The `else` part is optional; you must add one only if you need it.

Testing Values

The program must also manage the value in `redCountingUp` so that when it reaches the upper limit, it starts to count down, and when it reaches the lower limit, it starts to count up again. In other words:

1. When `redIntensity` reaches 255, set `redCountingUp` to `false`.
2. When `redIntensity` reaches 0, set `redCountingUp` to `true`.

To do this, you need another kind of condition, one that performs a comparison. Figure 2-12 shows how such comparisons are created. This performs the first of these two tests.

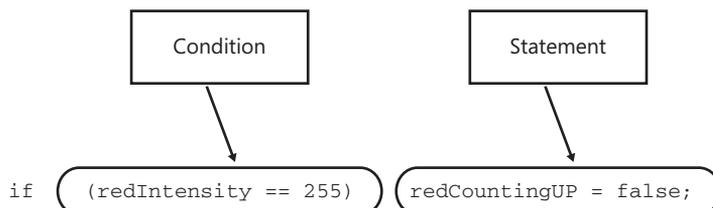


FIGURE 2-12 Performing a comparison using the *if* condition

The key to understanding what is happening is the `==` comparison operator. When the program evaluates this condition, the values on the left and right of the `==` operator are compared. If they are the same, the result of the comparison is true, and the statement that follows the condition is performed. If they are different, the result of the comparison is false, and the statement that follows the comparison is ignored.

The sequence `==` is the comparison operator. It is completely different from the `=` operator, which we know as the “gozzinta.” It is important that you don’t get these two confused. Unfortunately, you have both a gozzinta and a comparison taking place in the `if` statement because you want to put a new value into `redCountingUp` if the comparison succeeds.

Fortunately, the compiler can usually detect when you use the wrong operator and produce a message. There are other comparison operators that can test to see if one value is greater or less than another; we will use these later. An `if` statement that uses a comparison operator can have an `else` part; it is just that we don’t need one here. The final code to make our red intensity value move up and down ends up as follows:

```
if (redIntensity == 255) redCountingUp = false;
if (redIntensity == 0) redCountingUp = true;
if (redCountingUp) redIntensity++; else redIntensity--;
```

The program needs a second test to change the direction of the counting when the bottom limit of the intensity value is reached. The tests are performed before the intensity value is updated. This is because when the program starts running we want it to work correctly for any initial value of `redIntensity`. If the starting value is 255 the program must count down. If the starting value is 0 the program must count up.



Note Pay very careful attention to the three statements shown in this section. Go back and read our original instructions to Mrs. Update and make sure you are absolutely clear how these have been converted into C# statements that perform the job. You will notice that Mrs. Update’s original design has had to be changed so that it works with any starting value.

The Completed Mood Light

You now have the code that lets you create a smoothly pulsing mood light:

```
// The Game World - our color values
byte redIntensity = 0;
bool redCountingUp = true;

byte greenIntensity = 0;
bool greenCountingUp = true;

byte blueIntensity = 0;
bool blueCountingUp = true;
```

```
protected override void Update(GameTime gameTime)
{
    // Allows the game to exit
    if (GamePad.GetState(PlayerIndex.One).Buttons.Back ==
        ButtonState.Pressed)
        this.Exit();

    // Update each color in turn
    if (redIntensity == 255) redCountingUp = false;
    if (redIntensity == 0) redCountingUp = true;
    if (redCountingUp) redIntensity++; else redIntensity--;

    if (greenIntensity == 255) greenCountingUp = false;
    if (greenIntensity == 0) greenCountingUp = true;
    if (greenCountingUp) greenIntensity++; else greenIntensity--;

    if (blueIntensity == 255) blueCountingUp = false;
    if (blueIntensity == 0) blueCountingUp = true;
    if (blueCountingUp) blueIntensity++; else blueIntensity--;

    base.Update(gameTime);
}

protected override void Draw(GameTime gameTime)
{
    Color backgroundColor;
    backgroundColor =
        new Color(redIntensity, greenIntensity, blueIntensity);
    graphics.GraphicsDevice.Clear(backgroundColor);

    base.Draw(gameTime);
}
```

These versions of `Update` and `Draw` produce a program that smoothly fades the screen between black and white.

Sample Code: Mood Light The project in the “04 MoodLight” directory in the source code resources for this chapter contains the `Update` and `Draw` methods presented in this section and provides a smoothly changing mood light that goes from dark to light and back again.

A Proper Funky Mood Light

Going from black to white and back is all very well, but it would be nice to have some additional variety to our light. It turns out that this is very easy to achieve. At the moment, the red, green, and blue intensities are all the same values, counting up from 0 to 255 and back down again. This just gives shades of gray. What you want is different combinations and the color intensities going up and down at different times. You can do this by changing the starting values of our intensity values and update directions:

```
byte redIntensity = 0;
bool redCountingUp = true;
```

```
byte greenIntensity = 80;  
bool greenCountingUp = false;
```

```
byte blueIntensity = 160;  
bool blueCountingUp = true;
```

Rather than all the colors starting at 0 and counting up, the green value now starts at 80 and counts down, and the blue value starts at 160. This means that instead of just different shades of gray, you now have lots of other colors being presented. This provides a very groovy display. If you change the values in your program to the ones shown in this section, you can get a much more interesting-looking display. You can even try values of your own and see what they look like.

For a much longer-lasting display, we need to change the rate at which the three colors are updated. This is not actually very hard to do, so I've written an "Ultimate Mood Light" that you can take a look at.

Sample Code: Ultimate Mood Light The project in the "05 Ultimate Mood Light" directory in the source code resources for this chapter contains a new version of `Update`, which changes the red, green, and blue intensities at different speeds, resulting in a display that never seems to actually repeat (although it does eventually). Look at the code and see if you can understand how it works.

Finding Program Bugs

Your younger brother has been reading this book and typing in the programs on his computer. He has just come and told you that the book is rubbish because the programs don't work. He has written an `Update` method and is complaining that for him the red value only gets brighter. You ask him to show you the code and you see this:

```
if (redIntensity == 255) redCountingUp = true;  
if (redIntensity == 0) redCountingUp = true;  
if (redCountingUp) redIntensity++; else redIntensity--;
```

At first glance, it looks fine, and the C# compiler is quite happy that it is legal, but it is obviously not working. There is a bug in the program. Note that the bug is not there because the computer has made a mistake, so the instructions themselves must be faulty. You don't want to bother the Great Programmer, as she seems to be busy playing Halo on her Xbox, so you take a look, bearing in mind something she said recently.

The Great Programmer Speaks: Run Programs by Hand to Find Bugs A good way to find out what a program is doing is to behave like the computer and "run" the program yourself. By working through the statements by hand, keeping track of the variables and making the changes to them that the program does, you can often find out what is wrong.

Your younger brother has actually made two mistakes in copying the program from these pages. See if you can find them by working through the statements.

Figure 2-13 highlights the errors that your younger brother has made.

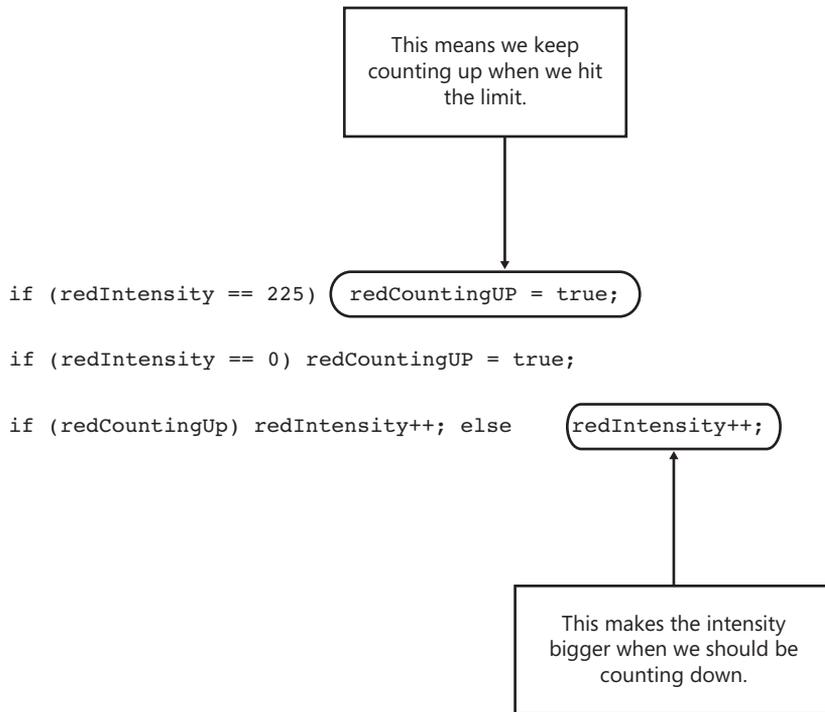


FIGURE 2-13 Finding the errors in the code

The two errors both have the same effect, they cause the screen to get brighter all the time. If you fixed only one of them the program would still appear broken.

Conclusion

You have learned a lot in this chapter. You now know the fundamentals of C# programs and the XNA framework. You have seen how to identify and create variables that store data and also how to write statements that change the values of these variables. You have seen that the data in a variable is held in a location in memory, which is a certain size and has a particular capacity. If you exceed this, the value does not fit and is damaged.

You know that in C#, programs are broken down into classes, each class having things it can do (methods) and things it can hold (member variables). Classes are like offices, where workers (methods) can be asked to do things. You also know that an XNA game is a particular kind of class that contains an Update method, which is used by XNA to update the state of the game world, and a Draw method, which is used to draw the current state of the game world. You have seen how our programs can be made to make decisions and change what they do, depending on the values of the data they hold.

Chapter Review Questions

Time for another review. Have a go at the questions before you move on. When you learn to program, you find that each step builds on the last, so it is important that you understand what is in this chapter before you move on to the next. Again, all the answers are either true or false, and you can work them out from this chapter and the Glossary.

1. A program is a sequence of variables.
2. Programs are always held in a file called Program.prog.
3. An identifier is a name that we give to something we want to use in our program.
4. Methods tell the computer how to do something.
5. The Draw method updates the game.
6. A block of statements is made of wood.
7. The compiler checks code comments for accuracy and spelling.
8. A Color value is held as a single byte.
9. The type of a variable determines what kind of data can be put into it.
10. A local variable is held inside the class.
11. An identifier is a name built into C# to identify things.
12. A variable has an identifier and a type and holds values that our program wants to work with.
13. A variable of type bool can hold only the values 0 and 1.
14. Conditional statements start with the word when.
15. An if condition must have an else part.
16. An algorithm is like a recipe.
17. The = operator is used to compare two values and test if they are the same.
18. A class holds method members and data members.
19. A good identifier for a class would be PlayGame.
20. A good identifier for a method would be Explode.
21. A byte holds a single bit of data.
22. The ++ operator works between two operands.
23. The C# compiler detects if a variable overflows when the program is running.
24. Boolean values can be either true or false.

Chapter 3

Getting Player Input

In this chapter, you will

- Find out how Microsoft XNA represents the gamepads and keyboards.
- Discover the C# language structures that let us get player input.
- Write some really silly games and scare people with them.

Introduction

You now know the basics of computer game programming. You know that a program is actually a sequence of statements, each of which performs a single action. You have seen that statements are held inside methods, each of which performs a particular task, and that methods are held in classes along with data. The program itself works on data values, which are held in variables of a particular type, and the program can make decisions based on the values that the variables have. (If none of this makes much sense, reread Chapter 2, “Programs, Data, and Pretty Colors,” until it does.)

Now you are going to expand your understanding to include how to receive input from the outside world so that games can actually react to what the player does. You shall see that once we have done this, a number of possibilities open up, and you can create some truly silly games, including “Color Nerve,” “Mind Reader,” “The Thing That Goes Bump in the Night,” and “Gamepad Racer.”

Program Project: A Mood-Light Controller

In Chapter 2, you created a light that changes color over time. I also mentioned that this is the kind of thing that will be used in the starships of the future. A color-changing light is not all that useful for reading books, but it’s great for setting moods; what our starship captain really needs is a light that she can set to any color. So now you are going to make a lamp that can be controlled by an Xbox gamepad. The user presses the red, blue, green, and yellow buttons on the gamepad to increase the amount of that color in the light. To make this work, you have to discover how to read the gamepad.

Before you start looking at gamepads, though, you need to decide how the program will actually work. Consider the following statement of C# from the previous mood-light program, which is part of the Update method:

```
if (redCountingUp) redIntensity++;
```

This is one of the tests that controls the intensity of the red part of the color. What it is saying is “If the Boolean value `redCountingUp` is `True`, increase the value of `redIntensity` by 1.” The statement is processed each time `Update` is called (at the moment that is 60 times a second), so this means that if `redCountingUp` is `True`, the red intensity of the screen gets progressively brighter over time.

You want to write some code that says, “If the red button on Gamepad 1 is being pressed, increase the value of `redIntensity` by 1.” Then, if the player holds down the button, the screen gets redder. So all you have to do is change this test to read the button on the gamepad, and you can create a user-controlled light easily.

Reading a Gamepad

The gamepads are actually very complex devices. They are connected to the host device either by a universal serial bus (USB) cable or by a wireless connection. As far as you are concerned, the way that programs work with gamepads does not depend on how they are connected. The connection to a gamepad can be used to read the buttons and joysticks and can also be used to send commands to the gamepad—for example, to turn the vibration effect on and off. The Xbox and XNA provide support for up to four gamepads connected simultaneously. The Zune has a single gamepad with two buttons that can be used for input. It is used in exactly the same way as the Xbox gamepad.

Gamepads and Classes

The gamepad information is represented in XNA by means of a class called `GamePadState`. The job of this class is to provide the connection between the program and the physical gamepad that the player is holding. To understand how you are going to use this, you have to learn a bit more about how classes work.

You have already seen what a class is in the section “Games and Classes” in Chapter 2. A class contains data (variables that can hold stuff) and methods (code that can do stuff). You can think of a class as an office, with a desk holding the variables and people acting as the methods. Figure 3-1 shows the office plan for the class `Game1`, which you have seen is the basis of an XNA game.

This class contains some variables on the desk (in this case, the background color intensities) and two methods, which we have called `Mr. Draw` and `Mrs. Update`. Each method has a corresponding telephone. Programs can place calls to the telephones to request that the method perform the required task.

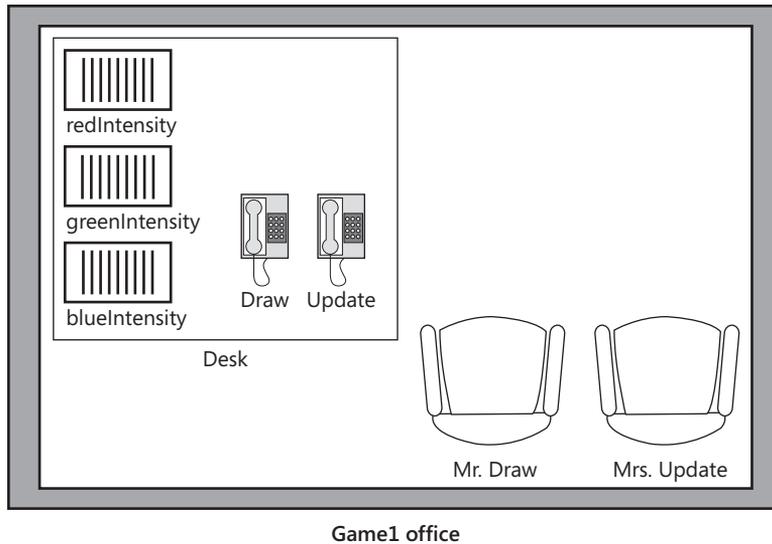


FIGURE 3-1 The Game1 class as an office plan

The Great Programmer Speaks: Classes Are Not Really Offices Our Great Programmer has been reading these notes and finds them quite amusing. She says that classes are not exactly like offices, but she thinks that for the purpose of getting an understanding of how programs are constructed, it is okay to regard them as such.

When an XNA game starts, the XNA system makes an *instance* of the Game1 class that it then can ask to Draw and Update. When an instance of a class is created, the instructions for the methods that it contains are loaded into memory and space is set aside for the data variables that the instance holds.

The class files that you write give the plans for the class so when the program runs, instances of each class can be created. In real life, you would make a game office by building a room, putting a desk and some telephones in the room, and then hiring a Mr. Draw and a Mrs. Update. The process of making an instance of a class is similar. However, to save memory, the running program uses only one copy of the method code, which is shared among all the instances of a class.



Note It is important to remember that this happens when a program runs. The process of creating instances of classes is not performed by the compiler. The job of the compiler is to convert your C# source code into instructions that the target device runs. By the time that your program has control, the compiler has done its job, and the computer is just running the machine language output that the compiler produced.

Finding a Gamepad

XNA also looks after a lot of other things when a game is running, one of which is the `GamePad` class connected to all the gamepads. You don't have to know how the gamepad is actually connected; for all you know, it might use tiny pixies traveling up and down the wires carrying pixie notes written on pixie paper saying "Master has pressed the Red Button," but then again it might not. Figure 3-2 shows how the `GamePad` class would look if it were an office.

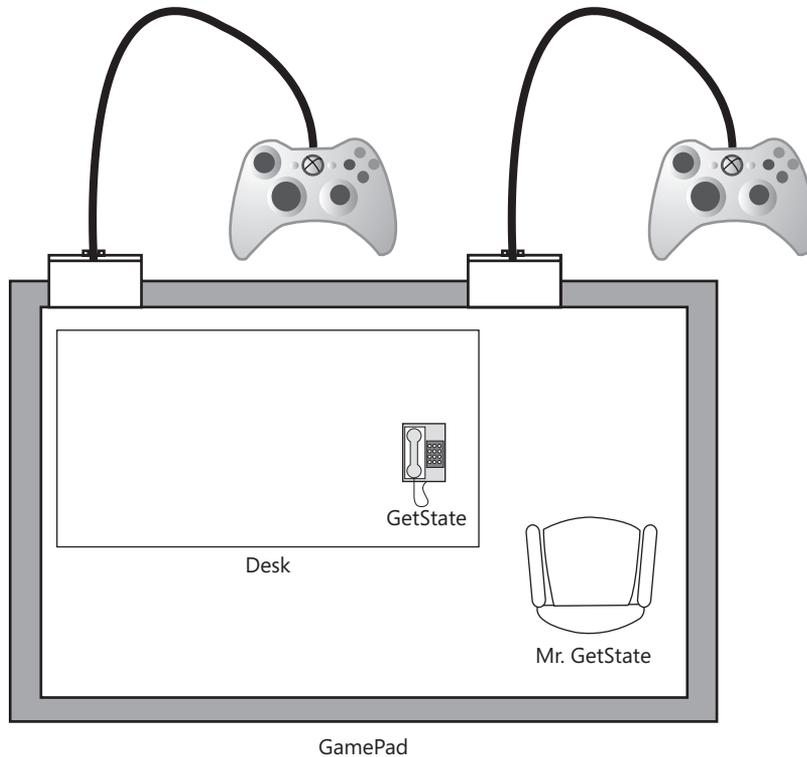


FIGURE 3-2 The `GamePad` class as an office

The `GamePad` class contains a method called `GetState`, which gets the state of one of the gamepads. When `GetState` is called, it looks at one of the gamepads, reads its settings, and then sends information back for use in the statement it was called from.

The `GetState` method is supplied with a parameter that identifies the gamepad to be read. A *parameter* is a way that a call can give information to a method. You have seen these before; in your very first programs, you were passing `Color` parameters into the `Clear` method to select the color of the screen that you wanted.

In the case of the `GetState` method, the parameter identifies the gamepad that you want to read. If you are thinking in terms of offices, you can think of a parameter as part of the instructions that come down the telephone. When the phone rings and Mr. `GetState` answers it,

he is asked, "Get me the state of Gamepad 1." The information about the state of the gamepad is sent back in a `GamePadState` structure, which is shown in Figure 3-3.

| GamePadState | |
|----------------|----------------------|
| Buttons | |
| Green A | ButtonState.Pressed |
| Red B | ButtonState.Released |
| Blue X | ButtonState.Released |
| Yellow Y | ButtonState.Released |
| Start | ButtonState.Released |
| Back | ButtonState.Released |

FIGURE 3-3 GamePadState structure with the green A button pressed

You can think of this as a set of items filled in on a form if you wish, but actually it is a C# structure that contains the data members shown in Figure 3-3, as well as some other data.

So, if Mrs. Update wants to know the state of one of the gamepads on the Xbox, she calls the `GetState` method in the `GamePad` class and asks, "Can you give me the state of the gamepad for Player 1, please?" Mr. `GetState` jumps up, fills in a "GamePadState" form, and sends it back to her. Figure 3-4 gives the breakdown of the C# statement that gets the state of a gamepad into a variable of type `GamePadState`.

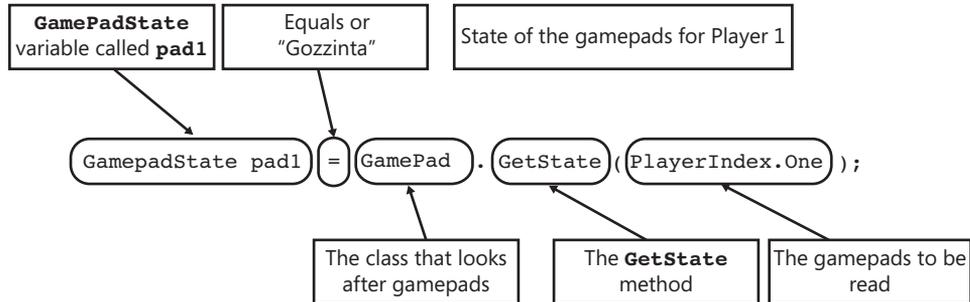


FIGURE 3-4 Getting the status of a gamepad

Testing the Gamepad Status

Now that you have the status, you can use it in the program to see if a button has been pressed. Figure 3-5 shows the breakdown of the C# statement that will perform the test.

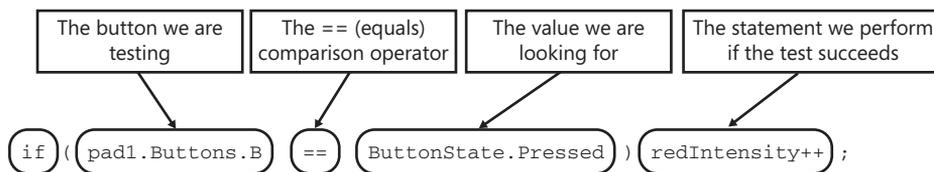


FIGURE 3-5 Testing a button on a gamepad

This compares the state of the red button B with the value `ButtonState.Pressed`. If the two are equal, this means that the button is down, and the `Update` method must make the red intensity bigger. You can then use the same principle to manage the blue and green values, which means that you now have an `Update` method that looks like the following:

```
protected override void Update(GameTime gameTime)
{
    // Allows the game to exit
    if (GamePad.GetState(PlayerIndex.One).Buttons.Back == ButtonState.Pressed)
        this.Exit();

    GamePadState pad1 = GamePad.GetState(PlayerIndex.One);

    if (pad1.Buttons.B == ButtonState.Pressed) redIntensity++;
    if (pad1.Buttons.X == ButtonState.Pressed) blueIntensity++;
    if (pad1.Buttons.A == ButtonState.Pressed) greenIntensity++;

    base.Update(gameTime);
}
```

The only problem with the `Update` method described here is that the program doesn't handle the yellow button yet. When the yellow button is pressed, the program needs to increase the green and the red intensities; that is, it must perform two statements if the condition is true. It turns out that doing so is very easy; you can just put the two statements into a block that is controlled by the condition, as shown here:

```
if (pad1.Buttons.Y == ButtonState.Pressed)
{
    redIntensity++;
    greenIntensity++;
}
```

You have seen blocks before; the body of a method (the bit that does the work) is a block. In *C#* terms, a *block* is a number of statements that are enclosed in curly braces. The code shown here performs both statements if the condition is true because they are in a block controlled by the condition.

The Great Programmer Speaks: Blocks Rock Our Great Programmer tends to use blocks after `if` conditions even when she doesn't actually need to. She says that it makes the program text clearer and that it is much easier to add extra statements later if you need to.

If you put the preceding statements into the `Update` method of one of your earlier Mood-Light programs, you get compiler warning messages because the new version of `Update` doesn't use all the variables that were created for previous versions of the program. To get rid of these warnings, you must delete the statements that create the unused

variables. The Great Programmer doesn't like it when programs have variables in them that are not used. She says this looks unprofessional, and I agree with her.

Zune Buttons

You can run this program on a Zune. However, it doesn't have colored buttons—the Play button is the same as button B (Red) on a gamepad, and pressing the center of the joypad is the same as pressing A (Green), but the other buttons are not supported. However, you can create a Moodlight for the Zune by using the Dpad inputs as follows:

```
if (pad1.DPad.Left == ButtonState.Pressed) blueIntensity++;
if (pad1.DPad.Right == ButtonState.Pressed) redIntensity++;
if (pad1.DPad.Down == ButtonState.Pressed) greenIntensity++;
if (pad1.DPad.Up == ButtonState.Pressed)
{
    redIntensity++;
    greenIntensity++;
}
```

The Zune control pad is mapped onto the Dpad on the gamepad, so this code also allows the MoodLight to be controlled by the Dpad on a gamepad.

Sample Code: Manual MoodLight All the sample projects can be obtained from the course instructor. The sample project in the directory “01 Manual MoodLight” in the resources for this chapter implements the Update method, as shown in this section. You can increase the brightness of the colors on the screen by pressing the buttons on the gamepad or by using the Dpad.

Game Idea: Color Nerve

Every now and then, we are going to try out a game idea. These start out very simply and then build up to more complicated and interesting games. You can use the Manual MoodLight code to create your first game. The game uses something we saw in Chapter 2. You noticed that if you keep making a value bigger, there comes a point where it won't fit in the memory store allocated for it, and then it overflows. This is what caused the screen to go from bright white to black. However, you can use this to create our first “Very Silly Game.”

Color Nerve is a game for two or more players. The players take turns pressing one or more buttons on the gamepad. (The other players must watch carefully to make sure that they actually do press at least one button.) Each player can press as many buttons as he wants for as long as he wants during his turn, but if the screen changes suddenly (because one of the color values has gone from 255 to 0), he is out, and the game continues. The last player left in the game is the winner.

This game can be very tactical. Players can press the buttons for very short times, or at the start of the game, they can show their nerve by holding the buttons down for longer periods, trying to cause problems for the next player. They can also try to work out which color has wrapped around so that they can press that button when it is their turn. The game works very well at parties, any number of people can take part, and the rules are very easy to understand. In Chapter 4, “Displaying Images,” you will improve the game to add pictures as well as a plain screen.

Using the Keyboard

XNA works with keyboards as well as with gamepads. You might be surprised to learn that you can plug a USB keyboard into an Xbox 360 and use it just as you’d use the keyboard on the PC. If you want the program to work with the keyboard, you can add code that does this, as shown here:

```
KeyboardState keys = Keyboard.GetState();

if (keys.IsKeyDown(Keys.R)) redIntensity++;
if (keys.IsKeyDown(Keys.B)) blueIntensity++;
if (keys.IsKeyDown(Keys.G)) greenIntensity++;
if (keys.IsKeyDown(Keys.Y))
{
    redIntensity++;
    greenIntensity++;
}
```

Note that the process is very similar to how the gamepad works, but there are slight differences. You don’t need to tell the `GetState` method on the `Keyboard` which keyboard to read because XNA supports only a single keyboard. The `KeyboardState` item that is returned from the call is not actually a piece of paper; instead, it is an object that provides methods that the program can use to discover whether a particular key is pressed. Rather than seeing if the state of a button is set to the value `ButtonState.Pressed`, the program can call the method `IsKeyDown`. You supply the `IsKeyDown` method with a parameter that identifies the key you are interested in, as follows:

```
if (keys.IsKeyDown(Keys.R)) redIntensity++;
```

This code is a conditional statement that increases the value of `redIntensity` if the R key is pressed. The method `IsKeyDown` returns `true` if the key is down and `false` if not. You can, therefore, use it to control the update of the `redIntensity` value.

Stopping the Game with the Escape Key

The Update method that is created when you make a new XNA game contains a test that checks for the Back button on gamepad 1 and calls the `Exit` method to stop the game when the Back button is pressed. If you are using a keyboard instead of a gamepad you will not be able to press this button to stop the game. You can add a test for the Escape key on the keyboard. This key is a “control” key, in that it does not actually relate to a printable character, but is designed to signal an action you want the program to take. Other control keys include the Enter key and the Backspace key. You can use the same `IsKeyDown` method to test for the Escape key.

```
if (keys.IsKeyDown(Keys.Escape)) Exit();
```

This code stops the game when the Escape key is pressed.

Using a Gamepad and a Keyboard at the Same Time

If you want to use a gamepad and a keyboard simultaneously, you have to test for both. This means that the Update method now looks like this:

```
protected override void Update(GameTime gameTime)
{
    GamePadState pad1 = GamePad.GetState(PlayerIndex.One);

    if (pad1.Buttons.Back == ButtonState.Pressed) Exit();
    if (pad1.Buttons.B == ButtonState.Pressed) redIntensity++;
    if (pad1.Buttons.X == ButtonState.Pressed) blueIntensity++;
    if (pad1.Buttons.A == ButtonState.Pressed) greenIntensity++;
    if (pad1.Buttons.Y == ButtonState.Pressed)
    if (pad1.Buttons.B == ButtonState.Pressed) redIntensity++;
    {
        redIntensity++;
        greenIntensity++;
    }

    KeyboardState keys = Keyboard.GetState();

    if (keys.IsKeyDown(Keys.Escape)) Exit();

    if (keys.IsKeyDown(Keys.R)) redIntensity++;
    if (keys.IsKeyDown(Keys.B)) blueIntensity++;
    if (keys.IsKeyDown(Keys.G)) greenIntensity++;
    if (keys.IsKeyDown(Keys.Y))
    {
        redIntensity++;
        greenIntensity++;
    }
    base.Update(gameTime);
}
```

This code is not good because you are doing the same thing twice, just triggered in a different way. The Great Programmer, if she ever saw this, would not be impressed. Fortunately C# provides a way that a program can combine two conditions and then perform some code if either condition is true. This way of combining conditions is called the *OR* logical operator because it is true if one thing or the other is true, and it is written in the program as two vertical bars (||):

```
GamePadState pad1 = GamePad.GetState(PlayerIndex.One);
KeyboardState keys = Keyboard.GetState();

if (pad1.Buttons.B == ButtonState.Pressed ||
    keys.IsKeyDown(Keys.R)) redIntensity++;
```

The *OR* logical operator is placed between two Boolean expressions that can be either true or false. If one or the other expression is true, the combined logical condition works out to be true. In this code, if the red button is pressed on the gamepad *or* the R key is pressed on the keyboard (or both), the `redIntensity` value increases. This is exactly what you want, and it means that Color Nerve can now be played with the gamepad or the keyboard (or both at the same time). Logical operators are so called because they produce logical rather than numerical results. There are other logical operators that you will use as you create more complex programs.



Note If you find this logical operator stuff hard to understand, just go back to the problem that you are trying to solve. You want the program to perform a statement (`redIntensity++`) if the red key is pressed on the gamepad *or* if the R key is pressed on the keyboard. So you use the *OR* operator (||) to combine the two tests and make a condition that triggers if one or the other condition is true.

Sample Code: Color Nerve The sample project in the directory “02 Color Nerve” in the resources for this chapter implements the game. You can adjust the colors of the screen by pressing the gamepad buttons or a key on the keyboard.

Adding Vibration

The communication between the gamepad and the game works in both directions. Not only can you read buttons on the gamepad, but also you can send commands to the gamepad to turn on the vibration motors. Again, you don't have to know exactly how these messages are delivered; all you need to know is the features of XNA that are used to control this vibration effect.

This means you can make your Color Nerve game even more exciting by making the gamepad vibrate when the intensity values are getting close to their limits. It is interesting how features like this can enhance even a simple game. You will be using the vibration effect on the gamepads quite a lot in the next few games.

Controlling the Vibration of a Gamepad

The `GamePad` class provides a method called `SetVibration` that lets a program control the vibration motors:

```
GamePad.SetVibration(PlayerIndex.One, 0, 1);
```

The `SetVibration` method uses three parameters. The first one identifies which gamepad you want to vibrate. The second parameter is a value between 0.0 and 1 that controls the vibration of the left motor. The bigger the number, the more the gamepad vibrates. The third parameter controls the right motor in the same way as the left one. The statement shown here would set the right motor of Gamepad 1 vibrating at full speed. The left motor is the low-frequency vibration, and the right motor is the high-frequency vibration.

If you think of the `GamePad` class/office having a man called Mr. `SetVibration`, this means that he would be told which gamepad to vibrate and the settings for the left and right motors. Once the method has been called, the gamepad starts to vibrate, and it keeps vibrating until you call the method again to change its setting. In other words, you can think of the `SetVibration` method as a switch that can be set to a number of different positions. Initially, both of the gamepad motors are set at 0, which means no vibration.

Testing Intensity Values

The game needs to decide when to turn on the vibration. To do this, it must test the intensity values and turn on the vibration motor if any of them is getting too large. The program can decide to turn on the motors if any of the red, green, or blue intensity values is greater than 220. To do this, the program must test the intensity values as follows:

```
if (redIntensity > 220)
{
    GamePad.SetVibration(PlayerIndex.One, 0, 1);
}
```

This code shows another form of condition. In the previous examples, the conditions have been checking to see if two values are equal. This code tests if one value is greater than another. The greater-than sign (`>`) is another logical operator. Placed between two values, it returns `true` if the value on the left is greater than the value on the right and `false` if not. That is exactly what you want.

Using the preceding code, the gamepad starts to vibrate using the right motor when the red intensity value goes above 220. If you add this code to the `Update` method in the `Color Nerve` game, you find that if you increase the red value, the gamepad starts to vibrate. Unfortunately, our program has a bug. When the red intensity value returns to 0, the vibration does not stop. You need to add some code that turns off the motor when the

intensity value is less than 220. It turns out that this is very easy to do—you can add an `else` part to the condition:

```
if (redIntensity > 220)
{
    GamePad.SetVibration(PlayerIndex.One, 0, 1);
}
else
{
    GamePad.SetVibration(PlayerIndex.One, 0, 0);
}
```

The statement after the `else` is performed if the condition is found to be `false`. (You can add an `else` part to any `if` condition that you create.) This means that when the red intensity value returns to 0, the vibration stops. You can extend the tests using *OR* so that the program tests all the intensity values:

```
if ( redIntensity > 220 ||
    greenIntensity > 220 ||
    blueIntensity > 220 )
{
    GamePad.SetVibration(PlayerIndex.One, 0, 1);
}
else
{
    GamePad.SetVibration(PlayerIndex.One, 0, 0);
}
```

Now the vibration is controlled by all the intensity values. As an improvement to the game, you might want to experiment with different kinds of vibration for different colors, perhaps by using the low-frequency motor as well. This is controlled by the other value in the call of `SetVibration`:

```
GamePad.SetVibration(PlayerIndex.One, 1, 0);
```

The line of code shown here turns on the low-frequency vibration. You might also want to experiment with the thresholds at which the vibration starts.

The program still has one more problem. If you run it and make the gamepad vibrate, when the program finishes, the gamepad doesn't always stop vibrating. You need to add code that stops the vibration when the game ends. The game stops when the player presses the Back button on the gamepad. The test for this is in the `Update` method. If the Back button is pressed, the `Exit` method is called to stop the game:

```
if (GamePad.GetState(PlayerIndex.One).Buttons.Back == ButtonState.Pressed)
    this.Exit();
```

The `Exit` method removes the game display and shuts the game down in a tidy fashion. What the program must do is turn off the gamepad motors before `Exit` is called. To do this,

the program needs to perform more than one statement if the Back button is pressed, so we need another block:

```
if (GamePad.GetState(PlayerIndex.One).Buttons.Back == ButtonState.Pressed)
{
    GamePad.SetVibration(PlayerIndex.One, 0, 0);
    this.Exit();
}
```

Now, when the player presses the Back button to end the program, the vibration motors are turned off.

The Great Programmer Speaks: When in Doubt, Make Sure Yourself The Great Programmer says that if you are in a situation where you are not sure whether something is always the case, you should add code to remove all possible doubt. Testing the vibration behavior described in this section, I discovered that the gamepad is left vibrating on earlier versions of XNA, but not on some newer ones. To make absolutely sure that the vibration stops regardless of the version of XNA under which your game runs, you should include the code to stop the vibration yourself.

Sample Code: Vibration Color Nerve Game The sample project in the “03 Color Nerve with Vibes” directory in the source code resources for this chapter holds a version of Color Nerve that has the vibration effect enabled.

Game Idea: Secret Vibration Messages

Once you see that it is easy to read gamepad buttons and drive the motors, you can start to have more fun with XNA, particularly with wireless gamepads. You can create mind-reading games where your assistant seems to know exactly what you are thinking. What the audience doesn't know is that both of you are holding Xbox gamepads in your jacket pockets and using them to send signals back and forth using the vibration feature. The code to do this is actually very simple, and you should be able to understand what it does:

```
protected override void Update(GameTime gameTime)
{
    // Allows the game to exit
    if(GamePad.GetState(PlayerIndex.One).Buttons.Back == ButtonState.Pressed)
    {
        GamePad.SetVibration(PlayerIndex.One, 0, 0);
        GamePad.SetVibration(PlayerIndex.Two, 0, 0);
        this.Exit();
    }

    GamePadState pad1 = GamePad.GetState(PlayerIndex.One);
    GamePadState pad2 = GamePad.GetState(PlayerIndex.Two);
```

```
    if (pad1.Buttons.A == ButtonState.Pressed)
    {
        GamePad.SetVibration(PlayerIndex.Two, 0, 1);
    }
    else
    {
        GamePad.SetVibration(PlayerIndex.Two, 0, 0);
    }

    if (pad2.Buttons.A == ButtonState.Pressed)
    {
        GamePad.SetVibration(PlayerIndex.One, 0, 1);
    }
    else
    {
        GamePad.SetVibration(PlayerIndex.One, 0, 0);
    }

    base.Update(gameTime);
}
```

The Update method reads the A button on the gamepad for Player 1. If this is pressed, it turns on the fast vibration motor in the gamepad for Player 2. It then repeats the process the other way, sending signals from Gamepad 2 to Gamepad 1. This gives you a way in which you can send wireless signals from one gamepad to another. Note that both conditions have else parts so that if the button is not pressed, the vibration is turned off.

You could also use this for practical jokes; for example, just leave a gamepad underneath your victim's bed and then wait until he turns the light off and settles down. Then give the vibration a quick blast for the maximum scare factor. Just don't blame me if you never get the gamepad back!

Sample Code: Vibration Messages The sample project in the "04 Mind Reader" directory in the source code resources for this chapter holds a version of the vibration message program. Just remember to use it wisely. The program also turns the display screen black so that it is not obvious that there is a program running.

Game Idea: Gamepad Racer

The final game idea in this chapter is really silly, but it can be great fun. The first thing you need to do is find a large, smooth table. Put a couple of books under the legs at one end so that the table is sloping, not horizontal. If you put a wireless Xbox gamepad at the top of the table and make the gamepad vibrate, it slides down the table toward the other end. You may need to experiment with the angle, but I've found that with

care, you can arrange things so that a gamepad takes around 30 seconds to slide all the way down the table with vibration at full power. If you line up four gamepads on the top of the table, players can pick the one they think will win, and then you can race them down the slope.

The code for this game is very simple indeed; the Update method just turns on all the vibration motors in the gamepads:

```
protected override void Update(GameTime gameTime)
{
    // Allows the game to exit
    if(GamePad.GetState(PlayerIndex.One).Buttons.Back == ButtonState.Pressed)
    {
        GamePad.SetVibration(PlayerIndex.One, 0, 0);
        GamePad.SetVibration(PlayerIndex.Two, 0, 0);
        GamePad.SetVibration(PlayerIndex.Three, 0, 0);
        GamePad.SetVibration(PlayerIndex.Four, 0, 0);
        this.Exit();
    }

    GamePad.SetVibration(PlayerIndex.One, 1, 1);
    GamePad.SetVibration(PlayerIndex.Two, 1, 1);
    GamePad.SetVibration(PlayerIndex.Three, 1, 1);
    GamePad.SetVibration(PlayerIndex.Four, 1, 1);

    base.Update(gameTime);
}
```

The only complication is that when the game ends, you must turn off all the vibrations. Put all the gamepads at the top of the slope and then run the program. Press the Back button on Gamepad 1 to stop the game.

Sample Code: Gamepad Racer The sample project in the “05 GamepadRacer” directory in the source code resources for this chapter holds a version of the Gamepad Racer program.



Note By carefully tuning vibration values it is possible to “sabotage” gamepads so that the same one wins each time. Note that I do not condone such behavior.

Program Bugs

Your younger brother is still trying to learn to program, but he keeps having problems. He claims that this book is faulty because the programs don’t work properly when he types them in. He is trying to get the Color Nerve game to work, but every time he runs the

program, the yellow intensity gets brighter whether he presses the button or not. You take a look at his program and find the following code in the Update method:

```
if (pad1.Buttons.Y == ButtonState.Pressed ||
    pad1.DPad.Down == ButtonState.Pressed ||
    keys.IsKeyDown(Keys.Y)) ;
{
    redIntensity++;
    greenIntensity++;
}
```

This is the only part of the program where the yellow intensity is being increased, and it seems that the condition is being ignored.

This looks perfectly okay, and it seems to compile and run correctly, but it seems to be making the yellow intensity brighter every time. At this point, it is a good idea to look at Microsoft Visual Studio and see if the compiler is trying to tell you anything about the code. Figure 3-6 shows your brother's code after he has compiled it.

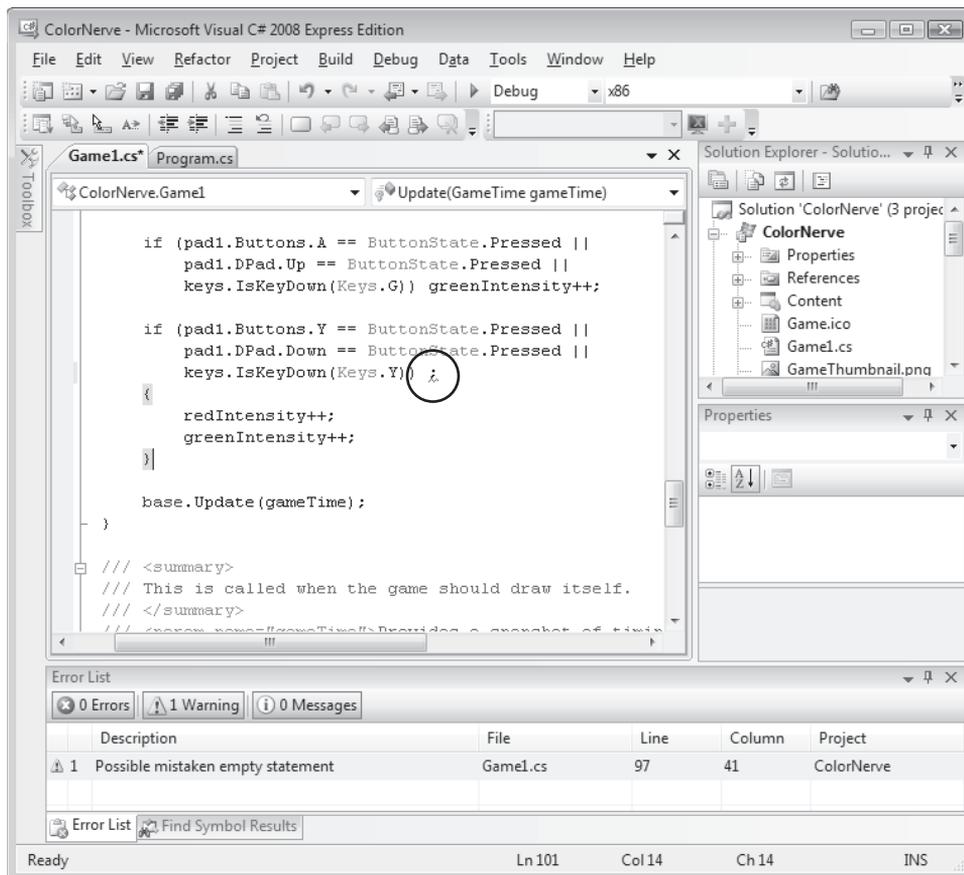


FIGURE 3-6 Visual Studio compiler warning display

Your attention is drawn to the bottom left corner, where the message “Possible mistaken empty statement” appears. If you double-click this message, you find that the cursor moves to a point just after the `if` condition (I’ve drawn a circle around it in Figure 3-6).

The C# compiler is trying to tell us something about this statement. If we go back to the original listing, we find that your brother has added an extra semicolon at the end of the condition. The problem is that this ends the statement controlled by the condition. So if the R button or the R key is pressed or the Dpad is pressed down, the program decides to do nothing (an empty statement) and then goes on and performs the next statements no matter what, leading to the effect that we are seeing. Figure 3-7 shows how this happens.

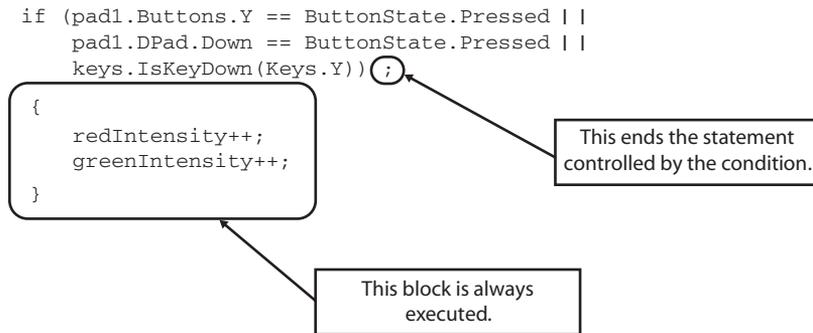


FIGURE 3-7 The effect of an extra semicolon

You remove the semicolon, the warning goes away, and the program works fine. Your younger brother is now starting to revise his opinion of you and offers to take out the trash that night, even though it is your turn.

The Great Programmer Speaks: Helping Other People Is a Good Plan The Great Programmer has been watching all this with approval. She figures that it is always a good idea to try to help people who are stuck with a problem. Sometimes when a programmer working on uncovering a bug has the chance to explain what is going wrong with a piece of code to an innocent bystander, that can be enough to allow the programmer to work out what is broken. That means you can get a reputation as a fearsome bug fixer just by standing by. Furthermore, seeing what mistakes other people make can give you hints on things that you need to look out for when your programs go wrong. Oh, and sometimes you get your trash taken out for free.

Conclusion

You have learned a lot in this chapter, and you have finally managed to create some games that players can have fun with. You have seen how XNA allows programs to interact with physical devices by calling methods on classes, and we have seen how a program can make decisions on the information that it receives from the devices and use this to make simple (and silly) games.

Chapter Review Questions

No chapter would be complete without a review. So here it is. You should know the routine by now; just decide whether a statement is true or false and look the answers up in Appendix A at the back of the book to find out whether you are a winner or a loser.

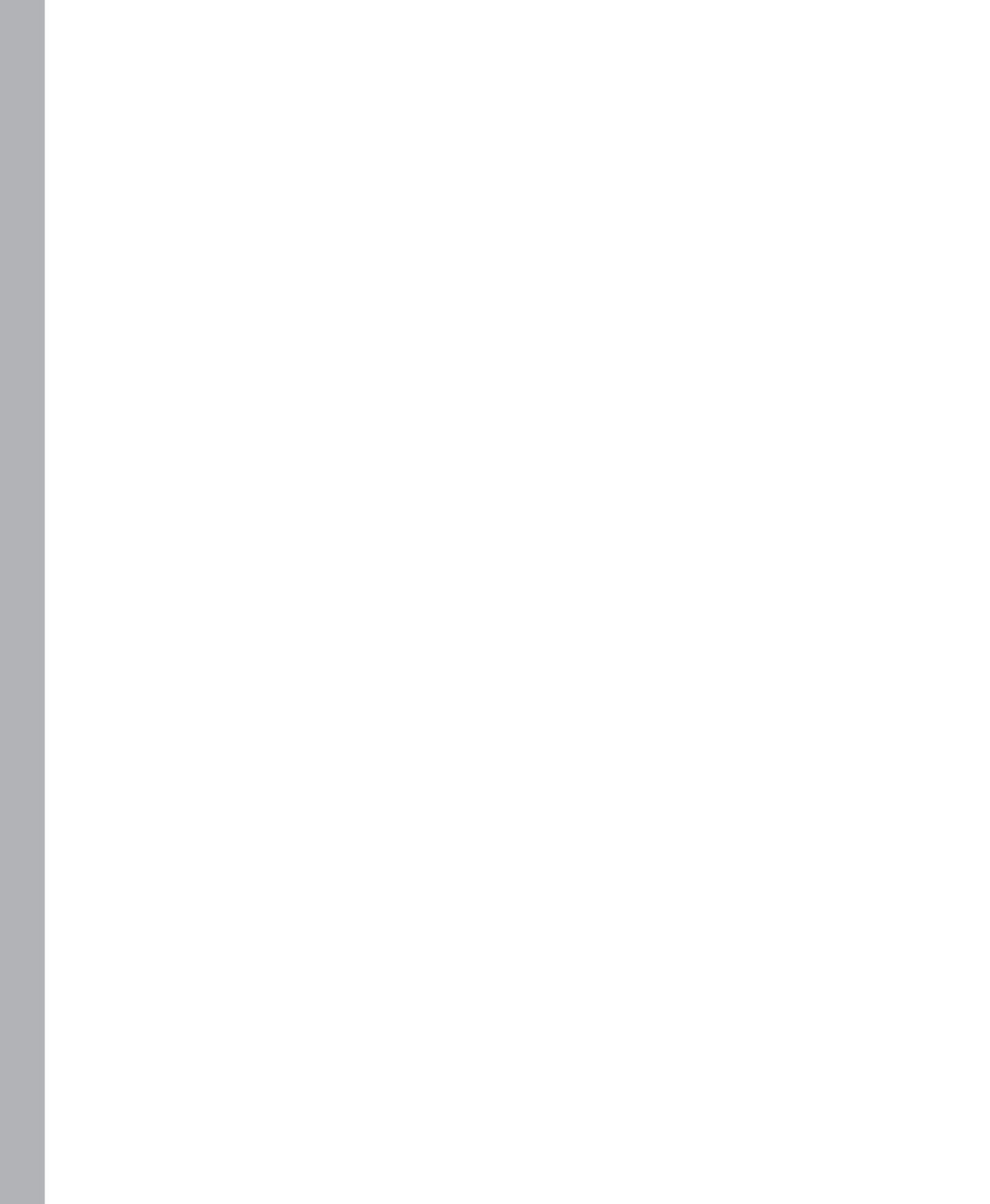
1. If a class is an office, a method is a desk.
2. The compiler creates all the instances of classes in a program.
3. An `if` statement must have an `else` part.
4. A parameter is used to feed information into a class.
5. The `else` part of an `if` statement is always performed.
6. The state of a gamepad is represented in an XNA program by a byte value.
7. The `GamePad.GetState` method can be used to see if a button is pressed on a gamepad (this is a tough question; you are allowed to look at the chapter to work it out).
8. A block is a number of C# statements enclosed in curly brackets.
9. The C# condition `(true || false)` means “true or false” and would work out to `true`.
10. The C# condition `(redIntensity > 220)` evaluates to `true` if the value in `greenIntensity` is greater than 220.
11. The gamepad vibration always turns off automatically when an XNA game stops running.

Part II

Images, Sound, and Text

In this part:

| | |
|---|-----|
| Chapter 4: Displaying Images | 65 |
| Chapter 5: Writing Text | 85 |
| Chapter 6: Creating a Multi-Player Game | 105 |
| Chapter 7: Playing Sounds. | 115 |
| Chapter 8: Creating a Timer. | 127 |
| Chapter 9: Reading Text Input | 141 |



Chapter 4

Displaying Images

In this chapter, you will

- Find out how the Content Manager lets you add pictures to Microsoft XNA games.
- Discover how pictures are manipulated in game programs.
- Display your pictures on the screen.
- Make a better version of Color Nerve and an even groovier mood light.

Introduction

Your understanding of computers and programs should be coming along nicely by now. You are starting to get a grasp of classes, methods, and data, as well as the C# constructions that let your programs make decisions depending on the values in your variables. You also know how to read information from the gamepad and the keyboard and how to use this information to change what a game does when it runs.

In this chapter, you learn how to use images in your programs, improve Color Nerve so that it lets you use your own pictures, and make an even more impressive mood light.

Program Project: Picture Display

Pictures in games are always nice. XNA provides features that are extremely useful for manipulating images on the screen. Many games use image resources to generate the view that the player sees. In this project, you get XNA to display a picture. Once you have some of your images loaded into your programs, you can see about using them in games. Doing this very simple thing requires a lot of work, including the following steps:

1. You need to get the picture that you wish to draw into your game project so that it becomes part of the program when it is loaded into the target device.
2. You must add code to the program that fetches the image into the program when it runs.
3. You need to tell XNA where on the screen the image is to be drawn.
4. You go ahead and draw the item.

The good news is that while you're learning how to do this, you're finding out a lot about how games, C#, and XNA work.

Resources and Content

In the early days of computers, a program simply read in numbers and printed out results. Things have moved on a bit since then, and now computer programs can work with images, video, and sound. This is especially useful where games are concerned; a large part of the enjoyment of a game results from an attractive game environment. And sometimes the graphics themselves form part of the game play. If you want to become a game developer, you need to know how these resources are made part of your program. In fact, many programs today have significant graphical content in the form of splash screens, icons, and the like. So the first thing you need to do is get some images and incorporate them into your project. Later, I'll show you how to use other kinds of resources, including fonts (for writing text) and sounds.

Unfortunately, I won't be able to help you create your graphics for use in computer games. I have no artistic abilities whatsoever, although I do know how to use a camera. If you need artistic resources, my advice is to find someone who is good at art and commission him or her to do the drawings for you. The same goes for any music or sounds that you might need.

This means that you can concentrate on what you are supposed to be good at: creating the game itself. This is what professional game developers do. They have a team of programmers who make the game work and a team of artists and sound technicians who work on the sensory aspects of the game. Having said that, you might be good at graphic design as well as programming, in which case you can do both. However, I still advise getting an artist involved, as it helps spread the work around and provides you with a useful sounding board for ideas. It also makes it more fun.

Getting Some Pictures

At this point, you need some pictures. You need to tailor your images to fit the screen of the XNA device you are going to use. The Xbox screen is capable of showing high-resolution images. A high-resolution image is made up of a large number of dots, or pixels. Modern digital cameras can create images that are thousands of pixels in height and width. However, from a game point of view, you want to make the images as small as you can. This reduces the amount of memory they consume and also reduces the work required to move them around the screen. You won't usually need very high resolution for your games, so your pictures need be no more than 600 pixels in each direction. The Zune display is 240 pixels wide and 320 pixels high, so you should use even smaller images for XNA games intended to run on this device.

There are a number of different formats for storing pictures on computers. Your pictures should be in the Portable Network Graphics (PNG), Windows Bitmap (BMP), or Joint Photographic Experts Group (JPEG) format. The PNG and BMP formats are lossless, in that they always store an exact version of the image that is being held. PNG files can also have transparent regions, which is important when you want to draw one image on top of another.

The JPEG format is lossy, in that the image is compressed in a way that makes it much smaller, but at the expense of precise detail. The games that you create should use JPEG images for the large backgrounds and PNG images for the smaller objects that are drawn on top of them.

If you have no pictures of your own (which I consider highly unlikely), you can use the ones that I have provided with the sample files for this chapter, but the games will work best if you use your own pictures. Figure 4-1 shows my picture of Jake. I will be using this for my first XNA graphics programs. You can use another picture if you wish.



FIGURE 4-1 Jake

I have saved the image in the JPEG file format with a width of 600 pixels. If you need to convert into this format, you can load an image using the Microsoft Paint program and then save it in this format. With Paint, you can also scale and crop images if you want to reduce the number of pixels in the image. For more advanced image manipulation, I recommend the program Paint.Net, which you can obtain for free from <http://www.getpaint.net/>.

Content Management Using XNA

As far as XNA is concerned, *content* (images, sounds, 3-D models, and video) is what makes games more interesting. XNA treats items of content in the same way that variables are created in programs. XNA can import a content item of a particular type (for example, my file containing a picture of Jake) and give it an identifier. When the game program is running, XNA fetches the game content items as they are requested by name. These content items are sometimes referred to as *assets*. In the same way that a company has assets, such as buildings, machinery, and staff, a game has assets such as sounds and images.

Working with Content Using XNA Game Studio

You use XNA Game Studio to put content into your game. When the finished program is constructed, XNA Game Studio makes sure that the assets are available to your game. The good news is that you don't need to worry about any of this; you need only know how to load assets into XNA Game Studio and get hold of them from within your game programs.

XNA Game Studio Solutions and Projects

You start making a game by creating a brand-new project. I called mine JakeDisplay. You create the project using the New Project dialog box as you've done for all your previous projects. Remember that the project you are creating is either a Windows Game (3.0), an Xbox Game (3.0), or a Zune Game (3.0). You can see this dialog box in use in Figure 1-4 in Chapter 1, "Computers, Xboxes, C#, XNA, and You." Note that the Create Directory For Solution option is selected in this dialog box. Whenever you create a project, you should ensure that this option is selected. This creates a directory structure that contains the program and all the other items that are required to make the game work.

Figure 4-2 shows what is created when I make a new project called JakeDisplay.

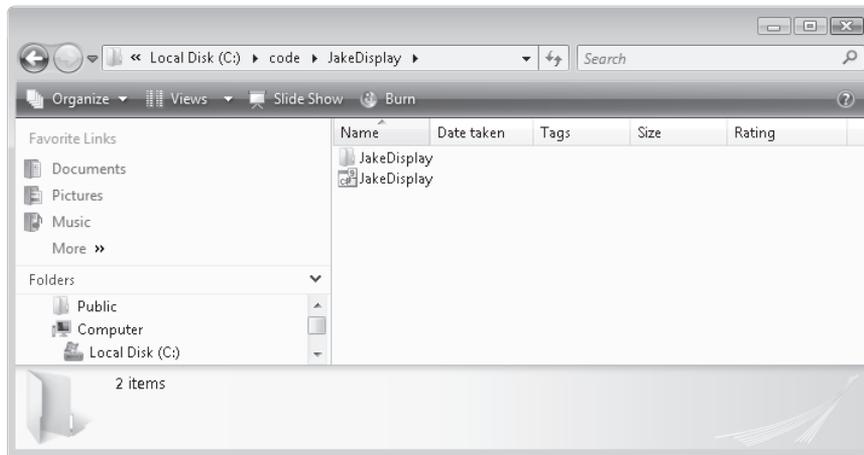


FIGURE 4-2 The JakeDisplay solution directory

However, the file JakeDisplay that you can see in the directory is a solution. This might be confusing. You've used the New Project command in XNA Game Studio and have ended up with a solution. In this case, XNA Game Studio has created a solution called JakeDisplay and then added a single project to that solution. The project is also called JakeDisplay. You can think of a *solution* as a "shopping list" of projects. Figure 4-3 shows how this works. The solution holds a list of the names of project files. Each of the project files holds a list of the names of the files used in that project. Each item on the list is often referred to as a *reference* to that item, in that it tells XNA Game Studio how to get to it.

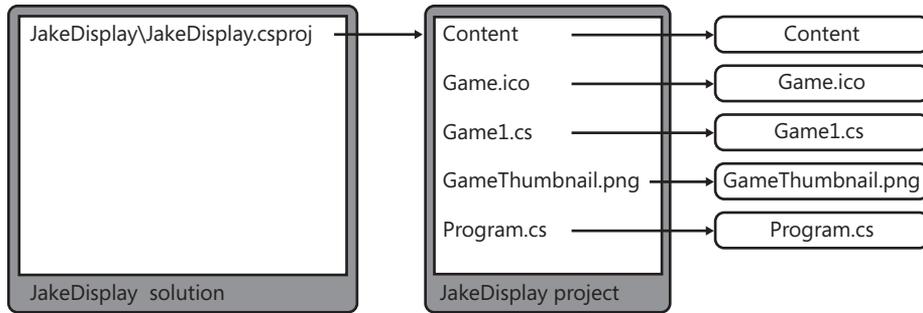


FIGURE 4-3 The JakeDisplay solution

The solution file holds the name of the JakeDisplay project. The project file holds the names of the C# files in the project (Game1.cs and Program1.cs) and other resources used by the project including the Content directory. At present, the only two resources are GameThumbnail.png, which is an image used as a thumbnail on the display when the game is stored on the Xbox or Zune, and Game.ico, which is the icon used for the game program file on a Microsoft Windows PC. When you add your image of Jake to the project, you add the name of the file to the project file so that XNA Game Studio knows where to go to get the asset. XNA Game Studio displays the contents of the solution and project files as a diagram in Solution Explorer, as shown in Figure 4-4. Note that the solution file and project files also contain other settings (the Properties and References) that you'll use later.

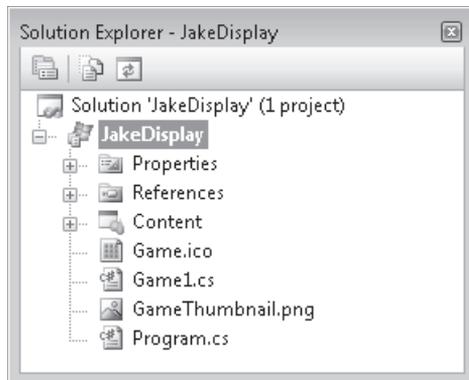


FIGURE 4-4 JakeDisplay in XNA Game Studio Solution Explorer

You have already seen that a single game solution can hold projects for deployment to an Xbox, a Zune, or a Windows PC. Sometimes you might want to add more projects to a solution so that you can separate your code into reusable portions or because you want to reuse code that you already separated that way. For example, you might make a project called HighScoreManager, which would be in charge of displaying high-score tables for your game. High scores work the same way in many games, so it makes sense to write the code only once and then use it in those games. You would do this by creating a library project to deal with the high scores and then add this project to the “shopping list” of those projects. However, for now, you simply create games that are single projects.

The Great Programmer Speaks: Architecture Is Important Our Great Programmer is very keen on using projects to reuse code. The way she sees it, that way she can get paid several times for writing the same piece of software. When she starts work on a new system, she takes a lot of time to try to structure things into projects so that different parts of the system are in separate projects.

Adding Resources to a Project

An XNA Game Studio project contains references to everything that it uses. To keep things simple, you can keep everything used by a project in a single file directory. Figure 4-5 shows the content of the JakeDisplay project directory that XNA Game Studio created for you when you made the new project. You can see the C# source files and also some other resources.

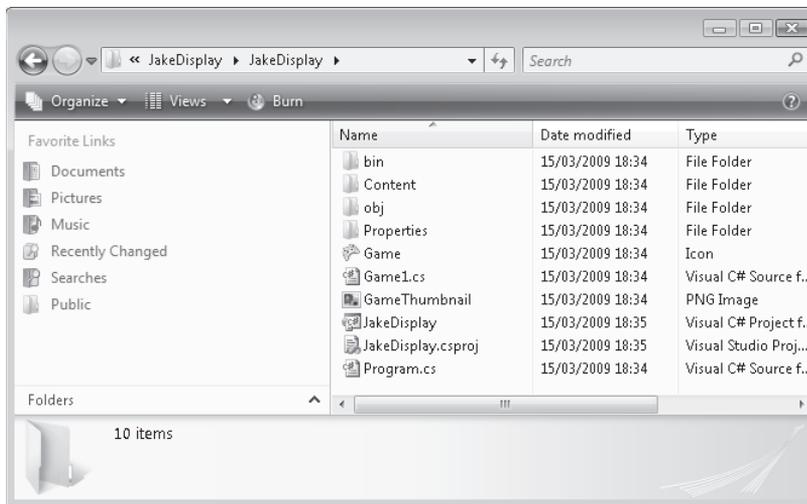


FIGURE 4-5 The contents of the JakeDisplay project directory

The project contains a Content directory. When you add an asset to this project, it is stored in this directory. Figure 4-6 shows the JPEG image of Jake that I used in my Pictures directory. You need to place the picture that you want to use into a directory somewhere on the computer.

You can either use one of the graphics images that are available in the sample projects or create your own picture at this point. Now that you have your graphics resource, you can tell XNA Game Studio to use it. To do this, you need to add the content to the project. Resource references are added by using the Add Existing Item – Content dialog box, which can be opened as shown in Figure 4-7. Start by right-clicking the JakeDisplay project's Content item in Solution Explorer. From the menu that appears, select Add and then select Existing Item.

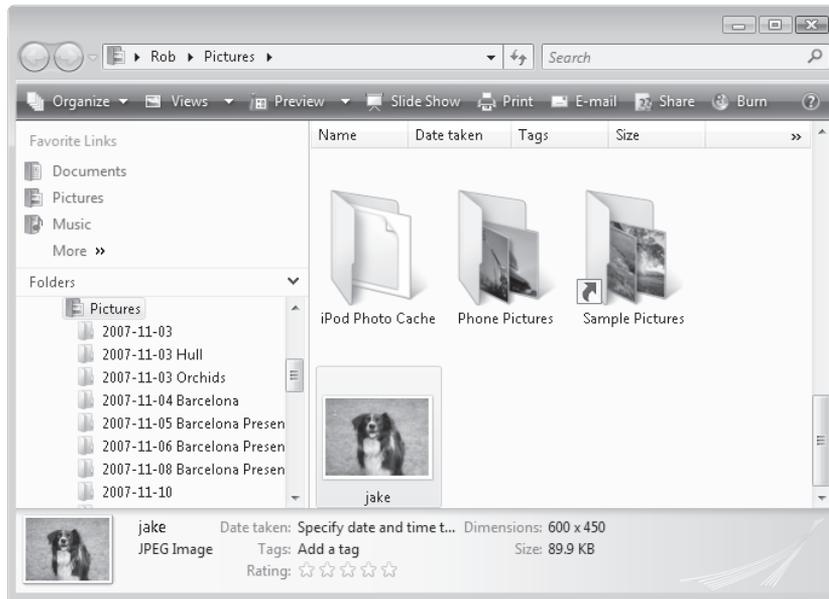


FIGURE 4-6 My Jake image in my Pictures directory

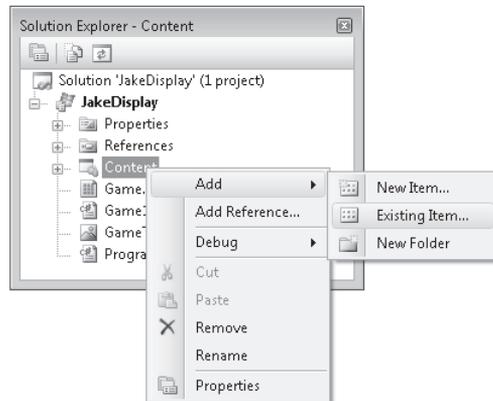


FIGURE 4-7 Opening the Add Existing Item – Content dialog box

Figure 4-8 shows the dialog box that you can use to select an item to add to the project.

Now you can select the image file that you want to use and click Add to add it. The project now contains the resource. Figure 4-9 shows the resource reference in the project once you've added it. You follow the same process to add other images to a game.

If you want to add more than one image to a project, simply repeat the process. Remember that each image is stored as part of the game program, so the more images you add, the larger your game becomes and the longer it takes to transfer it into the target when it runs.

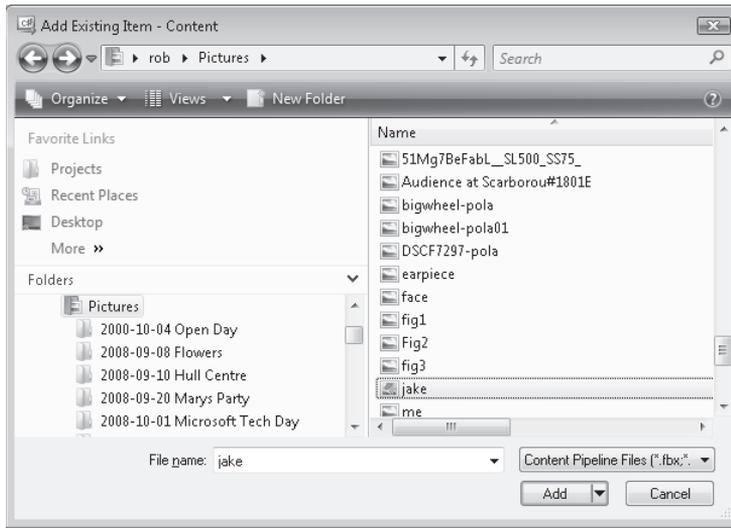


FIGURE 4-8 The Add Existing Item – Content dialog box

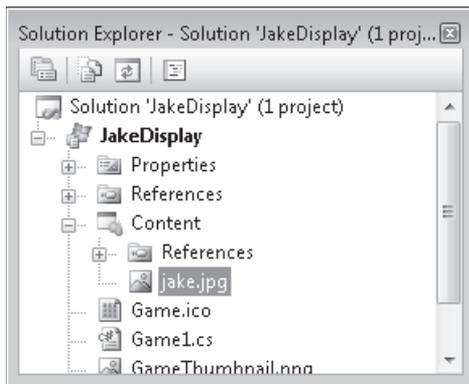


FIGURE 4-9 The JakeDisplay project containing the image resource



Note The Xbox and Windows PC have plenty of memory in which to store loaded images. However, the Zune device is restricted in the space that it has available. If you want to store lots of pictures in the Zune, you need to use small images (320 x 240 pixels or less) to make sure that you don't run out of space.

Adding Links to Resources

When you add a resource using the process described previously, XNA Game Studio makes a copy of the resource and places the copy in the Content directory of the project. If you want several projects to share a single copy of a resource, you can add a link to it instead. You do this by clicking the down arrow at the right of the Add button in the Add Existing item dialog box, as shown in Figure 4-10, which allows you to add the resource as a file or as a link.

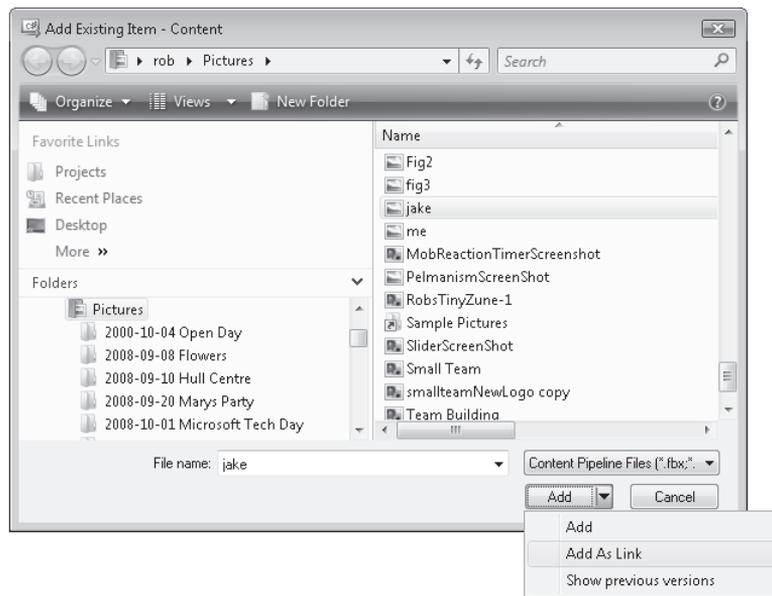


FIGURE 4-10 Adding the Jake image as a link

Each time XNA Game Studio builds the game, it follows the link to the resource to use it. If the resource is moved or deleted, the build process fails.

The XNA Content Pipeline

The process of feeding resources in at one end and getting a complete game assembly out of the other is a bit like a *pipeline*. In fact, the XNA Framework refers to this part of the game-building process as the Content Management Pipeline.

Using Resources in a Game

You've done a lot of hard work, but your program still can't draw any pictures. If you run the solution that you've created, you get the familiar blue screen. Next, you have to write some C# code that fetches the image resource and draws it on the screen at a particular location.

Loading XNA Textures

Within XNA, images that you want to draw in your games are called *textures*. Textures can be drawn as flat pictures, and they can also be wrapped around 3-D models. You've already seen how to use the XNA `Color` type, which lets you manipulate color information. Now you'll use another type of XNA data variable so that you can work with your picture as a texture. XNA provides a range of types that are used to deal with textures. The type you'll

use is called `Texture2D`. This holds a texture that you manipulate in two dimensions; that is, it is drawn on the screen as if it were a flat surface.

You use the same program structure that you used for previous games. Members of your game class represent the “game world.” These are updated by the `Update` method and used by the `Draw` method to draw the output. The game data takes the form of a single variable that holds the texture, as shown here:

```
// The Game World
Texture2D jakeTexture;
```

The `Draw` method draws this texture on the screen, and you could use the `Update` method to make the image move around the screen by changing the draw position.

You also can use another method that lets the program take control when the graphics need to be loaded. Figure 4-11 shows how this works. It is a more detailed version of Figure 2-5 in Chapter 2, “Programs, Data, and Pretty Colors,” which showed how XNA calls the `Draw` and `Update` methods as a game runs. It shows that there is also a `LoadContent` method that is called by XNA when a game starts running.

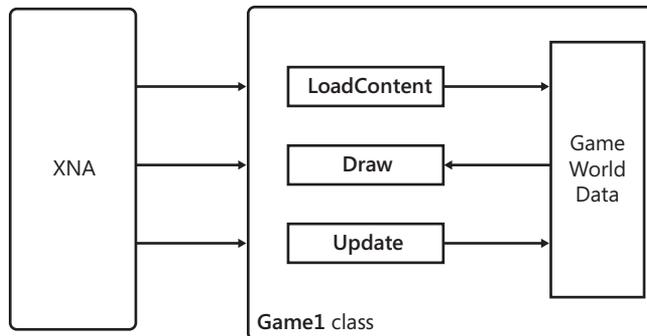


FIGURE 4-11 The `Game1` class with the `LoadContent` method

You can think of `LoadContent` as another person in the `Game1` office. That person has his or her own telephone. When the phone rings, that person must load all the content and make it ready for use, as follows:

```
protected override void LoadContent()
{
    // Create a new SpriteBatch, which can be used to draw textures.
    spriteBatch = new SpriteBatch(GraphicsDevice);

    // TODO: use this.Content to load your game content here
}
```

In addition to loading the content that the game needs, the `LoadContent` method also creates a `SpriteBatch` for the program to use. You will use this later to draw the texture on

the screen. You've even been given a comment to tell you where to place the code that loads your texture. This is the place where the program must ask the Content Manager to fetch the texture:

```
protected override void LoadContent()
{
    // Create a new SpriteBatch, which can be used to draw textures.
    spriteBatch = new SpriteBatch(GraphicsDevice);

    jakeTexture = this.Content.Load<Texture2D>("jake");
}
```

When the game starts, XNA calls the `LoadContent` method to fetch content for use in the game. The method then performs the statement that loads the texture content:

```
jakeTexture = this.Content.Load<Texture2D>("jake");
```

The `Load` method is a kind of multipurpose tool called a *generic* method. Because it's generic, it can be used to fetch any kind of item, from textures to audio files to 3-D models. You tell `Load` to fetch a `Texture2D` by placing the name of the type you want after the method name. You then give the method the asset that you want it to fetch. If you select the `Jake.jpg` item in Solution Explorer, as shown in Figure 4-9, and then look in the XNA Game Studio Properties pane (which should be in the lower right of the XNA Game Studio window), you can see that the asset name has been taken from the file name of the resource. Figure 4-12 shows the property information for the `Jake` image resource.

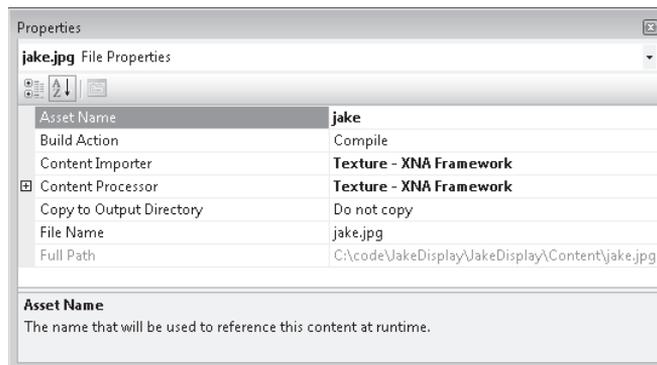


FIGURE 4-12 Jake image resource properties

This property information tells XNA Game Studio where the image file is located, what to do with the file when the project is built, and the name to use in the program. So, once the `Load` method has completed, you have a copy of the image in the texture in your game. If the game had lots of different images, you would declare additional `Texture2D` items in your game world and assign them to textures using the `LoadContent` method as well.

If you get the name of the texture wrong, the game program fails in this method, as it is looking for an asset that is not there. The program fails by throwing an *exception*. Figure 4-13 shows the error that is produced if the asset name of a content item is incorrect.

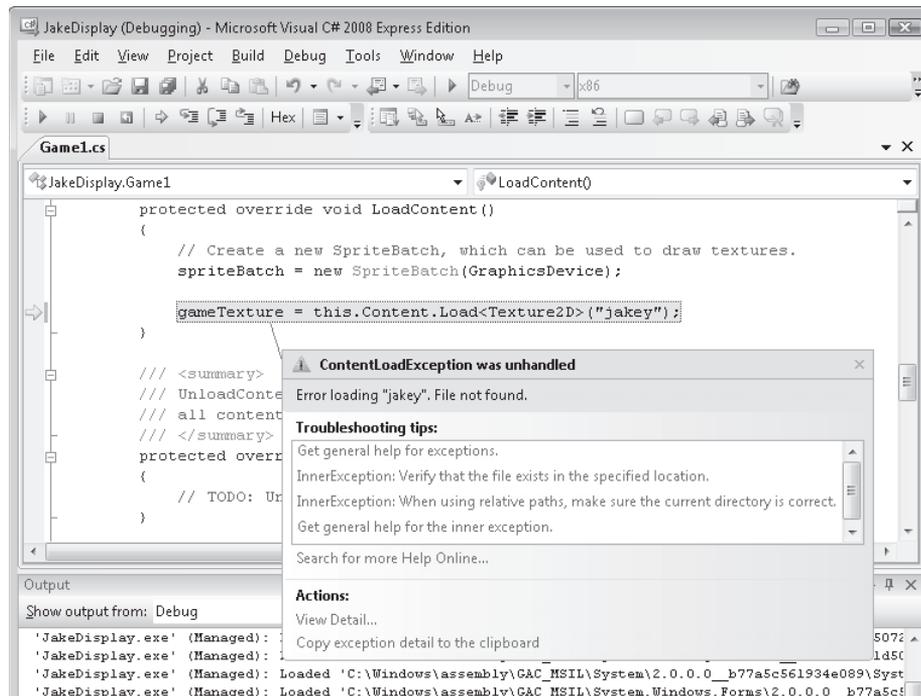


FIGURE 4-13 The texture file not found exception

Later, you'll find out how to take control when things go wrong like this; for now, you should make sure that the asset name you use in the call of `LoadContent` matches the name of the content item.

The Great Programmer Speaks: Always Worry About Things Going Wrong Our Great Programmer spends a lot of time worrying about things that might go wrong. She figures that in a commercial application, such as one that might be used in a bank, she has to write at least as much program code to deal with all the potential errors as she writes to perform the actual job. Game programs are probably not as critical as bank code in that, if they go wrong, nobody actually loses any money, but if a game constantly crashes, it will never become popular. Later, you'll see how to make sure that your program fails as seldom as possible.

Positioning Your Game Sprite on the Screen

In computer gaming terms, you can think of the image of Jake as a *sprite*. A *sprite* is a flat, preloaded image that is used as part of a computer game. Sprites can be large, such as background sky, or smaller, such as spaceships and missiles in a space shooter game. From

the point of view of XNA, a sprite is an image resource along with location information that tells XNA where to draw the image. This means that you need a way to tell XNA where on the screen you want to put your sprite. You do this by using yet another XNA type, the `Rectangle`. This holds information about the position and size of a rectangle. You don't need to worry about how a rectangle works at the moment; you need only know how to create one and set the size and position of it. Figure 4-14 shows how you use a rectangle to express where on the screen you want Jake to be drawn.

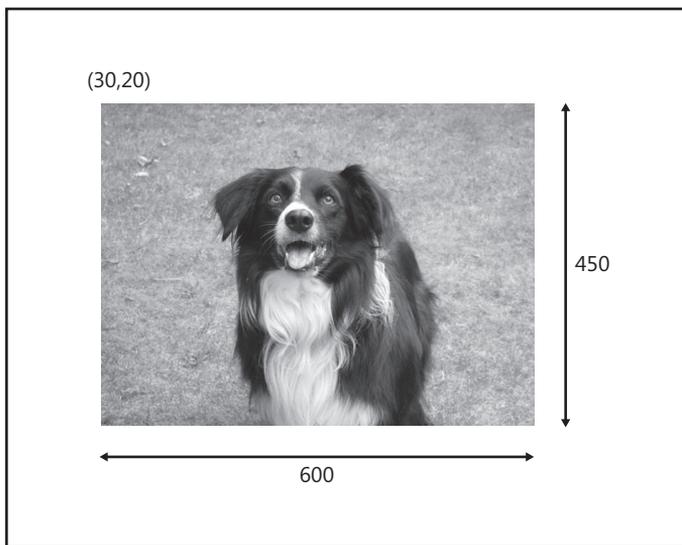


FIGURE 4-14 Placing a drawing rectangle on the screen

The position of the rectangle is given by the coordinates of its top left corner. You can regard the screen as a piece of graph paper. You express a position on the screen by giving an x coordinate value (the distance across the screen from the left) and a y coordinate value (the distance down the screen from the top). This means that the position with the coordinate of (0, 0) is the top left corner. Note that this is not quite the same as graphs that you may have drawn in the past. In a conventional graph, the y value increases as you go up the page. In computer graphics, the y value increases as you move down the page.

In Figure 4-14, you can see that the top left corner of the Jake sprite is at position (30, 20). This means 30 steps across and 20 down. The units are called pixels. *Pixel*, an abbreviation for “picture element,” refers to the smallest dot that can be drawn on the screen. The Xbox can drive displays with a range of different sizes, so the pixel at position (30, 20) may be a different physical distance across the screen, depending on the type of screen being used. Later, you’ll find out how to write games that automatically scale themselves to fit any screen.

A rectangle is also used to give the width and height of the sprite. In Figure 4-14, I am drawing the texture in an area that is 600 pixels wide and 450 pixels high. The good thing about this is

that I don't have worry about the original size of the image; XNA simply scales the image to fit in a rectangle that size. Later, you'll have some fun modifying the size. The rectangle where Jake is drawn is another item in the game world for the program, as shown here:

```
// The Game World  
  
Texture2D jakeTexture;  
Rectangle jakeRect;
```

The actual `Rectangle` you are going to use is created using `new`:

```
jakeRect = new Rectangle(30, 20, 600, 450);
```

This code sets a `Rectangle` variable to one with the position and dimensions that you need. When the rectangle is created, it is passed the `x`, `y`, `width`, and `height` values so that these can be held within the rectangle structure. This means that if you ever want to move the image or change its size on the screen, you need to change only one of the values that is held in the rectangle. These values are members of the `Rectangle` structure. In C#, members that hold values are called *fields*.

You can think of a field as a variable that has been declared inside a structure or class. In the case of your `Game1` class, the game world data that you created (for example, the color intensity values for your mood light) are fields of that class. Later, you'll see how to get hold of individual fields inside the `Rectangle` so that you can change its size and position.

The `Rectangle` needs to be created when the game program starts. You could do this in the `LoadContent` method, but XNA provides another place where it is more sensible, namely, the `Initialize` method. This is called when the game starts up. If all these methods are confusing, think about what happens when you organize a party. This takes a number of steps:

1. Set up the tables and chairs.
2. Fetch the food and drink.
3. Repeatedly play music and dance.
4. Tidy up afterward.

When an XNA game runs, it goes through the same process:

1. Set things up: `Initialize`
2. Load game content: `LoadContent`
3. Repeatedly update the game and draw the display: `Draw` and `Update`
4. Free up all the content: `UnloadContent`

When the game ends, the XNA system calls the `UnloadContent` method. You can add statements to that method to release resources explicitly that your game has used, but for now, you can leave this out.

In fact, you need not provide code for all these methods; they are there only so that you can take control at various points of the game's life cycle. The code that you put in the `Initialize` method needs to create a `Rectangle` that describes the destination of the draw operations:

```
protected override void Initialize()
{
    jakeRect = new Rectangle(30, 20, 600, 450);
    base.Initialize();
}
```

Sprite Drawing with *SpriteBatch*

You now have all the information about your sprite and are ready to draw it. Next, you need to take control in the `Draw` method and put your image onto the screen. But before you can do the drawing, you need to take some time out and discover more about how game consoles work.

A modern game console is not one powerful computer; in fact, it is several. Some of these run the game itself, whereas other special graphics processors drive the display. The graphics processor unit (GPU) contains optimized hardware to allow it to update the screen as fast as possible. When the `Draw` method runs, the method assembles a bunch of instructions for the GPU and sends the instructions into the GPU. The GPU then follows those instructions to put a picture on the screen. Complex games contain many images that may be drawn at several different positions on the screen. It is important that the transfer of the position information and associated images is organized as efficiently as possible. XNA provides a special class called `SpriteBatch` to batch up a set of sprite-drawing instructions. Your program calls methods on a `SpriteBatch` variable to get the drawing done. This means that a `SpriteBatch` needs to be created for the program to use. When XNA Game Studio creates a new project, it adds the statements to the `LoadContent` method that create a `SpriteBatch` for you to use. The variable is called `spriteBatch`.



Note It might look as if you have two items with the same name in your program. However, if you look carefully, you see that the class `SpriteBatch` starts with an uppercase `S`, but the `spriteBatch` variable starts with a lowercase `s`. This works because the C# compiler considers the case of the letter as significant in an identifier. In other words, your program could have two variables, `Fred` and `fred`, and they would not be confused.

Now you can use `spriteBatch` to draw the sprite. You must tell `spriteBatch` when you've started drawing sprites and when you've finished:

```
protected override void Draw(GameTime gameTime)
{
    graphics.GraphicsDevice.Clear(Color.CornflowerBlue);

    spriteBatch.Begin();
    spriteBatch.Draw(jakeTexture, jakeRect, Color.White);
    spriteBatch.End();
    base.Draw(gameTime);
}
```

You call methods on the `spriteBatch` variable to begin the draw process, draw the sprite, and then end the drawing. The `Draw` method is part of the `SpriteBatch` class and is given parameters that identify the image to be drawn, the rectangle to place it in, and the color of the light to “shine” on the texture.



Note The game class contains a `Draw` method, which is used to draw the entire game. The `SpriteBatch` class also contains a `Draw` method, which is used to draw textures. Although the methods have the same name and are both involved in the draw process, they actually do different things. However, both are performing a drawing operation in their own way, so it is appropriate for the designers of XNA to call them `Draw` methods.

If you put a program together with the previously described methods, you can finally run a program that will display an image on the screen.

Sample Code: Jake Display All the sample projects can be obtained from the course instructor. The sample project in the `01 JakeDisplay` directory in the resources for this chapter draws a picture of Jake.

Figure 4-15 shows the output that you get when you run your program to display Jake on the screen.

If you change the content of the file `Jake.jpg`, you can make this program display other pictures.

If you run this program on a Zune device you will find that the picture is too large to fit on the Zune display, which is limited to 240 by 320 pixels. This will not cause XNA to report an error, but not all of the image will be displayed. You can fix this by reducing the width and height of the rectangle to 180 and 120 respectively. This preserves the aspect ratio, but makes sure the image will fit on the screen.

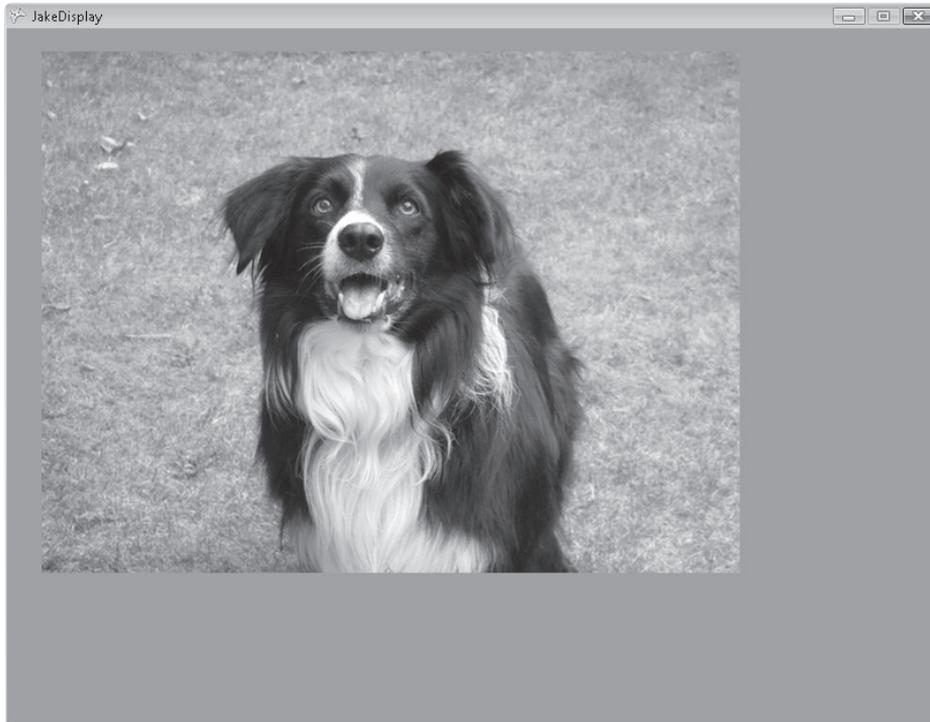


FIGURE 4-15 Displaying Jake on a PC screen

Filling the Screen

It would be nice if the image that you display could exactly fill the screen. You've used values that let you see the picture, but the picture does not completely cover the display, and if you run the program on differently configured systems, you notice that the picture takes up a different amount of space on the screen. It turns out that filling the screen is easy to do. Your program can ask the XNA environment the width and height of the screen and use this to set the size of the display rectangle, as follows:

```
jakeRect = new Rectangle(  
    0,    // X position of top left corner  
    0,    // Y position of top left corner  
    GraphicsDevice.Viewport.Width, // rectangle width  
    GraphicsDevice.Viewport.Height); // rectangle height
```

I've changed the layout of my call to construct the `jakeRect` variable. Rather than put everything on one line, I've spread the call out a bit and added some comments. This makes it easier to see what's happening. The code is constructing a `Rectangle` instance. When you do this, you can feed information into the construction process to set up the value. This particular call is feeding in the position of the top left corner in the form of `x` and `y` and the

width and height of the rectangle that is required. I can get the width of the screen by using the following code:

```
GraphicsDevice.Viewport.Width
```

This looks a bit scary but is easy to understand. It's rather like the way that we explain where things are. My office is on the third floor of the Robert Blackburn Building on the Hull campus of the University of Hull. You could express this information as follows:

```
HullCampus.RobertBlackburn.ThirdFloor.RobMiles
```

The Hull campus contains a number of buildings, the Robert Blackburn Building contains a number of floors, and so on. You can now find your way to my office by starting at the Hull campus, looking for the Robert Blackburn Building, going to the third floor, and then finding the office with "Rob Miles" written on the door. The identifier is `GraphicsDevice.Viewport.Width`, which means, "Start at the `GraphicsDevice` variable, go to the `Viewport`, and then get the `Width` field from it." The `GraphicsDevice` variable is the Graphics Device manager for your program. It is created by XNA and provides methods and data that you can use in your program (you've already used the `Clear` method to clear the screen). The `GraphicsDevice` contains a `Viewport`, and so on. Part of the skill of using XNA is knowing where these data items are.

Intellisense

You can find your way around the XNA framework by using the *Intellisense* feature, which is part of XNA Game Studio. Whenever you type an identifier into the editor, it finds the variable that the identifier represents and offers you options based on that identifier. These can save you a lot of typing. Figure 4-16 shows how it works. I have just typed the identifier `graphics` followed by the period that separates it from the next item. Intellisense is showing me all the possible items that are available. I can scroll down the list, select the one I want by pressing `Enter`, and then move on to the next item.

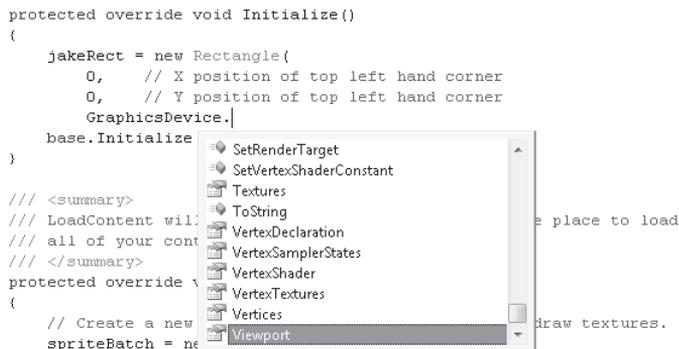


FIGURE 4-16 Intellisense for the Graphics Device manager

You can move quickly up and down the list of items by typing the first few letters of the name of the selection you want. Intellisense also shows you brief help snippets about the items that you can select. It makes writing programs much easier and reduces the amount you have to remember. The Great Programmer doesn't think she could write programs without it.

Sample Code: Jake Full Screen The sample project in the 02 Jake Full Screen directory in the resources for this chapter draws a picture of Jake that completely fills the screen.



Note If you are using an Xbox that is connected to a TV, you might notice that not all the picture is visible. This is because TVs use an “overscanned” display, where only the middle part of the picture is displayed. I'll describe how to fix this in Chapter 11 in the section “Dealing with Display Overscan.” You'll also find that if the shape of your picture does not exactly match that of the screen, the image appears stretched. I'll discuss these problems of “aspect ratio” in Chapter 11 in the section “Drawing and Aspect Ratios.”

Game Idea: Color Nerve with a Picture

Now that you can display pictures, you can improve your Color Nerve game and display a picture rather than a blank background. This makes the game much more fun, especially if a familiar picture is used.

The key to this is the way that you select the color you want to use to “light” any sprite that you draw:

```
spriteBatch.Draw(jakeTexture, jakeRect, Color.White);
```

When drawing this image, I used a white light so that the colors look natural. You can use any color of light, and XNA processes the image accordingly. If you want the image to be drawn more dimly, you can draw with the color gray; if you want to tint the image, you can simply change the color. You can use any color that you can create to tint your sprite, as follows:

```
protected override void Draw(GameTime gameTime)
{
    Color textureColor;
    textureColor = new Color(redIntensity, greenIntensity, blueIntensity);

    spriteBatch.Begin();
    spriteBatch.Draw(jakeTexture, jakeRect, textureColor);
    spriteBatch.End();

    base.Draw(gameTime);
}
```

Rather than using white as the drawing color, this version of Draw uses the color it creates based on the red, green, and blue intensity values.

Sample Code: Jake Color Nerve The sample project in the 03 Image Color Nerve directory in the resources for this chapter is a version of Color Nerve that uses the picture of Jake.

You can use the same principle to make a picture mood light; this works especially well if you use a black-and-white image or one with really strong colors in it. You can also make a picture recognition game here, where the aim of the game is to be the first one to recognize a picture as you slowly make it brighter.

Sample Code: Image MoodLight The sample project in the 04 Image MoodLight directory in the resources for this chapter is a version of the ultimate mood light that uses an image background. The image contains a pattern of blocks of different colors. One interesting challenge is to try to work out which of the blocks is white (only one of them is).

Conclusion

You have learned a lot in this chapter. You've seen how you can add graphical resources to XNA projects and use them in your game programs. You've also found out how images are positioned and drawn on the screen in XNA.

Chapter Review Questions

Just in case you thought you were having too much fun, here's a chapter review to bring you back down to earth. You can look up the answers in Appendix A.

1. The C# compiler manages images.
2. In an XNA program, an image can be held in a texture.
3. XNA uses the `LoadContent` method to load the graphics images onto the display.
4. A sprite is a small, pixie-like creature who lives with the fairies.
5. The `SpriteBatch` class is used to batch up sprites before they are drawn.
6. There is no need to add any code to the `Initialize` method to make an XNA game work.
7. A `Rectangle` has a `Width` field that specifies how wide it is.
8. The XNA system can store only one image at a time.
9. A pixel is a measure of screen size.
10. The origin of the XNA drawing operations is the top left corner of the display area.
11. PNG images would be good for background images in a game.
12. It is impossible to find out how wide the screen is from an XNA game program.

Chapter 5

Writing Text

In this chapter, you will

- Discover how text is drawn using Microsoft XNA.
- Add some font resources to your XNA program.
- Draw some funky text.
- Create the biggest clock you've ever seen.
- Find out how to fake 3-D images.

Introduction

Your programming skills are really coming along. Your programs can store different kinds of numbers, do things with them, and even make decisions. You also know how to add image assets to your games and place them on the screen.

In this chapter you find out how to use some XNA features to make your games even better. Then you can move on to create fully formed games. The first thing you want to do is add some text output so that your games can talk to the players.

Program Project: Giant Clock

The Xbox, the Zune, and the PC each has a clock inside, so each device always knows the date and time. You can use this feature to turn the entire display into a digital clock.

Text and Computers

In the early days of computers, the appearance of text that you could print was limited by the shapes built into a mechanical printer. Later, dot-matrix, laser, and inkjet printers came along, giving high-resolution graphical displays that could draw any character design you wanted. XNA programs are capable of drawing very high-resolution images, and you can use this ability to display text.

Text as a Resource

Before you can start drawing text on the Xbox, you need to understand just how computers manage character designs. The design of the shape of the characters is described in a *font* file.

Microsoft Windows provides a very large number of these font files. The shape of the text that you are reading now is described in a font called "Segoe." Windows also provides a font called "Arial," used in this book for headings, and "Courier New," used here for program listings.

The font file gives the shape of each of the characters. When a character shape is needed for either printing on paper or drawing on the screen, the font data is used to draw this shape at the required size. To get an XNA program to display text in a particular font, you need to add a reference to that font file to the program project. You then use the XNA Content Management System to bring the font into the program for use when you want to draw text.

Creating the XNA Clock Project

You create the project (called BigClock) using the New Project dialog box as you've done for all your previous projects. You can see this dialog box in Figure 1-4 in Chapter 1, "Computers, Xboxes, C#, XNA, and You." Note that the Create Directory For Solution option is selected in this dialog box. Whenever you create a project, you should ensure that this option is selected.

Adding a Font Resource

Figure 5-1 shows how to add a new resource to a game project. In Solution Explorer, right-click the Content item in the BigClock project, then select Add, New Item.

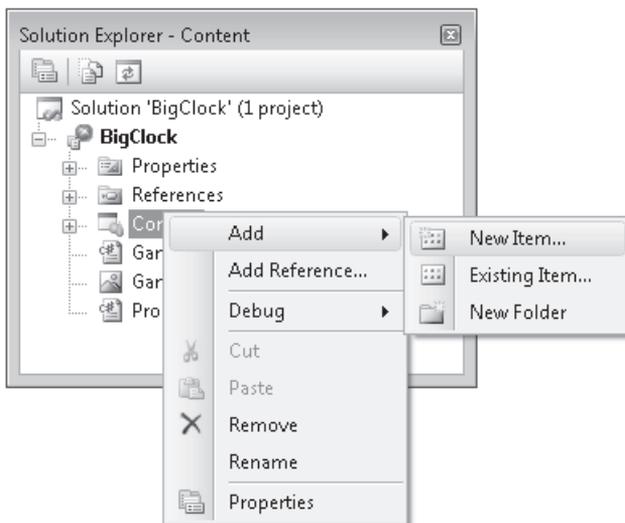


FIGURE 5-1 Adding a new item

You can add a number of different kinds of new items to a project. Figure 5-2 shows the dialog box that lets you select the kind of item you wish to add.

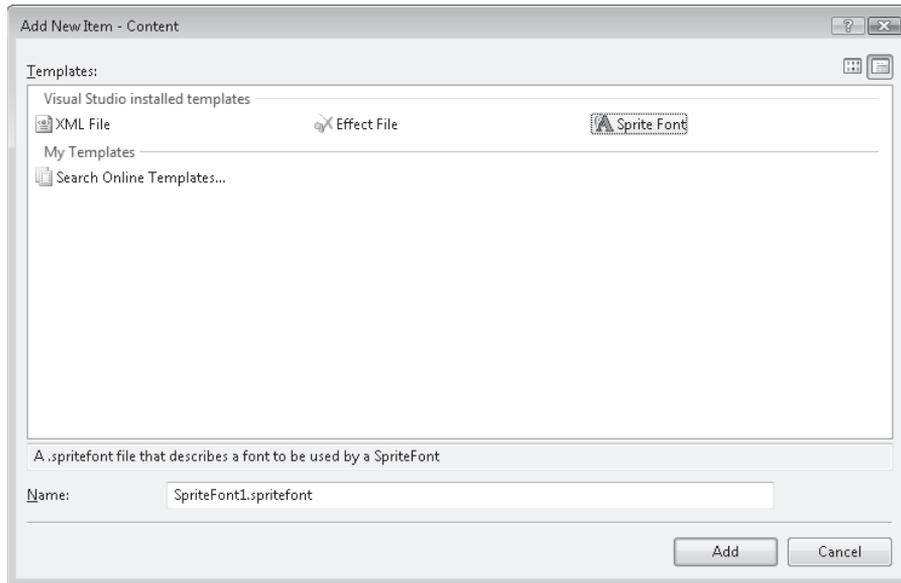


FIGURE 5-2 Selecting a new item

The range of items that you can add to your project depends on how many other Microsoft Visual Studio components you have installed. You might have more items available than those shown in Figure 5-2. If you select the Sprite Font item, you can create a sprite font reference. When you do this, you find that XNA Game Studio has filled in the Name information at the bottom of the dialog box with `SpriteFont1.spritefont`. This is the name that you use within your program to refer to this item of font content. We are going to use this for now, but in later games, you might want to change it to a name that has a bit more meaning.

When Visual Studio builds the `BigClock` project, it reads an existing font on your Windows PC to build the `SpriteFont` that is used when the game runs. When a new font resource is created, it is initially set to use a font called `Kootenay`, which is supplied with XNA Game Studio.

You can use a different font if you want, but if the name you give does not match a font that's installed on your computer, you won't be able to build your program because the Content Manager will be unable to find the requested item.

You can have more than one font in your game if required, but you need to add each font that you want to use as another resource. Remember, though, that adding extra fonts makes your output program bigger because the character designs need to be made part of the program. The name that you give must match a font available on the computer that's being used to build the game because the XNA Content Manager uses the font file on the host computer to build the sprite design for use in your XNA program.

Figure 5-3 shows the font item in Solution Explorer in XNA Game Studio as added to the project. If you select this item in Solution Explorer and open it by double-clicking it, you can see that it's a file describing the font that's to be used in your program.

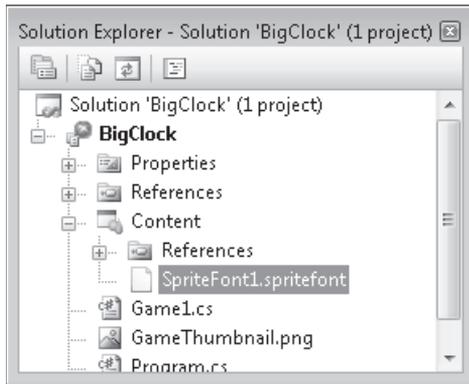


FIGURE 5-3 The font reference in the BigClock project



Note It's important you understand what's happening here. When you add a resource to a project, you simply add a reference to the item that you want to use. You can think of the reference as an item on a shopping list. Just like an item on a shopping list would remind you to buy a new toothbrush the next time you were shopping, a resource reference tells the Content Manager that a certain resource must be fetched when the program is to be built.

When the project is built, the Content Manager follows the reference to the required item and then adds it to the program that's being built. The purpose of the resource information is to tell the Content Manager what to retrieve and how to use the resource in the project.

This reference file is not written in C#, nor is it plain text. It's written in a format called *Extensible Markup Language (XML)*.

The XML File Format

A markup language is used to describe things. It contains the names of these things and information about them. As its name indicates, XML is extensible, so you can use it to describe just about anything. As an example, a snippet of XML that describes a high score might look as follows:

```
<?xml version="1.0" encoding="us-ascii" ?>
<highscore game="Breakout">
  <playername>Rob Miles</playername>
  <score>1500</score>
</highscore>
```

This high score information is for the Breakout game; it shows the name of the player and the score the player reached. The format of the lines and the way that the open bracket (<) and close bracket (>) characters are used to denote the names of the values and the values themselves are defined in the XML standard. The first line of the snippet identifies which version of XML you're using for the rest of the data. The nice thing about XML is that it's easy

for non-computers to understand the content, and it's a very well-established way in which computer software can exchange information.

In the case of your font, the XML tells the Content Manager the name of the font to fetch, the size of the font, whether it's to be drawn as bold or italic, and other font-related information. You don't need to worry too much about what's in this file at the moment, but you can take a look if you wish. Later, you'll edit the content of this file to change the size of the characters that are drawn.

Loading a Font

The Content Manager fetches a font and make it available for use in a very similar way to the images that you've used before. Each character design is delivered to your program as a little image that the Draw method displays on the screen. For your clock, the game world consists of a variable called `font`, which is of type `SpriteFont`. This holds a reference to the font the program will have loaded. `SpriteFont` is another XNA type (there are many more). Your `SpriteFont` will hold information about a font that the Content Manager loads for you. You can declare the variable for the game world as follows:

```
// Game World
SpriteFont font;
```

The font can be loaded in the `LoadContent` method:

```
protected override void LoadContent()
{
    // Create a new SpriteBatch, which can be used to draw textures.
    spriteBatch = new SpriteBatch(GraphicsDevice);

    font = Content.Load<SpriteFont>("SpriteFont1");
}
```

At this point, you might be experiencing *déjà vu* or at least think you've seen this code before. The pattern is the same as when you loaded your images, and even the name of the method is the same. However, this time you're using the generic `Load` method to fetch a `SpriteFont` rather than a `Texture2D` element. There is some strong programming magic at work here, but fortunately you don't need to worry about this at the moment; all you need to know is that the `Load` method gets whatever type it is asked to fetch. Later, you'll create some games that contain textures, fonts, and sounds, and for each type, the `Load` method behaves in an appropriate manner.

Drawing with a Font

Now that you have your font, you can draw with it. Remember that when you used the textures in Chapter 4, "Displaying Images," you used a `Rectangle` to tell the Draw method

where to place the texture. However, when drawing text, you don't do this. Instead, you use a *vector*, which tells the Draw method where on the screen to start. "Vector" is a fancy word that means "direction and distance." You're using the 2-D (x and y value) version of the vector. Games that work in 3-D space use values of x, y, and z (where z is the depth value).

A 2-D vector is given as two coordinates: the x value and the y value. It's a bit like a treasure map that pirates used. A pirate would say, "Start ye at the Old Oak Tree and take ye twenty paces East and thirty paces South, and there ye shall find my treasure chest." The vector says, "Start at the origin and move 20 units across and 30 units down." If you think about it, this means that a vector indeed specifies a direction so that a very smart pirate could work out that she could "cut corners" and get to the treasure more quickly by moving in the appropriate direction. Figure 5-4 shows how this would work, with a line showing the direct path to Blackbeard's treasure.

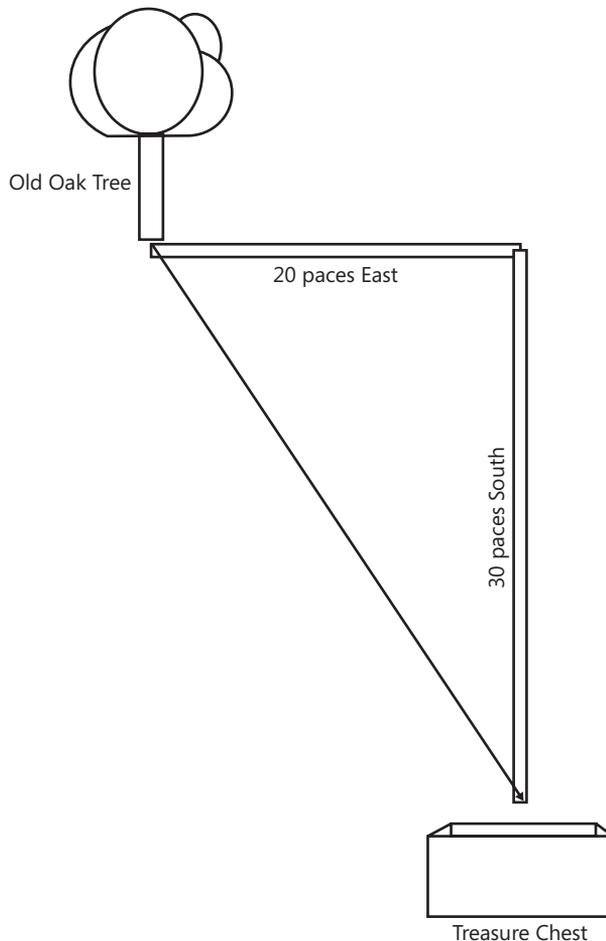


FIGURE 5-4 Vectors and directions to a pirate treasure

In a text-drawing program, you're using a vector like a coordinate in that it specifies the top left corner of the text you're about to draw. You feed it into the `DrawText` method as follows:

```
protected override void Draw(GameTime gameTime)
{
    graphics.GraphicsDevice.Clear(Color.CornflowerBlue);

    Vector2 textVector = new Vector2(20, 30);

    spriteBatch.Begin();
    spriteBatch.DrawString(font, "Hello World", textVector, Color.Red);
    spriteBatch.End();

    base.Draw(gameTime);
}
```

You've placed the top left corner of the text at the spot 20 pixels across the screen and 30 pixels down. The text that you're writing is the famous string "Hello World," which is, by one of the laws of the universe, what your first program that prints text should say. In a C# program, you enter a string as a sequence of characters enclosed in double quotation marks. You're printing the text in Red. If you run this program, you get the display shown in Figure 5-5.



FIGURE 5-5 "Hello World" on the big screen

Although it is perfectly okay to make your first program print something other than “Hello World,” I take no responsibility for any misfortune that you suffer as a result of offending the programming gods in this way.

Sample Code: “Hello World” All the sample projects can be obtained from the course instructor. You can make your “Hello World” program by creating an empty project, adding the font reference, and then adding the game world section and the `LoadContent` and `Draw` methods described in this and the preceding section. If you don’t want to do that, you can load the sample project in the 01 Hello World directory in the resources for this chapter, which writes “Hello World” on the screen. Either flesh out your own `BigClock` solution or just open the 01 Hello World method to continue with the rest of the chapter.

Changing the Font Properties

The program works all right, but you really wanted something larger than this small text. It is possible to scale text sprites, but at the moment it’s easiest to get larger text simply by changing the XML in the `SpriteFont` resource file. This also means that if anybody asks you what you were doing today, you can say, “Oh, I hand-coded some XML,” which should impress them a bit. To get hold of the file that describes the font, open it by double-clicking it in Solution Explorer for the `BigClock` project. Figure 5-6 shows which item to select.

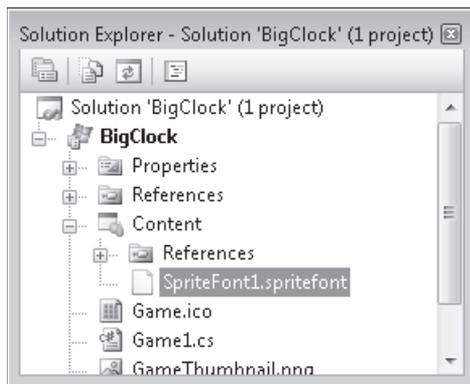


FIGURE 5-6 Selecting the Arial SpriteFont resource

The left window in XNA Game Studio changes to show you the XML that describes the font to be loaded. The font and the size of the text are set as shown here:

```
<!--
Modify this string to change the font that will be imported.
-->
<FontName>Kootenay</FontName>
```

```
<!--  
Size is a float value, measured in points. Modify this value to change  
the size of the font.  
-->  
<Size>14</Size>
```

You can change the name of the font that you want to use and the size of the font by adjusting the items shown in bold in this code. You can also adjust the style and the spacing between letters. You can change `FontName` to select any font installed on your computer (but personally, I really like Kootenay). Use Control Panel on your Windows operating system to find out what fonts are available. Make sure you type the name correctly, including spaces and capital letters. You need to adjust the font size depending on the font design that you select. I've found that a font size of 100 gives nice large text using the Kootenay font on an Xbox or a Windows PC screen. If you are using a Zune a size of 25 works well.

Getting the Date and Time

You can now display text on the screen in a variety of sizes and fonts. You could use this to write a program that simply displays messages on the screen. Next, you need a way to determine the correct time for the clock in your program to display. The PC, the Zune, and the Xbox have internal clock hardware that is used by some games to change the way they play so that, for example, if it's dark outside, it's dark in the game as well. To accomplish this, the XNA Framework must provide a way of finding the date and time.

The date and time values are held in a special structure called `DateTime`. You already know that XNA provides types that are tailored to different needs. You've seen the `Color` type, the `Texture2D` type, and the `SpriteFont` type, to name a few. The `DateTime` type holds all the information about the date and time of a particular instance. The structure is not part of XNA as such; rather, it's part of the Microsoft .NET Framework, which provides resources to all C# programs. Thus, when you want to manipulate dates and times in a C# program running on a Windows operating system, you can do it in exactly the same way.

For your clock, you need a `DateTime` structure that's set to the current date and time. It turns out that `DateTime` provides a property that creates one for you. A *property* is a value or setting that an object in a C# program can expose for you to use. You've already seen these; when you used `Color.CornflowerBlue`, you were asking the `Color` structure to give you a color that represents that shade of blue. You use `DateTime.Now` in the same way. Later, when you start using structures and classes to design more complicated game programs, you'll get more of an insight into how all this works. For now, you simply get a `DateTime` value that holds the current time and use that to drive your clock, as follows:

```
DateTime nowDateTime = DateTime.Now;
```

The `Now` property of the `DateTime` structure is always set to the current date and time. This works by taking values from an internal hardware clock, which means that after a while, the

value will be out of date. In fact, you could use a `DateTime` variable to record the time at which the game was started.

Once you have your `DateTime` variable, you can ask it to do things for you. One thing it can do is give you a string that contains the time in text form:

```
DateTime nowDateTime = DateTime.Now;
string nowString = nowDateTime.ToLongTimeString();
```

These two statements create a variable of type `DateTime`, which holds the current date and time, and then use this to create a string. A string does exactly what you would expect, it holds a string of text. The `DateTime` structure contains a method with the identifier `ToLongTimeString`. You know that objects contain methods; this method has the job of converting the date and time information inside the object into a string that you can put on the screen in text form. In fact, `DateTime` provides several methods that you can use (see Table 5-1).

TABLE 5-1 Some *DateTime* String Methods

| Method Call | Output |
|----------------------------------|---------------------|
| <code>ToLongTimeString()</code> | 20:23:55 |
| <code>ToShortTimeString()</code> | 20:23 |
| <code>ToLongDateString()</code> | 16 March 2009 |
| <code>ToShortDateString()</code> | 16/03/2009 |
| <code>ToTimeString()</code> | 16/03/2009 20:23:55 |

We have previously considered different types in C# as offices. You can think of these methods as a number of different people sitting in the `DateTime` office, all of whom have their own telephone and can be asked to deliver an appropriately formatted string of text. You can call any of these methods to get a string of text that describes the value being held by the variable `nowDateTime`. You can use them to add the date and time to your clock if you wish.



Note The precise format of the date and time produced depends on the *localization* of your system. Most software products are configured to display the date and time in a manner in keeping with the country where they are being used. The previously given samples are for a Windows PC used in England. Yours might look slightly different.

Putting all this together, you can create a version of the `Draw` method that displays the current time on your screen:

```
protected override void Draw(GameTime gameTime)
{
    graphics.GraphicsDevice.Clear(Color.CornflowerBlue);

    DateTime nowDateTime = DateTime.Now;
    string nowString = nowDateTime.ToLongTimeString();
    Vector2 nowVector = new Vector2(50, 400);
```

```
spriteBatch.Begin();
spriteBatch.DrawString(font, nowString, nowVector, Color.Red);
spriteBatch.End();

base.Draw(gameTime);
}
```

I've changed the name of the vector to `nowVector` to better describe what it is used for. I've also moved the draw position so that if you set the font size to 100, this `Draw` method gives you a big clock on your Xbox that nicely fills the bottom of the screen. If you want to display the clock on a Zune I've found that with a font size of 25 you can use an X position of 50 and a Y position of 280.

Sample Code: Big Clock The sample project in the 02 Big Clock directory in the resources for this chapter contains an XNA Game Studio solution for the program in this section. Note that Xbox, PC, and Zune versions are available. However, you should remember that because of localization differences, you might not see exactly the same display on each device.

Because the `Draw` and `Update` methods are called automatically for you by the XNA environment, the clock is repeatedly redrawn with the up-to-date time.

Making a Prettier Clock with 3-D Text

At the moment, your clock is very boring; it just displays the time in red on a blue background. You can make the text more interesting by changing the way that you draw the time. This kind of multiple drawing is performed a lot in computer games.

Drawing Multiple Text Strings

One way to make the display more interesting is to draw different-colored versions of the text at slightly different positions on the screen:

```
protected override void Draw(GameTime gameTime)
{
    graphics.GraphicsDevice.Clear(Color.CornflowerBlue);

    DateTime nowDateTime = DateTime.Now;
    string nowString = nowDateTime.ToLongTimeString();
    Vector2 nowVector = new Vector2(50, 400);

    spriteBatch.Begin();

    spriteBatch.DrawString(font, nowString, nowVector, Color.Red);

    nowVector.X = nowVector.X + 4;
    nowVector.Y = nowVector.Y + 4;
}
```

```

    spriteBatch.DrawString(font, nowString, nowVector, Color.Yellow);

    spriteBatch.End();

    base.Draw(gameTime);
}

```

This version of the Draw method is very similar to the original, except that DrawString is now called twice, first drawing in red and then in yellow. In between the draw operations, the values of the X and Y properties of the position vector are increased by 4 using the following statements:

```

nowVector.X = nowVector.X + 4;
nowVector.Y = nowVector.Y + 4;

```

Figure 5-7 shows how this works. The thing on the right side of the “gozzinta” is an *expression*. This generates a result that is then placed in the destination.

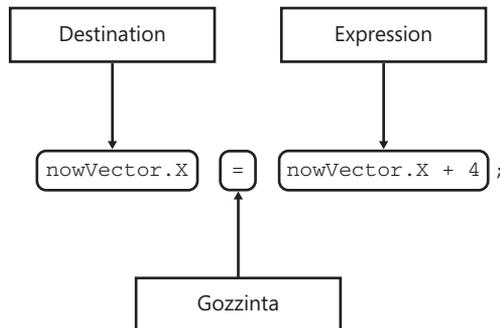


FIGURE 5-7 A statement that evaluates an expression and updates the value for a variable

The sequence of instructions that the compiler creates to work out the statement is as follows:

1. Fetch the value of the X property of nowVector.
2. Add 4 to it.
3. Store the value back in the X property of nowVector.

The effect of adding 4 to the X and Y properties is to move the drawing position for the text across and down the screen. Figure 5-8 shows the result of these changes.



FIGURE 5-8 A more interesting time display

From this, you can see that when you draw on the screen, the images are laid on top of each other in the order they are drawn. The red version of the time string is overwritten by the yellow one. The nice thing about this approach is that it gives a good 3-D effect. The human eye interprets the darker color as being in the “background,” making the letters appear to pop out of the display. However, the 3-D effect is not quite perfect. The image in Figure 5-9 is an enlargement of part of the text and shows that the red part is not actually “solid”; instead, it’s simply a layer drawn behind the yellow one.



FIGURE 5-9 A zoomed-in detail of the overwritten text

If you want the 3-D effect to be perfect, you need to draw lots more red versions to “fill in the gaps.” You could do this by simply copying the code four times, but perhaps you remember reading somewhere that computers are supposed to make life easier, and this doesn’t feel very easy at all. What you really want to do is perform a block of statements a given number of times, and it turns out that C# provides a way to do this: it’s called the *for* loop construction.

Repeating Statements with a *for* Loop

A program can do three things as it runs. It can perform a single action (a statement), it can make a choice of what to do (a condition statement), or it can repeat something (a loop construction). It might surprise you to learn that with these three programming constructions, you could write any program. You’ve seen how to write statements and conditions; now you need to discover how to create a loop. With a loop, you need to write the drawing instructions only once, and the loop construction then performs them as many times as you like:

```
spriteBatch.Begin();

int layer;
for (layer = 0; layer < 4; layer++)
{
    spriteBatch.DrawString(font, nowString, nowVector, Color.Red);
    nowVector.X++;
    nowVector.Y++;
}

spriteBatch.DrawString(font, nowString, nowVector, Color.Yellow);

spriteBatch.End();
```

This code performs four drawing operations with the red color. The code in the block controlled by `for` is repeated a given number of times. When the loop finishes, the final `DrawString` puts the yellow version on top of all the red ones. Note that the yellow `DrawString` is not repeated four times because it is not inside the block of code controlled by the `for` loop.

The loop itself is controlled by the three items in brackets that follow the key word `for`. These are shown in Figure 5-10. Each of the three items is used to manage the behavior of the loop.

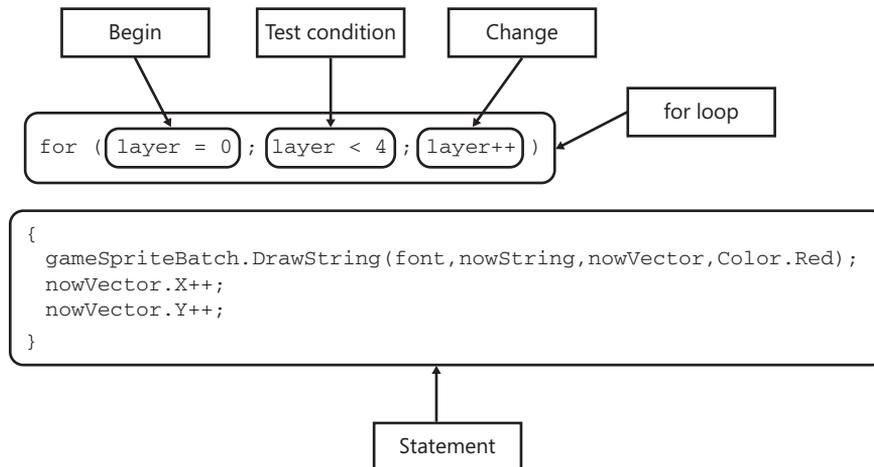


FIGURE 5-10 How a `for` loop is constructed

- **Begin** This is a statement that is obeyed when the loop starts. In this example, you're using an integer variable called `layer` to count each of the layers that you're drawing, and the loop must set this to zero at the beginning.
- **Test Condition** The condition controls when the loop finishes. It can be either `true` (the loop continues) or `false` (the loop ends). The condition in your loop is `layer < 4`. You might not have seen the `<` operator before; it performs a "less-than" comparison between the two operands. If the item on the left is less than the item on the right, the result of the comparison is `true`. If the item on the left is not less than the item on the right, the result of the comparison is `false`. C# provides a range of different comparison operators.
- **Change** Each time the statements in the loop are completed, the change is performed. In this case, the change statement `layer++` makes the value in `layer` 1 larger each time. After the change has been performed, the test condition is evaluated to see whether the statements controlled by the loop are to be executed again.

The C# compiler has the job of producing the machine instructions that perform the loop when the program runs. The precise sequence that's followed by the code that the compiler produces is as follows:

1. Perform the `Begin` statement to start the loop.
2. Perform the `Test` and finish if the test is false.
3. Perform the statement in the loop body.
4. Perform the `Change` statement.
5. Return to step 2.

Sample Code: 3-D Big Clock The sample project in the 03 3D Big Clock directory in the resources for this chapter contains an XNA Game Studio solution that uses a `for` loop to draw multiple versions of the time.

Other Loop Constructions

C# also provides two other loop constructions, called `do - while` and `while`. These are not actually vital, in that you can always get the looping behavior that you want by using an appropriately designed `for` loop, but they can be useful in situations where you don't want to go to the trouble of creating a `for` loop construction. You can find out more about these kinds of loops and when they would be useful in the glossary in the `do - while` entry.

Fun with *for* Loops

You can test your understanding of the `for` loop behavior by looking at some `for` loops and trying to work out what they would do. For instance, look at this one:

```
for (layer = 0 ; layer > 4 ; layer++)
```

There's a mistake in this statement, but it's rather hard to spot. The mistake is that the test is now `layer > 4`. The `>` character means "greater than." This means that the test is now true only when the value of `layer` is greater than 4. Because the initialization sets the value of `layer` to 0, this condition is never true. The result is that the code in the statement controlled by the loop is never performed. Now look at this statement:

```
for (layer = 0 ; layer < 4 ; layer--)
```

There's another mistake here. The less-than character (`<`) is in the correct place, but rather than increasing the value of `layer` each time around, the change makes `layer` smaller by using the `--` operator each time. This means that the value of `layer` never becomes greater than 4, so the loop never ends. The result is that your program appears to "get stuck" at this point.

You can write code to request this as follows if you really want a loop that goes on forever:

```
for (layer = 0 ; true ; layer--)
```

Simply putting the value `true` in the position of the condition causes the loop to never stop. If you're wondering what would happen if you ran a loop like this, you can try it if you like, but I can save you the trouble. If you run either of these never-ending loops, you eventually get the message shown in Figure 5-11. This is the message that XNA displays when it runs out of memory.

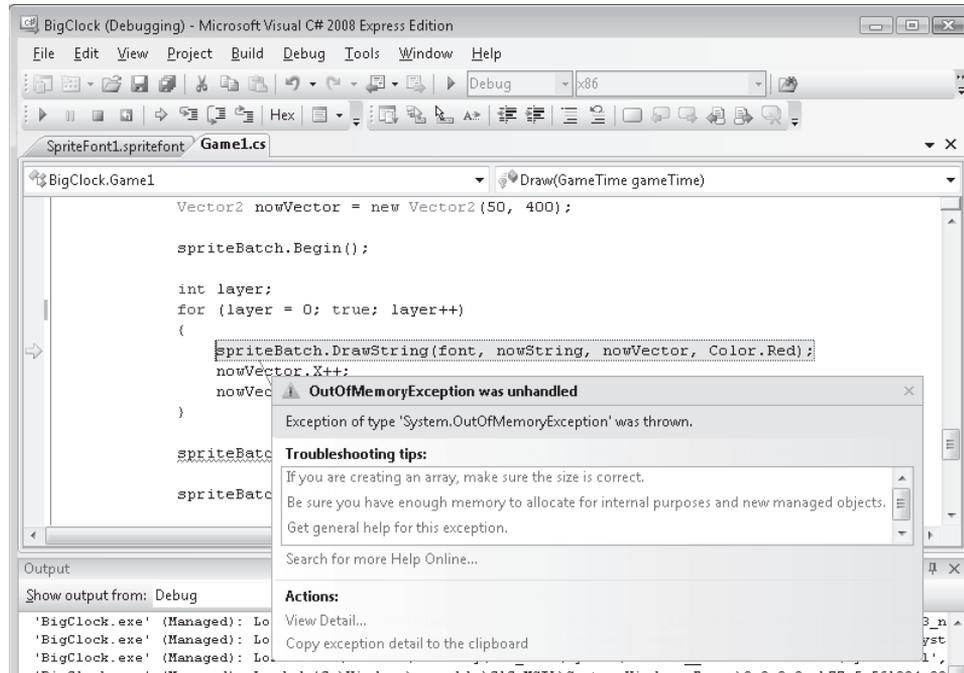


FIGURE 5-11 Out-of-memory error message

The reason you get this message is that each time the `DrawString` method is called in the body of the loop, it uses a small amount of memory to record what is drawn. If you call the method a large number of times, it eventually uses up all the memory available for this purpose, and the memory allocation part of XNA throws an exception when it is asked for memory it doesn't have. The good news is that this doesn't cause any damage, but it does cause serious damage to your credibility.

One of the nice things about loops is that you can get a lot more work done by the computer simply by changing the values that cause them to stop. For instance, look at this code:

```
for (layer = 0; layer < 40 ; layer++)
```

This version of the loop draws 40 red time values before putting the yellow one on top. It gives rise to the rather funky display shown in Figure 5-12.



FIGURE 5-12 Funky time

This is nice, but you can do even better. You can make the display even more funky by using some other drawing tricks that XNA provides.

Creating Fake 3-D

Lots of the graphics in games are faked. Rather than make something 3-D, a game programmer makes something that looks 3-D but turns out to be much easier to program. In this section, you make some 3-D text, but without using any complicated rendering or models (although you can do this kind of thing if required). You use only two principles:

- Things that are 3-D have shadows.
- Things that have the light shining directly on them look the brightest.

This means that you need to draw your text in three stages. First, you draw the shadows, then the “sides” of the text, and finally the top layer of the text. This seems like a lot of work, but, as Figure 5-13 shows, I think it’s worth the effort.



FIGURE 5-13 3-D text that “jumps” out of the screen

Creating Shadows Using Transparent Colors

The first part of the text that you want to draw is the shadow at the back. You draw your picture from the back forwards and use the fact that each time you draw, you add to what’s already there. You use another feature of XNA drawing: colors that cause things to be drawn slightly transparent (that is, with part of the background showing through). By drawing

transparent colors on top of each other, you can get a nice blurry effect, as done in the following code:

```
Color nowColor = new Color(0,0,0,20);
for (layer = 0; layer < 10 ; layer++)
{
    spriteBatch.DrawString(font, nowString, nowVector, nowColor);
    nowVector.X++;
    nowVector.Y++;
}
```

This code is very similar to the previous code that draws the 3-D text except that it creates the value for `nowColor` in a slightly different way. The `Color` is constructed from four values rather than three:

```
Color nowColor = new Color(0,0,0,20);
```

The first three values give the intensity of red, green, and blue, which you've set to 0 because you're drawing in black. The fourth gives the transparency of the color. In graphical terms, this is often called the *alpha* channel value. The bigger the number, the less the background shows through. Just like your color intensity values, the transparency value can range from 0 (completely transparent) to 255 (solid color). If you don't give a transparency value, the `Color` is created as solid.

A value of 20 means that a lot of the background shows through the color that you draw. Figure 5-14 shows the display produced by drawing 10 times using a transparent black value. Note that because each of the drawing positions is slightly different, you get a blurring effect.



FIGURE 5-14 Creating a shadow using transparent colors

This works rather well in that the text is nicely blurred around the edges, as a shadow would be. Now you know one way video games achieve blur. They can do it by repeatedly drawing the same scene in slightly different positions.

The next part of the drawing process uses the same technique you've used before, except that you use slightly different colors. The complete drawing method is as follows:

```
protected override void Draw(GameTime gameTime)
{
    graphics.GraphicsDevice.Clear(Color.CornflowerBlue);

    DateTime nowDateTime = DateTime.Now;
    string nowString = nowDateTime.ToLongTimeString();
}
```

```
Vector2 nowVector = new Vector2(50, 400);
int layer;

spriteBatch.Begin();

// Draw the shadow
Color nowColor = new Color(0, 0, 0, 20);
for (layer = 0; layer < 10; layer++)
{
    spriteBatch.DrawString(font, nowString, nowVector, nowColor);
    nowVector.X++;
    nowVector.Y++;
}

// Draw the solid part of the characters
nowColor = Color.Gray;
for (layer = 0; layer < 5; layer++)
{
    spriteBatch.DrawString(font, nowString, nowVector, nowColor);
    nowVector.X++;
    nowVector.Y++;
}

// Draw the top of the characters
spriteBatch.DrawString(font, nowString, nowVector, Color.White);
spriteBatch.End();

base.Draw(gameTime);
}
```

This produces the display shown in Figure 5-13.

Sample Code: 3-D Shadow Clocks The sample project in the 04 3D Shadow Clock directory in the resources for this chapter contains an XNA Game Studio solution that shows the 3-D time over a blue background. If you want to draw the time over a picture, you can take a look at the solution in the 05 3D Picture Clock directory, which draws the same clock over a picture of Jake. Finally, if you want to see the time over your mood light, look at the solution in the 06 3D Clock MoodLight directory.

Drawing Images with Transparency

Something else that's useful is that if you draw an image using a color that has a transparency value, the image is drawn transparently. This is how game programmers get pictures to fade slowly onto the screen. The image is repeatedly drawn with different levels of transparency to make it slowly appear over a background.

Conclusion

In this chapter, you've learned how to add font resources to your programs. You've also gained a bit of insight into how 3-D effects can be created from 2-D images. You've also seen how you can use the for loop construction to repeat code a particular number of times.

Chapter Review Questions

At the risk of being somewhat predictable, the chapter ends with another set of true-false problems.

1. A font describes the color of the text to be printed.
2. An XNA game can use only one font to draw text.
3. The Content Manager creates your fonts.
4. A resource in an XNA project is a reference to an item that must be included in the game file when the program is built.
5. XML stands for Xbox Machine Language and is used to design the font graphics.
6. A vector describes a direction and distance of movement.
7. The first program you write that can print should display "Hello Mum".
8. The Xbox requires a network connection to load the date and time.
9. Dates and times are printed the same all over the world.
10. The `DateTime` structure holds the value of a particular date and time.
11. A property of an object cannot be used outside that object.
12. You can call the `ToString` method on an object to ask the object to supply a text description of itself.
13. A for loop construction always runs forever.
14. The C# code for `(1ayer = 0; 1ayer < 4; 1ayer++)` would repeat five times.
15. After a loop controlled by the C# code for `(1ayer = 0; 1ayer <= 10; 1ayer++)` has completed, the value in `1ayer` would be 10.
16. The C# code for `(1ayer = 4; 1ayer < 0; 1ayer++)` would repeat zero times.
17. The C# code for `(1ayer = 4; 1ayer > 0; 1ayer++)` would repeat infinite times.
18. Colors can be made "transparent."

Chapter 6

Creating a Multi-Player Game

In this chapter, you will

- Discover how to detect and use individual button-press events in a game.
- Learn how to create and debug a complex program.
- Write one of the only 16-player games for the Xbox in the world.

Introduction

Now that you can write programs that process data, read input from the gamepad, and display text and graphics, you can move on to create some proper games. The first games that you are going to create are simple to use and play, but are great fun, particularly if you have large numbers of people around to play them. While you create the behaviors for the games, you also learn some more C# constructions that can be used in later games.

Game Idea: Button-Bashing Mob

One very popular and easy-to-create game is one where a player has to repeatedly press a button as quickly as possible. Players compete against each other, and the winner is the one who can press their button the most in a given time. Because each gamepad has four buttons and the Xbox can support four gamepads, up to 16 players can take part, for maximum button-bashing fun.

Creating the Button-Bash Game

To get started, you need to create an empty project called ButtonBash. This project needs to be able to display text. The best way to do this is to create a new project and then initialize and load the font as for the Big Clock application in Chapter 5, "Writing Text." Set the size of the font to 30 in the `SpriteFont1.spritefont` file that you create.

To create the game, you first build a program that counts and displays the presses of a single button on the gamepad. Then you can scale up the program and use more buttons. This is a very common programming technique. "Make a button-bashing game for 16 players" sounds a bit daunting, but "Make a program that counts how many times the B button on gamepad 1 is pressed" is something you can probably do.



Note To complete this program, you are going to take two things that you already know how to do (read buttons on the gamepad and display messages on the screen) and use these abilities to create a game called Button Bash. You do this sort of combining a lot in programming; in fact, you can think of writing programs as stringing a set of behaviors together to get the required result.

Button-Bash Game Data

Your program needs to keep track of the number of times the button has been pressed. You can use an integer to hold the value as follows:

```
// Game World  
int count;
```

The range of an `int` variable in C# can go over 2,000,000,000. It's unlikely that anyone who was not Superman could press a button that number of times in a minute.

Starting the Button-Bash Game

The game is started by the player pressing the Start button on the gamepad to zero the counter. The program handles this in the `Update` method:

```
protected override void Update(GameTime gameTime)  
{  
    // Allows the game to exit  
    if (GamePad.GetState(PlayerIndex.One).Buttons.Back == ButtonState.Pressed)  
        this.Exit();  
  
    GamePadState pad1 = GamePad.GetState(PlayerIndex.One);  
  
    if (pad1.Buttons.Start == ButtonState.Pressed)  
    {  
        count = 0;  
    }  
  
    base.Update(gameTime);  
}
```

This program builds on the gamepad reading code that you wrote in Chapter 3, "Getting Player Input." It creates a `GamePadState` variable called `pad1` and then tests to see if the Start button has been pressed on it. When the Start button is pressed, the conditional statement in the `Update` method sets `count` to 0.

Displaying the Button-Bash Count Value

As the game is being played, it must display the current number of presses on the screen for the player to see. You can use a variant of the Draw method in the Big Clock program to display the value in count:

```
protected override void Draw(GameTime gameTime)
{
    graphics.GraphicsDevice.Clear(Color.CornflowerBlue);

    string countString = count.ToString();
    Vector2 countVector = new Vector2(50, 400);

    spriteBatch.Begin();

    spriteBatch.DrawString(font, countString, countVector, Color.Red);

    spriteBatch.End();

    base.Draw(gameTime);
}
```

Running this program gives you what you expect: the value 0 displayed on the screen.

Counting Button Presses

Now you need to add the statements to the Update method that count the number of times that the B button has been pressed:

```
if (pad1.Buttons.B == ButtonState.Pressed)
{
    count++;
}
```

This seems to be what you want; if the condition is true because the button has been pressed, the counter is incremented.

Sample Code: Broken Button Bash All the sample projects can be obtained from the course instructor. The sample project in the 01 Broken Button Bash directory in the resources for this chapter contains a Microsoft XNA Game Studio solution that contains a program that uses the Update method described in this section to implement a test button-bashing program.

You might have gathered from the example title “01 Broken Button Bash” that this won’t work. This is because the Update method is called 60 times a second. If you hold down the button, you find that each time Update is called, the value of count gets one bigger, so the score goes up at a rate of 60 times a second. This is impressive (and might be the basis of other games in the future), but it won’t give you the game you want.

Detecting Changes in the Button Position

You need to find a way of detecting when the state of the button changes from the up to the down position. Your program must increase count only when this happens, not when the button is simply being held down. Figure 6-1 shows the sequence of events when the button is pressed. The Update method is being called at regular intervals. At some point, the B button is pressed. This means that when Update is called the first time in the illustration, it detects that B is up, and the second time it is called, it detects that B has been pressed.

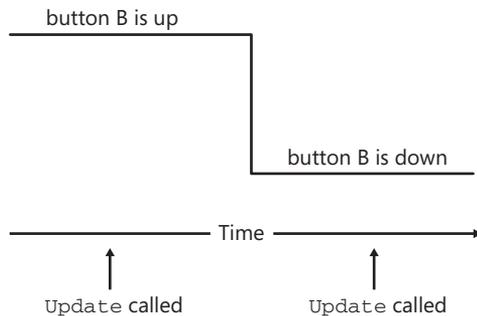


FIGURE 6-1 Time line for Update calls and the B button

This means that the Update method must perform a test along the lines of “If the button was up last time and is down this time, now the counter must be increased.” The Update method needs to know the state of the button the last time Update was called. It can then test to see if the button state has changed since it was called the last time. You can declare a GamePadState variable to hold this value and create an Update method as follows:

```
GamePadState oldpad1;

protected override void Update(GameTime gameTime)
{
    // Allows the game to exit
    if (GamePad.GetState(PlayerIndex.One).Buttons.Back == ButtonState.Pressed)
        this.Exit();

    GamePadState pad1 = GamePad.GetState(PlayerIndex.One);
    if (pad1.Buttons.Start == ButtonState.Pressed)
    {
        count = 0;
        oldpad1 = pad1;
    }

    if ( oldpad1.Buttons.B == ButtonState.Released &&
        pad1.Buttons.B == ButtonState.Pressed )
    {
        count++;
    }

    oldpad1 = pad1;
    base.Update(gameTime);
}
```

The variable `oldpad1` holds the previous state of the gamepad; at the end of the method, you store the current pad state in it. The test for the change makes use of the *AND* (`&&`) logical operator. Only if the previous state of the button was up *AND* the current state is down is the count value increased. You've already seen the *OR* (`||`) logical operator, which causes a condition to be true if one or the other condition is true (or both are true). The *AND* operator is used in the same way but produces a true result if the conditions on each side of it are both true. When the player presses Start to begin the game, the value of `oldPad1` is set to the current pad state, so that only changes to the gamepad after Start was pressed are registered.



Note This code is quite simple, but you need to understand exactly how it works. Make sure that you can follow what is going on: the way that `Update` is called 60 times a second and the way the method makes a copy of the previous gamepad settings at the end of each call.

If you had a *really* fast player who could press and release a button in less than 1/60 of a second, your program would not detect this, as the up-and-down changes would occur between two calls to the `Draw` method.

Level and Edge Detectors

The code in the previous section is an edge detector in that it detects a change from one state to another. This is the kind of code that you would use to detect when a game player selects an option or presses a switch. Up until now, you have used the buttons as level detectors in that only whether a button is up or down has been significant. When you design the controls for a game, you need to decide what kind of input you're using for the control. If you're creating a driving game, you'd use a level-based signal to control whether the accelerator was pressed and perhaps an edge-triggered signal to control the gear selections made by the player.

Sample Code: Working Button Bash The sample project in the 02 Working Button Bash directory in the resources for this chapter contains an XNA Game Studio solution that contains a program that counts the presses for button B.

Constructing the Complete Game

Now that you know how to make edge detectors, you can go on and create the button-counting code for all 16 buttons in the game. The best way to organize these is to track and examine each controller in turn. For each controller, you need some variables to hold information about the gamepad and the buttons:

```
// Gamepad 1
GamePadState pad1;
GamePadState oldpad1;
int count1;
int bcount1;
```

```

int xcount1;
int ycount1;

Vector2 apos1 = new Vector2(150, 250);
Vector2 bpos1 = new Vector2(200, 200);
Vector2 xpos1 = new Vector2(100, 200);
Vector2 ypos1 = new Vector2(150, 150);

```

The top two variables hold the gamepad states. The `pad1` variable holds the state of the gamepad during a call of `Update`. The `oldPad1` variable holds the value from the previous call of `Update`. Then there are counters for each of the buttons on the gamepad. Finally, there are four vectors that position the counters on the screen. The code that runs in the `Update` method is a variation on the edge detector that you saw previously but is extended to handle all the buttons on the gamepad:

```

pad1 = GamePad.GetState(PlayerIndex.One);

if (pad1.IsConnected)
{
    if (pad1.Buttons.Start == ButtonState.Pressed)
    {
        acount1 = 0;
        bcount1 = 0;
        xcount1 = 0;
        ycount1 = 0;
        // repeat for the other three gamepads
    }

    if (oldpad1.Buttons.A == ButtonState.Released &&
        pad1.Buttons.A == ButtonState.Pressed)
    {
        acount1++;
    }

    if (oldpad1.Buttons.B == ButtonState.Released &&
        pad1.Buttons.B == ButtonState.Pressed)
    {
        bcount1++;
    }

    if (oldpad1.Buttons.X == ButtonState.Released &&
        pad1.Buttons.X == ButtonState.Pressed)
    {
        xcount1++;
    }

    if (oldpad1.Buttons.Y == ButtonState.Released &&
        pad1.Buttons.Y == ButtonState.Pressed)
    {
        ycount1++;
    }

    oldpad1 = pad1;
}

```

This code makes use of the `IsConnected` property of the `GamePadState` structure. This property is true only if the gamepad is active, meaning that the program updates the values for the gamepad only when it is connected. Now that you have the game behavior working, you need to add the display part of the game code in the `Draw` method: This is the code for gamepad 1. A similar sequence of statements will be required for the other three gamepads.

```
spriteBatch.Begin();

if (pad1.IsConnected)
{
    spriteBatch.DrawString(font, acount1.ToString(), apos1, Color.Green);
    spriteBatch.DrawString(font, bcount1.ToString(), bpos1, Color.Red);
    spriteBatch.DrawString(font, xcount1.ToString(), xpos1, Color.Blue);
    spriteBatch.DrawString(font, ycount1.ToString(), ypos1, Color.Yellow);
}

spriteBatch.End();
```

This code uses the vectors that were set up at the beginning of the program to position the count values in the correct place on the screen. The code also draws the counters only if that gamepad is connected.

Sample Code: Button Bash The sample project in the 03 Multi Player ButtonBash directory in the resources for this chapter contains an XNA Game Studio solution that contains a program that you can use to play 16-Player Button Bash.

Code Design

If you look at the sample program, you notice that there's a lot of repetition. The same code is used four times in a row, once for each gamepad. In addition, the statements for each gamepad are fundamentally similar. It turns out that you can use more advanced features of C# to make this program much smaller and easier to understand. However, the game works well, and the more people who take part, the more fun it is. Simply begin the game by pressing Start on gamepad 1, and then all the players must bash their particular button as many times as possible in a certain amount of time. This turns out to be a test of stamina as much as anything else. Later, you might return to this code and add an automatic clock to time the games.

The Great Programmer Speaks: Make Sure You Can Test Your Code The Great Programmer has been looking at the code that you've been writing. She notices that your program is quite long and reckons that she could do the job with fewer statements. But because your game works and she enjoys playing it, she thinks it's a good solution. However, she's worried about one thing. The only way that the program can be tested completely is by using four Xbox gamepads. If you don't have four gamepads on hand, you can't prove that all the counter and display code works properly. In many of the programs that she has written, it's been very difficult to test parts of the code, particularly the bits that deal with errors. She therefore thinks that you need to work out a way that you can test the program without needing to have all the hardware present. I will show you how to do that next.

Adding Test Code

If you have four gamepads, you can simply connect them and play the game. However, if you have only one, you need a way to use it to test the code for the other gamepads as well. The simplest way to do this is to copy the state of gamepad1 into the other gamepads during the Update method:

```
pad2 = GamePad.GetState(PlayerIndex.Two);

// test code - copy the value of pad1 into pad2
pad2 = pad1;

if (pad2.IsConnected)
{
    // code for gamepad 2
}
```

The test code copies the value of pad1 into pad2. This means that the button presses on this gamepad are now copied onto the counters for this pad, too. If you also copy this information into the other two gamepads, you can test the code for all of them with only a single gamepad. Figure 6-2 shows you the display produced by a test version of the program. I found some faults in my original positioning of the counter displays by using this program on a PC with only one Xbox gamepad attached.



FIGURE 6-2 Test gamepad counter displays

Once the code has been tested, it's important that these tests are removed from the program. It turns out that C# provides a mechanism called *conditional compilation*, which lets you ask the compiler to ignore parts of a program. This provides a way that you can mark statements of program code that are to be ignored and that do not become part of the program when it is built, but that you can keep around for testing when you later update your code.

To understand what's going on here, you have to take the lid off the compiler and find out a bit more about how it works. The job of the compiler is to take the C# statements that you write and convert them into machine instructions for the Xbox or PC. The compiler opens the source file on the computer that holds your C# and reads it a line at a time. It finds all the variables, makes sure they are used correctly, looks for all the statements, and generates low-level instructions that are to be used when the program runs.

The part at the very front of the compiler that reads in the C# file is called the *preprocessor*. If you built a machine to make apple pies, you'd have to have a part at the front that peeled the apples, discarded any rotten ones, and got them ready for cooking. The preprocessor does this peeling job for the compiler. It takes the program source, removes all the comments (which the compiler should not see), discards blank lines and empty space, and passes on clean statements. However, the C# compiler preprocessor can also be told to do things to the source that it sees:

```
#if test
    // test code - copy the value of pad1 into pad4
    pad4 = pad1;
#endif
```

Commands to the preprocessor have a # at the start of the line and are called *directives*. What the previous statements say to the preprocessor is, "If the test symbol has been defined, pass on the following statements to the rest of the compiler; otherwise, ignore them." The statements to be passed on are between the #if and the #endif directives.

If you want to switch these lines on, you simply need to define the test symbol at the top of the source file as follows:

```
#define test
```

If the test symbol has been defined, all the test statements are compiled into the main program. Deleting the #define directive keeps the designated statements from being compiled.

Sample Code: Button-Bash Test The sample project in the 04 Button Bash Test directory in the resources for this chapter contains an XNA Game Studio solution that contains a program that you can use to test the button-bashing program with only one gamepad.

If you use XNA Game Studio to open the code file Game1.cs in the 04 Button Bash Test sample project, you see that the test code is "live." If you go to the top of Game1.cs and delete the #define line, you see that all the code controlled by the test symbol goes light gray in the editor to indicate that this code is no longer live. If you run the program, it now works with four gamepads as it should.



Note It's very important that you understand what's happening here. The program is not making a decision what to do when it runs; this decision is taking place when the program itself is built. If the symbol is not defined, the statements are not even part of the machine language program itself.

You can create as many symbols as you like, so if you wanted to, you could turn on and off different parts of the program. This is one of the ways that game manufacturers make "demo" versions of their games. Some game levels are compiled conditionally in the source so that they can make a limited version of the program just by recompiling with some of these symbols missing. Note that the test is not perfect, for example if your program was displaying the count for gamepad 1 in place of the count for gamepad 2, this would not be detected by this test. You would have to think of a different kind of test behavior to detect this fault.

The Great Programmer Speaks: Remember to Charge for Testing The Great Programmer is one of the most expensive programmers you'll ever meet. She charges a lot of money for her work. But her customers are happy to pay because they know they are getting a properly tested program and they never get any nasty surprises. She says that if you're asked how much a job will cost and how long it will take, you must make sure that you include the time it will take you to test your solution, as well as the time it will take to actually write the program that does the job. She's very careful to include the cost of these parts of the work in her prices, and her software is always very well tested and works the first time, so she makes the big bucks.

Conclusion

In this chapter, you've discovered how to detect edges on button presses and how to use this to create a good party game. Finally, you've seen the importance of testing and found a mechanism, conditional compilation, that makes testing easier.

Chapter Review Questions

Perhaps the world will end with a set of review questions. I'm not sure about that actually, but I am sure that this chapter does. As usual, say whether these statements are true or false.

1. Only the start button can be used as edge triggered.
2. You need to have the previous state of the gamepad if you want to detect an edge.
3. Edge-triggered inputs work only if the button is held down.
4. Conditionally compiled code is discarded when the program runs.
5. The preprocessor produces the output file from the compiler.

Chapter 7

Playing Sounds

In this chapter, you will

- Find out how to prepare sounds for inclusion in Microsoft XNA projects.
- Incorporate sounds into XNA.
- Play the sounds from within your programs.

Adding Sound

Now that you can display pictures and text, it's time to make some noise. Then you can set about making a proper gaming experience for your players. You add sound to a game in the same way as you add other resources. You can even grab your favorite sound sample and drop this into the XNA Game Studio project as you did for the graphics resources (remembering to respect copyrights, of course).

If you want even more control over the sounds that your game makes, you can use something called the Microsoft Cross-Platform Audio Creation Tool (XACT) to create the library of sounds that you want to use, insert the library into your game, and then create a sound engine in the game program to play those sounds at the appropriate times. This facility is very powerful, but it can be confusing to use, so we use simple sound playback in this chapter.

Program Project: Drum Pad

The first program you are going to build creates a very simple drum kit that is controlled from a gamepad. Each button is assigned a different drum sound, enabling you to use your console to play the drums.

Creating the Drum Pad Project

You create the project (called DrumPad) using the New Project dialog box as you've done for all your previous projects. You can see this dialog box in use in Figure 1-4 in Chapter 1, "Computers, Xboxes, C#, XNA, and You."

Capturing Sounds with Audacity

You start with a few drum sounds. The samples that I used were captured using the microphone input in my notebook to record live drum sounds. I used a program called

Audacity, which you can obtain for free from audacity.sourceforge.net. This program captures live sound and provides a graphical interface that you can use to select portions of recordings and export them as .wav files. Figure 7-1 shows a wave form that has been captured and a portion marked off to be exported.

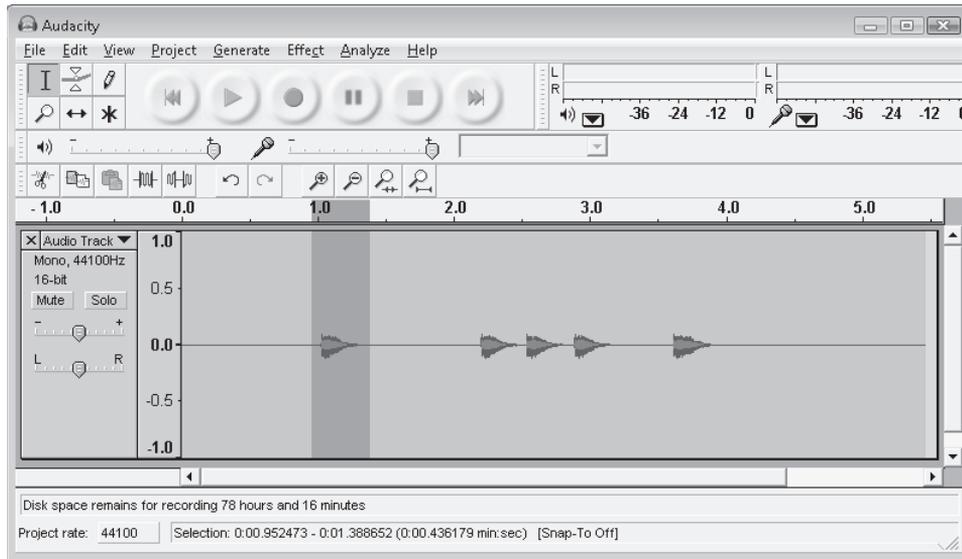


FIGURE 7-1 The Audacity user interface

Each time you click the round, red, record button in the controls at the top of the screen, a new track is recorded. Before you start recording, you should select the format of the sound that you are going to capture. The quality of a sound recording is controlled by the sample rate and the resolution of each sound sample. You need to be careful when recording sounds because the higher the quality of the sound, the more disk space and memory that the sample takes up. I have found that a sample rate of 44,100 hertz (Hz) and 16-bit resolution gives high-quality sounds that do not take up too much memory. You can select these by clicking the item on top of the track as shown in Figure 7-2, where the sample rate is being selected. The resolution is set using the Set Sample Format item immediately above the Set Rate option on the menu shown.

Once you have selected a sound quality setting, it is used for any future recordings. If you are recording very long sounds, such as background music, you might decide to reduce the quality so that the sound files are smaller.

Note that with sound samples, as with other assets in your game, you must be careful to observe copyright laws. Although it's very tempting to use parts of songs or TV shows as in-game sounds, you need to make sure that you don't get into trouble for doing this.

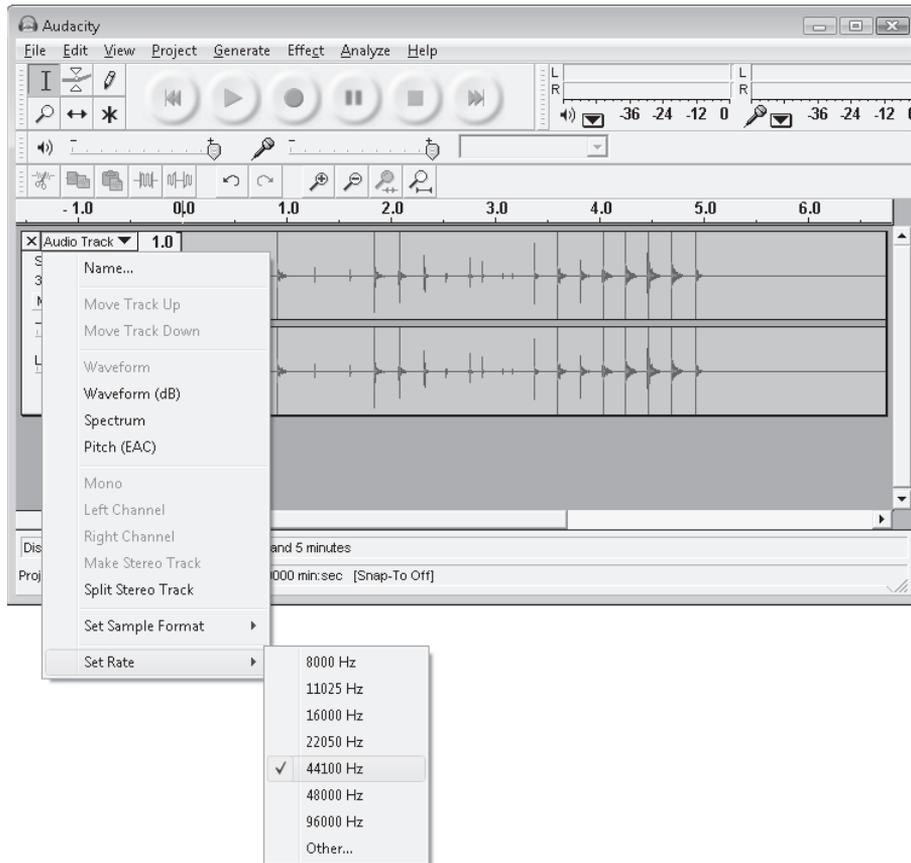


FIGURE 7-2 Selecting a sample rate in Audacity

Sounds and File Types

When I had finished with the drums, I had some sound files that were .wav files. Today, you're more likely to have heard of .mp3 or .wma files when storing sound. In these files, the sound information is compressed so that it takes up less space in your music player. The XNA Framework can play simple sound effects from .wav files. Later in this chapter, in the section "Playing Songs using the *MediaPlayer Class*," you find out how to create an XNA program that plays complete songs from .mp3 or .wma files.

Storing Sounds in Your Project

Sounds are just another item of content, along with images and fonts. You add them to your project in the same way. Start by right-clicking the Content folder in XNA Game Studio, then select Existing Item from the Add option, as shown in Figure 7-3.

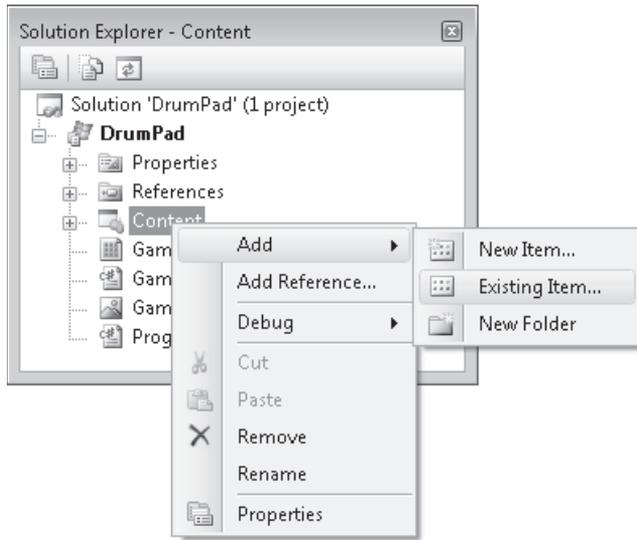


FIGURE 7-3 Adding items to the Content folder

This causes the Add Existing Item - Content dialog box to appear. You can then navigate to the folder on your system containing the sound files and open them as shown in Figure 7-4. Note that you can select multiple items in this dialog box if you want to add more than one thing at a time.

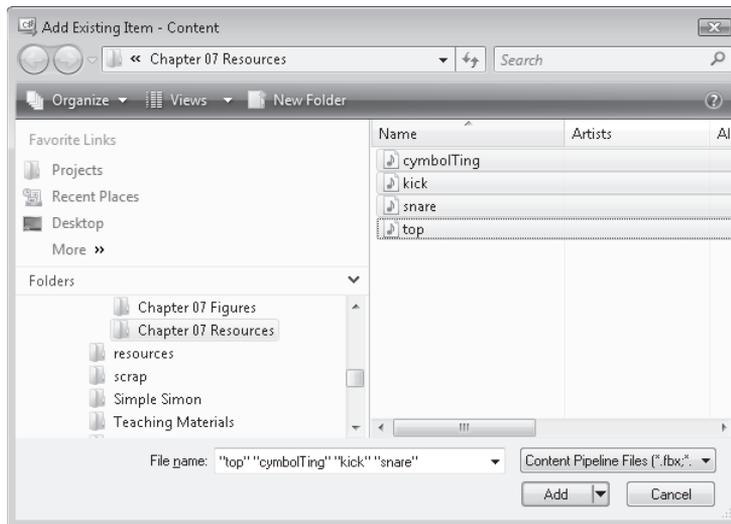


FIGURE 7-4 Selecting sound files



Note If you've installed any programs that work with sound files, you might find that your .wav files have different icons. The ones in Figure 7-4 are associated with Windows Media Player on my computer.

Once the files have been added to the game project, the Content Manager transfers them into the game and makes them available to the game program.

Resources: "Drum Sounds" All the sample projects and content resources can be obtained from the Web resources for this text, which can be found at <http://microsoft.learning.en/us/Books/13411.aspx>. You can find the drum samples in the resources directory for this chapter. Before you hit the drums, remember that sounds might be faint on your PC but play loudly through your Xbox, or vice versa. The program will work on the Zune, but you will need to change it to use the Zune Dpad to get all the drum sounds.

Using Sounds in an XNA Program

Now that you have the files, you can get them into a form that can be used in your XNA program. You follow the same pattern you have used twice before now, with fonts and images:

- Create a variable to hold the loaded content.
- Set the variable in the LoadContent Method.
- Use the resource in the game.

The variable type that you are going to use is `SoundEffect`. This represents a sound that you want to play. You need four of these variables, as you are giving our player four drum sounds to play:

```
// Game World
SoundEffect kick;
SoundEffect cymbolTing;
SoundEffect snare;
SoundEffect top;
```

Once you have the variables, you now need to load them from the Sounds folder in the content for this game:

```
protected override void LoadContent()
{
    // Create a new SpriteBatch, which can be used to draw textures.
    spriteBatch = new SpriteBatch(GraphicsDevice);

    kick = Content.Load<SoundEffect>("kick");
    cymbolTing = Content.Load<SoundEffect>("cymbolTing");
    snare = Content.Load<SoundEffect>("snare");
    top = Content.Load<SoundEffect>("top");
}
```

This code sets the `SoundEffect` variables with the samples that they are going to play.

Playing Sounds

Now you're at the point where you can play sounds in your program. You are going to make a program that plays different drums by pressing different buttons on the Xbox gamepad. The sound should be produced when the button is pressed. You can use the edge detection code from Chapter 6, "Creating a Multi-Player Game," to detect when to play the sounds:

```
// Current state of the gamepad during the Update
GamePadState pad1;

// Old gamepad state. XNA initializes this to all
// buttons not pressed. After the first call of Update
// this holds the previous gamepad state.
GamePadState oldpad1;

protected override void Update(GameTime gameTime)
{
    pad1 = GamePad.GetState(PlayerIndex.One);

    if (pad1.IsConnected)
    {
        // allow the game to exit when back is pressed
        if (pad1.Buttons.Back == ButtonState.Pressed)
        {
            this.Exit();
        }

        // test if A has been pressed since the last Update
        if (oldpad1.Buttons.A == ButtonState.Released &&
            pad1.Buttons.A == ButtonState.Pressed)
        {
            snare.Play();
        }
    }

    // record the current gamepad state for the next
    // call of Update
    oldpad1 = pad1;

    base.Update(gameTime);
}
```

This version of `Update` plays the "snare" sound when the A button is pressed on gamepad 1. It does this by calling the `Play` method provided by a `SoundEffect` object. You can expand this code so that each of the buttons on the controller plays one of your four sound effects.

Sample Code: 01 DrumPad All the sample projects can be obtained from the course instructor. The 01 DrumPad project in the resources for this chapter contains all the .wav files. It makes a different drum sound when each of the buttons is pressed. If you want to use your own sounds with this project, simply replace the .wav files in the Content folder with yours and rebuild the XNA Game Studio project.

If you play with the sample project, you find that you can get several versions of a given sound sample playing at the same time if you press the buttons very quickly.

Playing Background Music

You can also use the XNA sound system for playing background music. The technique described here could also be used for engine noise or background sounds for a particular location. Unlike the sounds you've used so far, you want the music to repeat when it finishes playing, and you'd also like a way to stop and start the music from within your program. The actual music file is a .wav file like all the other sounds, but it might be somewhat larger. It is loaded into the game project in the same way as the other sounds that you saw earlier.

Controlling Sound Playback

If you call the `Play` method on a `SoundEffect` instance, it causes that sound to play. However, the `Play` method also returns a result, which up until now our program has ignored. The result that `Play` returns is an object that represents the playing instance of the sound. This is held in a class called `SoundEffectInstance`. Each time `Play` is called, it returns a `SoundEffectInstance` for that particular instance of the sound playing. The program can use this value to control the background music playback.

Controlling the Sound Playback

In the next version of the game we use the shoulder buttons on the gamepad to control the music playback. The left shoulder button can start the playback, and the right shoulder button can pause it. We can use the by-now-familiar edge detection code to detect when a button is pressed:

```
if (o1dpad1.Buttons.LeftShoulder == ButtonState.Released &&
    pad1.Buttons.LeftShoulder == ButtonState.Pressed)
{
    // Start the music playing
}

if (o1dpad1.Buttons.RightShoulder == ButtonState.Released &&
    pad1.Buttons.RightShoulder == ButtonState.Pressed)
{
    // Pause the music
}
```

Now you just have to fill in the code that controls the playback.

Starting the Sound Playback

The very first time that the left shoulder button is pressed to start playback, there is no `SoundEffectInstance` to control because the sound effect is not playing. You can handle

this by using another feature of C#: the *null* reference. You can create a variable and explicitly set it to indicate that it doesn't refer to an object in memory at the moment:

```
// Game World
SoundEffect music;
SoundEffectInstance musicInstance = null;
```

These two variables are part of the Game World for the music player program. The variable `music` holds the sound effect, and the variable `musicInstance` refers to the `SoundEffectInstance` that is created the first time we play the sound effect. This is explicitly set to `null` when it is declared. The program can then test this value and create the instance if the value is `null`:

```
if (o1dpad1.Buttons.LeftShoulder == ButtonState.Released &&
    pad1.Buttons.LeftShoulder == ButtonState.Pressed)
{
    // Start the music playing
    if (musicInstance == null)
    {
        // Need to create a SoundInstance to play the music.
        musicInstance = music.Play();
    }
    else
    {
        // Already got a SoundInstance. Just play it.
        musicInstance.Play();
    }
}
```

This code repays careful study. The problem that it is solving is that the very first time that the play button is pressed, it must set the `musicInstance` variable. Every time after that first press, the code just needs to call the `Play` method on the `musicInstance` that it has created. It turns out that XNA doesn't mind if you try and play a `SoundInstance` that is already playing, and so the program works OK (although the Great Programmer might not approve of this).

Pausing the Sound Playback

The `SoundInstance` class provides a method called `Pause` that you can call to make the sound pause. This means that the code to pause the music looks quite simple:

```
if (o1dpad1.Buttons.RightShoulder == ButtonState.Released &&
    pad1.Buttons.RightShoulder == ButtonState.Pressed)
{
    // Pause the music
    musicInstance.Pause();
}
```

When the right shoulder button is pressed, the program just calls the `Pause` method on the `musicInstance`. This program looks OK, but unfortunately it has problems, which of course your younger brother finds straight away. Perhaps he feels it is his mission to break programs

whenever he gets the chance. Anyway, he has been playing with your program and tells you that if you press the right shoulder button before pressing the left one (that is, if you try to pause the music before it has started playing), the program fails. You try the program, and sure enough, when you press the right button you get the screen shown in Figure 7-5.

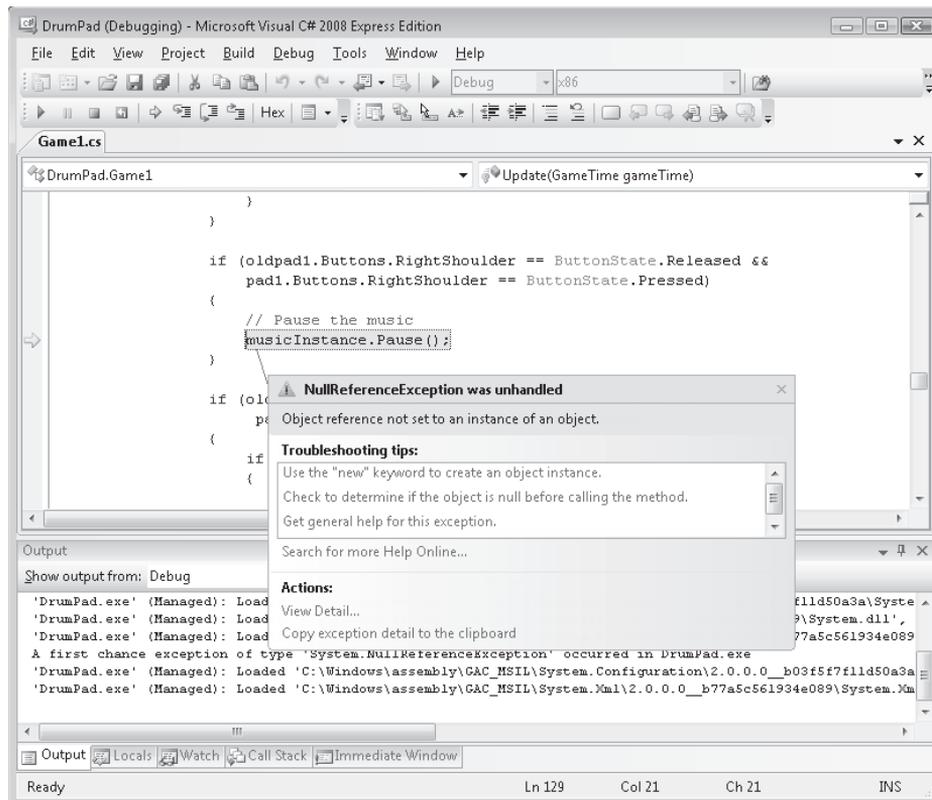


FIGURE 7-5 Throwing a *NullReferenceException*

The reason for this is quite simple. Some types in C# are managed by *reference*. This means that a variable of this type is actually a reference to an object in memory. When you use the variable, the program follows the reference to the object it refers to, and uses that object. A reference that is null is not set to refer to an object, so any attempt to follow this reference causes the program to fail. If the program tries to follow the `musicInstance` reference before it has been set to refer to the object produced by the call of `Play`, it is trying to go nowhere. This infringement is picked up by the system running our program, and the program is stopped at this point.

The good news is that this kind of problem is detected when the program runs and does not cause the Xbox, Zune, or Windows PC running the program to crash. Similar mistakes with other programming languages can sometimes result in the famous “Blue Screen of Death” appearing. The bad news is that the program still crashes, and your younger brother finds this very amusing. So it needs to be fixed.

The solution turns out to be quite simple. The program must check to see if the `musicInstance` variable is `null` before it tries to follow it. It should follow the reference only if the variable is actually referring to an object in memory:

```
if (oldpad1.Buttons.RightShoulder == ButtonState.Released &&
    pad1.Buttons.RightShoulder == ButtonState.Pressed)
{
    // Pause the music
    if (musicInstance != null )
    {
        musicInstance.Pause();
    }
}
```

The operator `!=` means “not equal to.” The reference is followed only if the program determines that the reference is not `null`.

Making a Sound Repeat

The `Play` method usually just plays a sound effect once. When the playback reaches the end of the sound, it stops. However, you want your music background to repeat in a loop. If you were using a sound sample as an engine noise, you would want it to repeat in this way. It turns out that there are several forms of the `Play` method where you can give extra detail about the way you want the sound played. One of the items of detail is whether the sound should loop. You can call this form of the `Play` method, as shown here. I’ve spread the call over several lines and added some comments to make it clear what each parameter does:

```
// Need to create a SoundInstance to play the music.
musicInstance = music.Play(
    1,    // volume - between 0 and 1
    0,    // pitch - between -1 (octave low) and 1 (octave high)
    0,    // pan - between -1 (left) and 1 (right)
    true); // loop (true means loop)
```

This form of the `Play` method has four parameters that you can use to control how a sound effect is played. You can set the volume of the sound, the pitch (whether it sounds squeaky, normal, or deep), and the pan (whether the sound is at the left, at the right, or in the middle of the soundstage). Finally, you can set whether the sound plays in a loop.

Sample Code: 02 Drumpad with Music The 02 Drumpad with Music project in the resources for this chapter contains an XNA project and all the .wav files, including a music file. The music can be controlled with the shoulder buttons on the gamepad. It also contains the drum pad code to make sounds when the buttons are pressed. There is no version of this program for the Zune because the music sound effect is too large to fit in the XNA program memory for this device. However, you can still play background music on this device, as you will see in the next section.

If you have the time, you can explore some of the more powerful features of XNA sound generation, including using the XACT audio tool, which is supplied with the XNA Framework.

This is a professional standard game sound creation program that can be used to create very impressive sound effects, including automatic random selection of different sounds for a particular event and changing the pitch and volume of sounds as they play.

Playing Songs Using the *MediaPlayer* Class

The sounds you have played so far have been created using `SoundEffect` values. These are intended for use in games, where the game program needs to be able to play the sounds quickly in response to game events. However, sound effects are not the best way to play longer sound samples, such as songs, because the sound data takes up too much program memory. Instead, you can use the media playing features of XNA which let your games use compressed `.mp3` and `.wma` files as background music.

Up until now you have used `.wav` files in your games. You have created these files using the Audacity program. However, any sound files that you have on your computer are unlikely to be held in this format. Instead you will probably find that your files are either `.mp3` or `.wma` files. These hold the sound in a compressed form which takes up less storage space. XNA is not able to use `.mp3` or `.wma` files as content for sound effects, but it does have the ability to play such files using the `MediaPlayer` class.

The `MediaPlayer` class provides a `Play` method which is used to start playback of a particular `Song` value. You can load a `Song` as you would any other item of content.

```
// Game World

// Song to be played by the MediaPlayer class
Song music;

protected override void LoadContent()
{
    // Create a new SpriteBatch, which can be used to draw textures.
    spriteBatch = new SpriteBatch(GraphicsDevice);

    music = Content.Load<Song>("music");
}

```

The music item in the `Content` folder is an `.mp3` file. This can be added into the game solution in exactly the same way as the drum sound samples.

It is very easy to control the playback of a song using the `MediaPlayer` class. The code here will use the `A` button to start/resume playback and the `B` button to pause it.

```
// test if A has been pressed since the last Update
if (oldpad1.Buttons.A == ButtonState.Released &&
    pad1.Buttons.A == ButtonState.Pressed)
{
    if (MediaPlayer.State == MediaState.Paused)
    {
        MediaPlayer.Resume();
    }
}

```

```
        else
        {
            MediaPlayer.Play(music);
        }
    }

    // test if B has been pressed since the last Update
    if (oldpad1.Buttons.B == ButtonState.Released &&
        pad1.Buttons.B == ButtonState.Pressed)
    {
        if (MediaPlayer.State == MediaState.Playing)
        {
            MediaPlayer.Pause();
        }
    }
}
```

The `MediaPlayer` class provides a property called `State` which your program can use to determine whether or not it is presently playing a song.

Sample Code: 03 Music Player The 03 Music Player project in the resources for this chapter contains an XNA project and an .mp3 music file. The music playback can be started/resumed with button A and paused with button B.

Conclusion

This has been an interesting chapter. You've seen how to capture sounds and store them on your computer. You've also discovered how to use XNA to make sounds and play music.

Chapter Review Questions

And now the ever-popular review. Some people say that for some things in life, there are no right answers. Well, I think that for these questions, there is—namely, true or false.

1. Sound in an XNA program is managed by the Content Manager.
2. Games can use .mp3 files for sound.
3. You have to copy your sound files onto your target device by hand.
4. You can play only one sound at a time in an XNA program.
5. The `Play` method loads a sound effect into memory.
6. The `Play` method does not return anything useful.
7. A `null` reference refers to a `null` object.

Chapter 8

Creating a Timer

In this chapter, you will

- Find out how your program can measure the passage of time.
- Create a multi-player reaction game.
- Use C# arrays to allow the program to determine who won.

Making Another Game

You are now going to use your knowledge of Microsoft XNA and C# to create another game. This builds on the party theme that you explored in Chapter 6, “Creating a Multi-Player Game,” where you created a button-bashing game.

Game Idea: Mob Reaction Timer

In this game, you test the reactions of your players. Each player is in charge of one button on a gamepad. The game plays a sound, and the player who presses his or her button the soonest after the sound starts playing wins. Anyone who presses the button before the sound starts playing is out.

You need to use a timer variable to keep track of time and a variable for each player to measure the reaction time of that player. Those variables are declared in the following code:

```
// Game World  
  
int timer;  
  
// Gamepad 1 scores  
int ascore1;  
int bscore1;  
int xscore1;  
int yscore1;
```

These are the variables for the timer and the first gamepad. The timer starts counting up from zero when the sound plays. Each time that XNA calls the Update method, the value in `timer` is increased by one and the program checks to see if the player has pressed his or her button. If the button has been pressed, the value of the timer is copied into the score variable for that button. The player with the lowest value is the winner. The first problem we have to solve is how to start the game. If the sound is produced as soon the game begins, the player who starts the game has an obvious advantage. One way to make this work is to

make the timer a negative number when the game starts and increase it each time Update is called. When it reaches the value 0, the sound is played and the game starts counting. Figure 8-1 shows how this works.

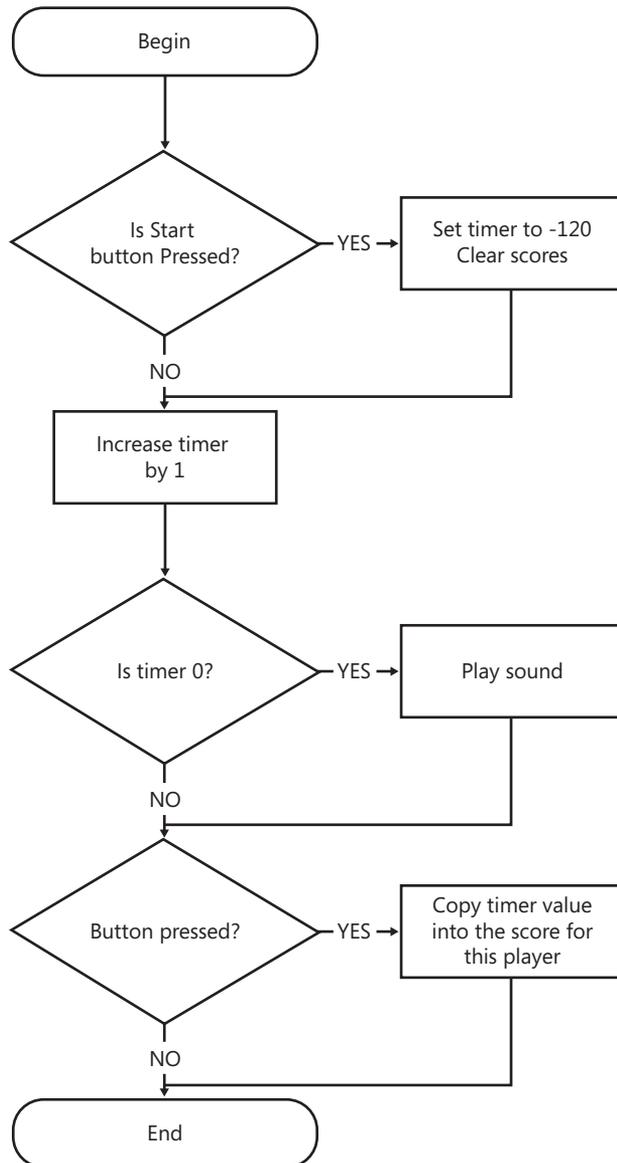


FIGURE 8-1 Flow diagram for a reaction timer

Each time Update is called, the flow in Figure 8-1 is performed. If the Start button is pressed, the timer variable is set to `-120`. Each time Update runs, the value in `timer` is made one bigger. When `timer` reaches zero, the sound is played. When a button press is detected, the program copies the current value of `timer` into the score for that button. If a player presses

a button before the sound has been played, he or she has a negative timer value. The player who gets the smallest positive value is the winner. The game world variables for this game will include the game timer variable along with the scores for each gamepad and the sound effect that is used to play the sound.

```
// Game World

// Display font
SpriteFont font;

// Game Timer
int timer;

// Game world sounds
SoundEffect dingSound;

// Gamepad 1
GamePadState pad1;
GamePadState oldpad1;
int ascore1;
int bscore1;
int xscore1;
int yscore1;
```

Each time that Update is called it must perform the actions shown in the flowchart, as shown in the following code:

```
protected override void Update(GameTime gameTime)
{
    pad1 = GamePad.GetState(PlayerIndex.One);

    if (pad1.Buttons.Back == ButtonState.Pressed)
    {
        this.Exit();
    }

    // start a new game
    if (pad1.Buttons.Start == ButtonState.Pressed)
    {
        timer = -120;
        ascore1 = 0;
        bscore1 = 0;
        xscore1 = 0;
        yscore1 = 0;
    }

    // update the timer
    timer++;

    // play the sound at the start of the game
    if (timer == 0)
    {
        dingSound.Play();
    }
}
```

```

// if A is pressed copy the timer
if (oldpad1.Buttons.A == ButtonState.Released &&
    pad1.Buttons.A == ButtonState.Pressed)
{
    ascore1 = timer;
}

// repeat for buttons B, X and Y

oldpad1 = pad1;
// repeat for gamepads 2, 3 and 4

base.Update(gameTime);
}

```

You should look carefully at this method because, although it is not very large, it is somewhat complicated. Remember that the `Update` method is called 60 times a second, so when the Start button is pressed and `timer` is set to `-120`, this means that there is a 2-second delay before the sound plays. The code runs and works well. In fact, I'm rather proud of it. Unfortunately, it has a rather nasty bug in it.

Sample Code: 01 Broken Reaction Timer Game All the sample projects can be obtained from the course instructor. The 01 Broken ReactionTimer project in the resources for this chapter contains a version of the game using the `Update` method from this section. Have a go with it and see if you can find the bug.

Reaction Timer Bug

You first notice the bug in the program when you find that your younger brother is beating everyone at the game. He seems to have amazing reflexes. Or he is cheating. It turns out to be the latter. He has noticed that although you get a negative (and therefore invalid) score if you press your button before the sound plays, you can press the button again later and have another go. What he does is press the button up and down very rapidly until he hears the sound and then stops. This usually results in his winning.

If you look at the code in the `Update` method, you find that there's nothing to stop a naughty player from pressing his or her button lots of times. There's no penalty for pressing the button before the sound plays because the player can just press the button again. You've designed the game without allowing for the fact that players might cheat and seem to have reckoned without your younger brother.

You need to change the program to fix the problem. At this point, you're doing proper programming. You've used an *algorithm* that gives a set of steps to make the game work, but you've found that it's faulty in some circumstances. Therefore, you need to either improve your solution or find a better one.

Because I wrote the first version, I'm going to start by asking you to work out what is going wrong. This might seem a little unfair, but I'm going to give you some help by suggesting things that might be the cause. Pick the one you think is the most sensible and then read on.

1. The problem occurs because you're not detecting when the player releases the button as well as when it's pressed.
2. The problem occurs because you should be using level detection on the buttons, not edge detection.
3. The problem occurs because you should register only the first press of the button.
4. The problem occurs because you need to reset the gamepad after it's been read.

If you look carefully at the flow diagram in Figure 8-1 and the code, you can simulate these ideas to see which makes the most sense. If this feels a bit like solving a puzzle, you're very close to what this part of programming is all about. If you get stuck trying to solve a programming problem, the best thing to do is to go back and consider what you're trying to achieve. What you mustn't do is just add lines of code in the hope that one of them fixes the problem.

Your younger brother is winning by pressing his button more than once. Because you can't physically stop him from doing this, you have to find a way to prevent later button presses having any effect on the score of the player. From the previous list, option 3 is the best one to try. So the problem now becomes: How can you tell if the button has been pressed more than once? Take a look at the flowchart and try to decide what the program could test to decide if this is the first or second time that the button has been pressed in a game.

It turns out that this is easy. The program works by copying the value of the timer into the score for each player. When the Start button is pressed, the program loads zero into the score values for each of the players. The very first time the player presses his or her button, the zero is replaced with a time value. Next time he or she presses the button, the score is not zero, so you should not update this value. The following code implements this fix:

```
// if A is pressed and ascore1 is 0 copy the timer
if (oldpad1.Buttons.A == ButtonState.Released &&
    pad1.Buttons.A == ButtonState.Pressed && ascore1 == 0)
{
    ascore1 = timer;
}
```

The program now contains a condition that tests whether the score is zero and sets the score only if it is. If the score is not zero (that is, the button has already been pressed), then the score is not stored.

Sample Code: 02 Fixed ReactionTimer The 02 Fixed ReactionTimer project in the resources for this chapter contains a mended version of the game using the `Update` method as fixed in this section.

Finding Winners Using Arrays

Your younger brother is now rather cross with you. The update means that he can't always win at the game anymore, and this has upset him somewhat. So he has taken to claiming that the game is rubbish anyway "because it doesn't tell you who won."

Unfortunately, he has a point. When the game finishes, the players must look at the screen and decide who the winner is. This doesn't seem right, bearing in mind that computers are supposed to make our lives easier. So now you have to work out a way of deciding who has the winning score. Any scores less than or equal to zero must be ignored because those players either pressed their buttons before the sound played or never pressed their buttons at all. Of the remaining scores, you want the one with the lowest value. You could write some complicated code like this:

```
if ( ascore1 > 0 )
{
    if ( ascore1 < bscore1 && ascore1 < xscore1 && ascore1 < yscore1 )
    {
        // if we get here button A of Gamepad 1 has won
    }
}
```

This code works only for the A button of gamepad 1. The first `if` statement checks to see if the score is greater than zero. If it is, the second condition is evaluated. This is a rather complicated `if` statement that checks to see if the score for the A button is less than the score for the other buttons on the gamepad. If the score is less than all of them, that button is the winner. You need to write three other conditions for the other buttons on the gamepad. This is a lot of work, and it gets even worse when you consider the possibility of four gamepads.

Creating an Array

What you need is a way of working through a list of scores using your program. In C#, a variable that holds a list of values is called an *array*. The type of values that you want your array to hold are integers, and it is "one-dimensional," in that it has only one list of values. Arrays can be declared and initialized just like any other C# variable:

```
int[] scores = new int[4];
```

This declares an array variable called `scores` that can refer to one-dimensional integer arrays and makes it refer to a new 4-element array instance. This would let the array hold the score values for the four buttons on gamepad 1.

You can think of an array as a row of numbered boxes, each of which can hold a single value. A single "box" in an array is called an *element*. Figure 8-2 shows how this works.

The size of the array is set when you create it. In the previous code, you made an array with four elements. If you want a different size, you simply change the 4 to a different number.

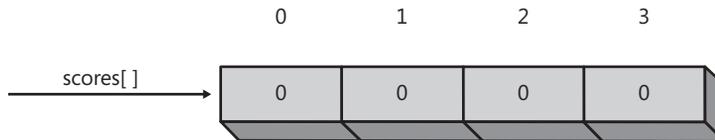


FIGURE 8-2 An array reference and an array instance



Note You may have noticed that I'm talking about "array instances" and that arrays are created using the key word `new`. I have used these terms before when I was talking about objects. This means that arrays are implemented in C# as objects, and you can ask them to do things for you. Later in this chapter, you'll see how you can use array properties and methods to make your life easier.

Using Data in an Array

Now that you have your array, you need to be able to get a hold of individual elements. If you take a look at Figure 8-2 again, you see that each element has a number above it. This is called the *subscript* or *index* of that element in the array. You can regard a subscript as telling the computer how far "down" an array to go to get to the element that is required. In this respect, array elements are similar to house numbers on a street (except that no houses have the number zero). To use a particular element in an array, you simply give the subscript of the element that you want. The following code shows how this works. The value of the subscript is enclosed in square brackets:

```
if (oldpad1.Buttons.A == ButtonState.Released &&
    pad1.Buttons.A == ButtonState.Pressed && scores[0] == 0)
{
    scores[0] = timer;
}
```

This C# code works in the same way as the original code, except that it uses the first element in the array, `scores[0]`, instead of a variable called `ascore1`. You can use `scores[1]` as `bscore1`, the score for the B button on gamepad 1, and so on.

At this point, it doesn't seem that creating an array has made life much easier; you've only found a quick way of declaring more than one variable. However, the real power comes when you use variables in your array subscripts, as follows:

```
for ( int i = 0; i < 4 ; i++ )
{
    scores[i] = 0;
}
```

This is a for loop construction that takes the value of `i` from 0 to 3 (remember that when the value of `i` reaches 4, the test "i less than 4" fails and the loop stops). The value of `i` is used as a subscript for the array access. This means that the first time around the loop, the statement

will set `scores[0]` to zero. The next time around the loop, the assignment statement works on `scores[1]`, and so on, up until the end of the array. This is how you'd set the scores array elements to zero at the start of a game.



Note The previous code uses an additional C# feature of the `for` loop that lets you declare the counter variable (in this case, a variable called `i`) in the loop itself. This variable exists only for the duration of the loop, being local to the `for` loop block. The Great Programmer thinks this is the right thing to do here, as you need the variable only for the duration of the loop block.

In this case, you want to work with only four elements, so the code doesn't look that much shorter than your original. However, if you needed to set 1,000 values, the code would contain the same statements, except that you'd change the limit value so that `i` goes up to 999.



Note If you have a mind like your younger brother, at this point you'll be wondering what would happen if you tried to use silly subscript values like `scores[101]`. Your younger brother would no doubt be hoping that this would cause the computer to crash or, better yet, allow access to secret memory locations. The boring answer is that if you step outside what are called the *bounds* of an array, your program is stopped in its tracks by an exception because this is just not allowed to happen in a proper language like C#. This form of naughtiness was not always detected in older computers, however, and was once one of the standard ways that a virus program could attack a system.

Scanning an Array

Now you need to use an array to help you find the best score. Figure 8-3 shows a typical arrangement of the values.

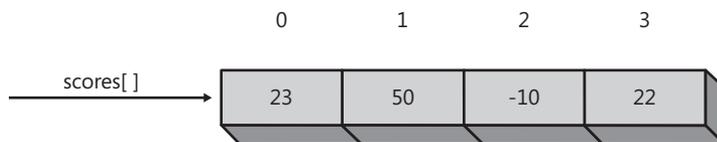


FIGURE 8-3 Sample scores

You now need to write some C# to work through the array and find the best score. At this point, you have a problem. If I ask you, "Which element in Figure 8-3 has the winning time in it?" you would glance at the page and say, "The element with subscript 3." And you'd be right. The problem is that you won't necessarily be able to tell me precisely how you worked it out. You simply looked along the row, and that number was the smallest number that wasn't negative. It was obvious.

Unfortunately, you can't say to the C# compiler, "Look along the row and find me the winner." You need to set things out in simpler and much more boring steps. The program

must look at each element in turn and see if it wins. At any given point in the process, the program would have an idea of the best result it has seen so far. If it sees a value that is better, it now has a new winner, and so on.

If you think about it, this is what people really do, particularly if they are working through 1,000 numbers instead of only a few. In that case, you would take care to remember the best result that you had seen so far as you went through and probably write it down on a piece of paper. With all this in mind, consider the following code:

```
int winningValue = 120;
for (int i = 0; i < 16; i++)
{
    if (scores[i] > 0)
    {
        if (scores[i] < winningValue)
        {
            winningValue = scores[i];
        }
    }
}
```

This code uses a variable called `winningValue` to hold the smallest value it has seen so far. It starts by setting it to a large value that is guaranteed not to be a winner. It then compares `winningValue` with each element in the array in turn. If the element is smaller than the current smallest value, it sets `winningValue` to the new value. Before it tests `winningValue`, the code makes sure that the count is a valid one (in that the button must have been pressed). At the end of the pass through the loop, the variable `winningValue` has the value of the winning score.

Now that you know the winning score, you can write some code to display the winner:

```
string winnerName;

if ( scores[0] == winningValue )
{
    winnerName = "Gamepad 1 button A";
}

if ( scores[1] == winningValue )
{
    winnerName = "Gamepad 1 button B";
}
```

This code selects the winning string for the A and B buttons on gamepad 1. The string `winnerName` is set with the name of the winning button and gamepad and can be displayed on the screen at the end of the game. You could write more statements for each of the other buttons and gamepads.



Note You need to make sure that when you check the buttons, you set the correct elements in the array; otherwise, the wrong names are displayed.

Using an Array as a Lookup Table

The previous code produces a string that contains the name of the winning gamepad and button. But you still need to perform all those conditional statements to decide the string to display. You do have a way to make your life easier, though, and it starts by finding out the position in the array of the winning score. Here's code that does that:

```
int winningValue = 120;
int winnerSubscript = 0;
for (int i = 0; i < 16; i++)
{
    if (scores[i] > 0)
    {
        if (scores[i] < winningValue)
        {
            winningValue = scores[i];
            winnerSubscript = i;
        }
    }
}
```

This is the same loop as before, but you now have a variable called `winnerSubscript` that holds the position in the array of the winning value. Note that the program copies the value of `i` into the `winnerSubscript` when it finds a new winning value. Remember that when you find a new winning value, the variable `i` holds the subscript in the array where that value is stored.

Now that you have the subscript value of the winning score, you can use it in another array to find the string that describes that player. The array is set up as shown in Figure 8-4.

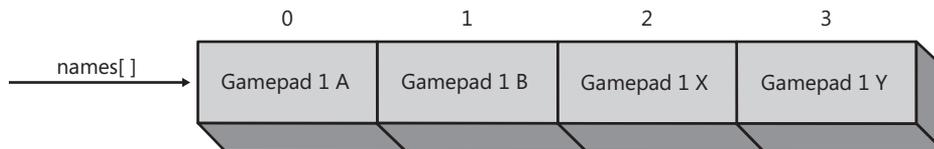


FIGURE 8-4 A player lookup table

This is an array of strings of text. There is an element in the array for each of the buttons on gamepad 1, and the names are lined up with the buttons that are tested. Now, to get the description of the winner, you simply need to look up the name in your table:

```
winnerName = names[winnerSubscript];
```

You need to have a way of setting up the lookup table with the correct strings. C# provides a way that you can create an array and set the initial values in it:

```
string[] names = new string[] {
    "Gamepad 1 A",
    "Gamepad 1 B",
    "Gamepad 1 X",
    "Gamepad 1 Y"
};
```

This creates an array with the preset values that you specify. Note that you don't need to tell C# how long the array is because the compiler can work this out automatically.

Displaying the Winner

You now have code that you can use to display the winner. Now you need to work out how to add this to the program. A good time to display the winner would be two seconds after the sound was produced, which is when the timer value reaches 120. By then, all the players should have pressed their buttons. The following code does that:

```
protected override void Update(GameTime gameTime)
{
    pad1 = GamePad.GetState(PlayerIndex.One);

    if (pad1.Buttons.Back == ButtonState.Pressed)
    {
        this.Exit();
    }

    // start a new game
    if (pad1.Buttons.Start == ButtonState.Pressed)
    {
        for (int i = 0; i < 16; i++)
        {
            scores[i] = 0;
        }
        winnerName = "";
        timer = -120;
    }

    // update the timer
    timer++;

    // play the sound at the start of the game
    if (timer == 0)
    {
        dingSound.Play();
    }

    // if A is pressed and scores[0] is 0 copy the timer
    if (oldpad1.Buttons.A == ButtonState.Released &&
        pad1.Buttons.A == ButtonState.Pressed && scores[0] == 0)
    {
        scores[0] = timer;
    }
    // Repeat for other buttons and gamepads

    if (timer == 120)
    {
        int winningValue = 120;
        int winnerSubscript = 0;
```

```

    for (int i = 0; i < 16; i++)
    {
        if (scores[i] > 0)
        {
            if (scores[i] < winningValue)
            {
                winningValue = scores[i];
                winnerSubscript = i;
            }
        }
    }

    if (winningValue != 120)
    {
        winnerName = names[winnerSubscript];
    }
    else
    {
        winnerName = "***NO WINNER**";
    }
}

base.Update(gameTime);
}

```

This version of `Update` works out the winner two seconds after the sound has been played. It places the name of the winner in the variable `winnerName`, which can then be displayed in the `Draw` method. When the game is started, the `winnerName` is set to an empty string so that the name appears only when it has been calculated.

There is one further improvement to this code, which is that if all the players have pressed their buttons before the sound, no one wins. The program checks to see if the `winningValue` has been changed by the search for the best time. If no value better than 120 was found, it means that everyone pressed their button too early. As a result, the program displays `***NO WINNER**`.

Sample Code: 03 ReactionTimer with Winner Display The 03 ReactionTimer with Winner Display project in the resources for this chapter contains a fully working version of the game that displays the winner.

Conclusion

In this chapter you've created another party game, discovered how to measure time and trigger events. You've also started to work with arrays as a means of allowing your programs to work much more effectively with collections of data.

Chapter Review Questions

And now yet another popular set of review questions. Just remember that there is nothing like knowing what you know. Prove it by saying whether these statements are true or false.

1. The C# code `int[] scores;` creates an array that could hold four integers.
2. An array can hold any type of data.
3. An array is an object.
4. The first element in an array has the subscript 1.
5. It doesn't matter if your array subscript values are out of range.

Chapter 9

Reading Text Input

In this chapter, you will

- Discover how the keyboard works in Microsoft XNA.
- Use enumerated types.
- Use arrays and references.
- Work with strings of text.
- Create a message board program.

Using the Keyboard in XNA

The Xbox itself does not have a keyboard, but you can plug any Universal Serial Bus (USB) keyboard into an Xbox and it will work. XNA programs use the keyboard in the same way whether they are running on an Xbox or a Microsoft Windows PC. In this chapter, you explore how you can use the keyboard in your XNA games. At the same time, you find out more about how C# programs can manipulate text.

Program Project: Message Board

The next program you make won't be a game as such, but rather an extension to one of your earlier programs. You create a message board that can be used to display text for all to see. You can use this to tell people where you are (really cool kids might have one on the outside of their bedroom door to show when they are free/busy and leave helpful messages for parents like "Please clean"). Or you could use it in the living room on the big-screen TV to avoid talking to people.

Creating the Message Board Project

You can use an earlier project, the BigClock project in the 06 3D Clock MoodLight folder in the resources for Chapter 5, "Writing Text," as the starting point of your message board. This provides a clock (which would be a nice thing to have on the message board) and also has the code that lets you display text on the screen.

Registering Key Presses

You've used the keyboard before in the Color Nerve game in Chapter 3, "Getting Player Input." You used it alongside the gamepad as follows:

```
GamePadState pad1 = GamePad.GetState(PlayerIndex.One);
KeyboardState keys = Keyboard.GetState();

if (pad1.Buttons.B == ButtonState.Pressed ||
    keys.IsKeyDown(Keys.R))
{
    redIntensity++;
}
```

This code increases the intensity of the red part of your color if the B button on the gamepad is pressed or the R key is pressed on the keyboard. The `IsKeyDown` method is provided with a parameter that tells it which key to test for. If that key is pressed down, the method returns `true`. By calling `IsKeyDown` with different parameters, you can check to see if particular keys are pressed. This is particularly useful in a game situation because a player might be holding down several keys at once, such as holding down an arrow key to move a spaceship as well as pressing the spacebar to fire a weapon.

The previous code is using inputs in a *level-sensitive* mode in that so long as the R key is held down, the intensity value increases. However, you've seen that this is not always how you want to use inputs. Sometimes you want them to be *edge-triggered* so that you register an event only when something changes. You used edge-triggered events to detect button presses to create the button-bashing games in Chapter 6, "Creating a Multi-Player Game," and also in the reaction timer game in Chapter 7, "Playing Sounds." For a keyboard to be useful, it must be edge-triggered; you want to know only when the key changes from up to down. You can't just say that a key has been pressed if `IsKeyDown` says it's down at any particular time.

There are two reasons that you can't do this. The first is that if you test the keyboard 60 times a second, your program might decide that a particular key has been pressed 60 times a second. The second reason is that when people type, they often press several keys at once. When I type the word "the," I find that as I press the "h" character, I still have the "t" held down. This is called "rollover," and hardware designers have been dealing with this ever since keyboards were first used on computers. So you need to write some kind of keyboard edge-triggered code.



Note At this point, it's worth mentioning that reading text from a keyboard in XNA is a lot trickier than reading text in other programming environments. This is because in XNA, the keyboard handling is really designed for playing games.



Note In conventional programming, there are commands that let you read in a line of text that the user enters. If you write programs using other frameworks to run in the Windows environment, you can request that a method be called each time the user presses a key. However, you're using XNA, so you just have to live with this. The only good news is that this does provide a good way to learn some fundamental programming principles along the way.

Detecting When Keys Are Pressed

You can detect a key being pressed by comparing the current state of the keyboard with the state it had previously. If a key is shown as being in the down position and it was previously up, this means that it must have been pressed, and you need to register it. You could do this on an individual key basis as follows:

```
if (keyState.IsKeyDown(Keys.R) && oldKeyState.IsKeyUp(Keys.R))
{
    // if we get here the key R has just been pressed
}
```

This code tests to see if the R key has just been pressed. The variable `oldKeyState` holds the previous state of the keyboard, and the variable `keyState` holds the current state. The problem with this approach is that you would need to perform this test for every single key on the keyboard, which would take a while to write. Fortunately, there's a slightly easier way to do this. The `KeyboardState` structure provides a method called `GetPressedKeys` that gives you an array of the keys that are currently pressed. You've seen arrays before; you made one to hold the score values of the reaction timer game in Chapter 8. This time, the array is being used to allow a method to return a set of answers, each of which identifies a key that is currently pressed. The elements in the array are of type `Keys`.



Note There is potential for confusion here. You can use a key on a keyboard to type a character. In this case, the word *type* means the action of typing. However, within the C# language the type of a variable determines what the variable can be used for.

The Keys Type

Part of the fun of programming is deciding the best way to store the things that a program must work with. You've seen that you can use the `byte` type to hold small integer values (in the range 0 to 255) and the `int` type to hold integer values in a wider range. We have also seen that XNA provides a variety of types that can hold game-specific things like textures and colors. The designers of XNA needed a way to represent a key on the keyboard so that programmers can write programs that react to a particular key being pressed. You've already used values of type `Keys` in your programs; `Keys.R` is used in the previous code to ask `IsKeyDown` to test whether the R key is being pressed.

Enumerated Types

The Keys type is a kind of type that I haven't discussed yet. It's an *enumerated type*. The word *enumerate* means to "count" or "number" items. Enumerated types are created by programmers when they need only a particular range of values to represent something. When the XNA team realized they needed to store information about a particular key on the keyboard, they could have used numbers (for example, they could have decided that A was 65, B was 66, and so on). However, they decided to create an enumerated type instead.

An enumerated type is one where the programmer defines the range of possible values that variables of this type can have and creates names for each of these values. Possible keys on a keyboard include the letter keys, A to Z, and the digit keys, 0 to 9, as well as the left and right Shift keys, the Enter key, and the Esc key, so the Keys type has a value for each of these.

The Great Programmer Speaks: Enumerated Types Are Useful The Great Programmer is a big fan of enumerated types. She says that if you create a type that can have only certain values, it reduces the chances of your program doing silly things. As an example, she says that if you had a game that was either in Attract mode (nobody playing), Play mode (game in progress), or High Score mode (entering the high-score value), it makes very good sense to represent these states with a variable that can have only one of those three values. You could use an integer to store this and remember that 0, 1, and 2 mean the three different states, but this would not stop an idiot programmer (or your younger brother) putting "97" in there and causing the program to do strange things.

The Keys enumeration does not include separate values for capital (uppercase) A and little (lowercase) a. It just represents the key itself. Your program needs to check if the A key and a Shift key are being pressed at the same time. If they are, the user is typing an uppercase A.

Working with Arrays, Objects, and References

The GetPressedKeys method returns an array of Keys values. Each element in the array describes a key that is presently pressed. The more keys that are pressed, the more elements are in the array. Figure 9-1 shows how such an array might look.

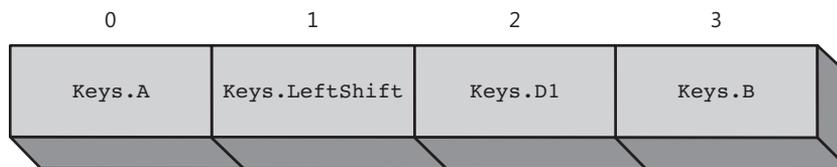


FIGURE 9-1 A sample Keys array

From the illustration, you can see that when the method was called, the A key, the left Shift key, the digit 1, and the B key are all pressed down. This means that to determine which keys have been pressed on the keyboard, you need to work through the array of key information supplied by the `GetPressedKeys` method. However, before you write the code to do this, it's time to take a detour into how arrays and objects work together and consider what the `GetPressedKeys` method actually gives you.

Values and References

Up until now, you've treated all objects equally. You've used `byte`, `string`, `Texture2D`, `double`, `Color`, `SpriteBatch`, and lots of other kinds of objects in your XNA programs and treated all of them in the same way. You know that different objects hold different amounts of data and that this data is held inside the object in *fields*. You also know that objects expose *properties* that you can use to access the values of the fields in the object and that objects also have *methods* that you can use to ask an object to do something for you. You can *declare* variables of these types, give them *identifiers*, and assign values to them using the `=` operator. Sometimes you need to use the key word `new` to create instances (for example, for `SpriteBatch`), and sometimes you don't (for `byte`). Now is the time to improve your understanding of how objects are organized in memory. You need to consider the difference between *value* and *reference* types.

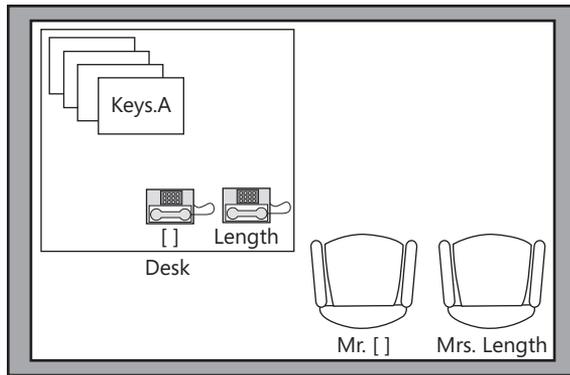
An array is a type that's managed by *reference*. It's very important that you understand how references work in C# programs. The Great Programmer reckons that you can't call yourself a proper programmer unless you understand how references work, and you need to consider this now. A reference is a kind of variable that refers to something. It doesn't hold any data; rather, it refers to the object in memory that contains the data. If you wanted an array that could hold four `Keys` values, you would write the following:

```
Keys[] pressedKeys;  
pressedKeys = new Keys[4];
```

The first statement creates an array reference called `pressedKeys`. The second statement makes an array that can hold four `Keys` values. These are two separate actions. When they are complete, you have an array reference that has been made to refer to a particular four-element array of `Keys` that is sitting in memory somewhere. At the moment, the `pressedKeys` reference is the only way that you can locate and use that four-element array.

Arrays as Offices

If you want to go back to the office scenario, you can think of an array as an office, as shown in Figure 9-2.



Array office

FIGURE 9-2 The Keys array as an office

The office holds the usual desk with the properties on it and the telephones for the behaviors that the object can support. The array type exposes a property called `Length` that's used to find out how many elements there are in the array. When the `Length` phone rings, Mrs. Length gets up, gets the number of array elements on the property table, and tells the caller the result as follows:

```
int keyCount = pressedKeys.Length;
```

This code shows how the `Length` property is used. If the `pressedKeys` reference refers to the array you created previously, the `keyCount` integer would be set to 4.

There's also another strange-looking property called `[]` in your array office. This is how elements are accessed. Mr. `[]` provides access to the pile of elements on the table. He is given the subscript value and then counts down the pile of elements on the table to get to the one that you want. If you give the subscript 0, you get the top one; the subscript 1 gets you the one below that; and so on. Mr. `[]` can read values off the array elements and also can write new values at the appropriate place in the pile. The following code shows how Mr. `[]` is used:

```
pressedKeys[0] = Keys.R;
```

It would cause him to put the value `Keys.R` in the element on the top of the pile.

You can think of a reference to an object as the phone number that you use to call to the people in that office. When a new instance of a class is created, it's as if you built an office, put in a desk and telephones, and hired a staff member for each behavior. Each telephone is identified with the phone number of the office, followed by an extension for the behavior in the object that you want to contact. So you could use `123435.Length` to get a hold of Mrs. Length in office 12345. Of course, in reality, a reference is the place in memory where the object is stored rather than a telephone number, but the principle is the same. When you're

given a reference, all you're told is how to get hold of something. The following code would create a new array and then set `pressedKeys` with the "telephone number" of that array:

```
pressedKeys = new Keys[4];
```

The only way that you can get hold of this array is by using `pressedKeys` to locate it. If the `pressedKeys` variable is destroyed or overwritten, the object might as well not exist, as you have no way of getting in touch with it. This is the same as if you met someone wonderful at a party and failed to get their telephone number. If you can't get to an object, it might as well not be there.

Say Hello to the Garbage Collector

Within C#, there's a special mechanism for getting rid of objects that might as well not be there. The *garbage collector* process has the job of looking for objects that do not have anything referring to them and removing them from memory. Memory allocation is an important part of programming, and you need to be careful not to make too much work for the garbage collector. An idiot programmer could write the following C# code:

```
Keys[] pressedKeys ;
pressedKeys = new Keys[100];
pressedKeys = new Keys[200];
```

This is very stupid code. It's completely legal and would compile and run, but it's still very stupid because the 100-element array that was created in the second statement is immediately made useless in the third, where `pressedKeys` is made to refer to another, larger array. This is like building a brand-new office and then destroying the only copy of the telephone number that could be used to contact it. The garbage collector would eventually notice that the array object had no references referring to it and would destroy it, but until this happened, a large chunk of memory would be unusable.

The Great Programmer makes sure that when she writes a program, it does not repeatedly create and destroy objects in this way; as a result, her software runs quickly and uses only the minimum amount of memory.

Using References and Values

You can see that reference variables are quite different from "ordinary" variables that simply hold values. It's important that you understand the difference. A reference variable holds the "telephone number" of an instance of an object. A value variable holds a particular value, for example:

```
int myAge;
myAge = 21;
```

These statements declare an `int` variable called `myAge` and set it to the rather optimistic (in my case) value of 21. You can think of `myAge` as a piece of paper with space to write a single integer value on it. When a value is assigned to the variable, it's equivalent to writing a new number on the paper. If I assign the value in `myAge` to another `int` variable, the value on the paper is copied across:

```
int myAge;  
myAge = 21;  
int tempAge;  
tempAge = myAge;
```

You now have a new `int` variable called `tempAge`. This has the value 21 written on it because that's the value that was copied from the `myAge` variable. In other words, when you work with value types, you're copying values from one piece of paper to another. Changing the value written on one piece of paper does not change the value on another:

```
tempAge++; // this will not change the value in myAge
```

If the value in `tempAge` is increased by 1, it now holds the value 22, but `myAge` still has the value 21.

However, consider what happens when the program performs assignments using references:

```
Keys[ ] pressedKeys ;  
pressedKeys = new Keys[100];  
Keys[ ] oldKeys;  
oldKeys = pressedKeys;
```

The `oldKeys` variable is a reference that can refer to an array of `Keys`. If I set `oldKeys` equal to `pressedKeys`, it means that it refers to the same object as `pressedKeys` does. In other words, it contains the same office phone number. Whether you use `oldKeys.Length` or `pressedKeys.Length`, you get the same `Mrs.Length` on the end of the line. So you can see that the following statements both set the element at the start of the same array:

```
oldKeys[0] = Keys.X;  
pressedKeys[0] = Keys.Y;
```

First, the element is set to X; then it is set to Y. At the end of these two statements, both `oldKeys[0]` and `pressedKeys[0]` contain Y.

An object managed by reference doesn't have a name; rather, it's identified only in terms of the things that are referring to it. You should never say "the array called `oldKeys`"; you can say only "the array that `oldKeys` is currently referring to." During the lifetime of the `oldKeys` reference, it could be made to refer to many different arrays.

Why Do We Have References and Values?

You might be wondering why the designers of C# have bothered with value and reference types. All they have done so far is make programming more confusing in that assignment statements can assign either references or values. Look at this code:

```
x = y;
```

This statement could mean, “Make the reference x refer to the same thing that y refers to,” or it could mean, “Take the value in y and copy it into x.” Without knowing what types x and y are, you can’t decide. However, references are very useful in programs. As an example, consider the `Texture2D` type. You’ve used this in your programs to store an image you might want to draw. The image might be very large, in which case a `Texture2D` instance would take up a lot of memory. Because of this, textures are managed by reference. If I want to give someone my texture, I’ll pass them a reference to it. In a game, you often want to do this because you can use the same texture to draw lots of objects. In a space shooter game, each of the identical aliens that are attacking your spaceship could be drawn using the same texture. Value types, on the other hand, are small and copies can easily be passed between different parts of a program.

References and *GetPressedKeys*

Up until now, you’ve been using value types and reference types without worrying too much about the difference, but as you write more complicated games, you need to deal with both kinds. In Chapter 14, in the section “References,” you’ll revisit the way that value and references are used when you design some data types of your own; for now, the important thing to remember is that an array is a type that is managed by reference, and that what you get back from `GetPressedKeys` is a reference to an array.

Displaying Keys

You start your message board off by writing a program that displays the keys that are presently being held down on a keyboard. The `Update` method sets a message string in the game world that the `Draw` method puts up on the screen for everyone to see. The code in the `Update` method must look through the array of pressed keys and add a description of each key to the message string as follows:

```
// Game World
string messageString;

protected override void Update(GameTime gameTime)
{
    KeyboardState keyState = Keyboard.GetState();
```

```

// Allows the game to exit by pressing the Esc key
if ( keyState.IsKeyDown(Keys.Escape) )
{
    this.Exit();
}

// Get the pressed keys and display them
Keys[] pressedKeys;
pressedKeys = keyState.GetPressedKeys();
messageString = "";
for (int i = 0; i < pressedKeys.Length; i++)
{
    messageString = messageString + pressedKeys[i].ToString() + " ";
}

base.Update(gameTime);
}

```

The first part of the method sets `messageString` to an empty string. Then the string representation for each `Keys` item in the array is added to the end of the message. You've used the `ToString` method before when you converted dates and times into strings for your clock. `ToString` asks an object to provide a string of text describing the information it holds. When you call `ToString` on an instance of an object, it should tell you what key it is. The string that is built in the `Update` method is displayed by the `Draw` method:

```

protected override void Draw(GameTime gameTime)
{
    graphics.GraphicsDevice.Clear(Color.CornflowerBlue);

    Vector2 messageVector = new Vector2(50, 100);

    spriteBatch.Begin();
    spriteBatch.DrawString(font, messageString, messageVector,
        Color.White);
    spriteBatch.End();

    base.Draw(gameTime);
}

```

This `Draw` method simply draws the `messageString` on the screen. Figure 9-3 shows the output of the program if the Caps Lock key, the A key, and the left Alt key are held down.

Sample Code: Key Viewer All the sample projects can be obtained from the course instructor. The `KeyViewer` project in the `01 KeyViewer` directory in the resources for this chapter contains a program that uses the `Draw` and `Update` methods described in this section to display the keys that are being pressed on the keyboard. Note that different hardware is able to support different numbers of keys being held down at the same time.

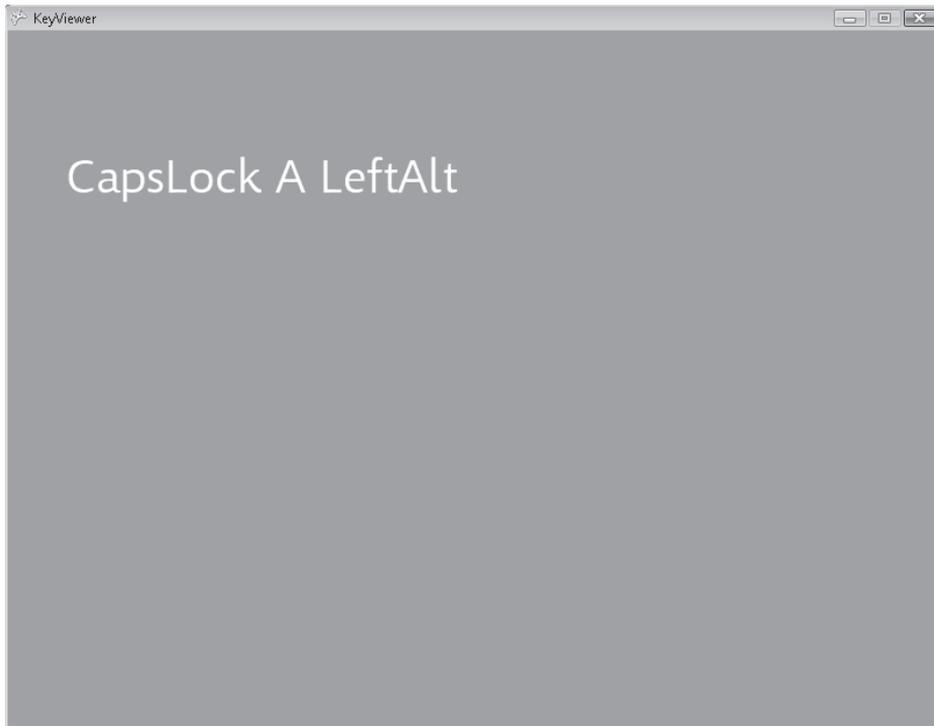


FIGURE 9-3 Drawing level-detected key presses on the screen

Detecting Key Presses

As you see with the `KeyViewer` program, the name of the key that is pressed is displayed so long as the key itself is held down. However, as we found with the gamepad, you want to register a key press only when you see a key change from up to down. You detect such changes by comparing the present state of the keyboard with the previous state. Figure 9-4 shows how this might work. It shows the `oldKeys` that were previously pressed and the `pressedKeys` that are presently pressed. Your program must decide which key has just been pressed.

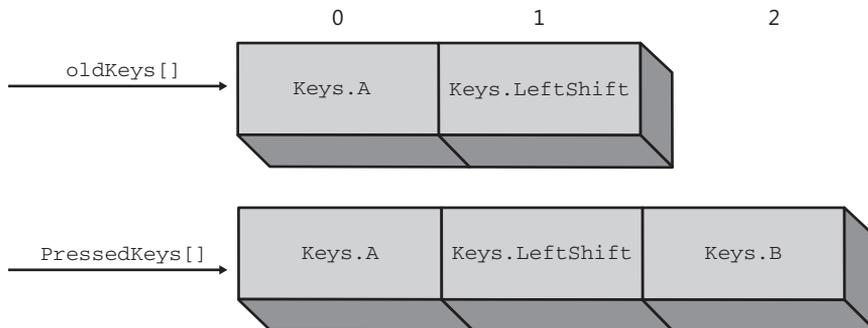


FIGURE 9-4 Detecting key presses

If you look at Figure 9-4, you can see that the key that must have just been pressed is the B key. The A key was already pressed, as was the left Shift key. You need to find a sequence of operations that can work this out. This means that it is time to create another *algorithm*.

When faced with a situation like this, I think that it's a bit like being a detective. A detective arrives at the scene of a crime, looks at the evidence, and then tries to build up a sequence of events that explains everything that has been found. A programmer has some information that comes in from which he or she must produce the desired output by a process that he or she needs to devise. If you have a problem like this, it's often useful to set out what you know and what you want to find out and then try to find a way of getting one from the other.

In this case, in the input side, you have a list of keys that were pressed before and a list of keys that are pressed now.

The output that you want is any keys that have been pressed since you last looked. If you think about it for a while, you can come up with a way to tell which keys have just been pressed:

"Any keys in the list of keys that are pressed now that are *not* in the list of keys that were pressed before are ones that have just been pressed."

You can test this by applying it to the keys in Figure 9-4. Both the A key and the left Shift key are in the `o1dKeys` array and the `pressedKeys` array. However, the B key is only in the `pressedKeys` array, so it must have just been pressed down. At the moment, your solution does not give you any steps to follow; what you need to do now is convert it into a proper algorithm. Initially, you can write this in English; then you can convert it into C# code.

"Take each value in `pressedKeys` in turn and check to see if it occurs in `o1dKeys`. If you don't find the value in `o1dKeys`, that key must have been pressed since you last looked."

You know that to work your way through an array, you need to use a for loop of some kind. In this case, you need to put one for loop inside another because you need to look through the `o1dKeys` array for each of the values in `pressedKeys`. This is called "nesting" the for loops and is a very common programming technique:

```
// String we are going to display - initially an empty string
string messageString = "";
// the keys that were pressed before - initially an empty array
Keys[] o1dKeys = new Keys[0];

protected override void Update(GameTime gameTime)
{
    KeyboardState keyState = Keyboard.GetState();

    // Allows the game to exit by pressing the Esc key
    if (keyState.IsKeyDown(Keys.Escape))
    {
        this.Exit();
    }
}
```

```
// the keys that are currently pressed
Keys[] pressedKeys;
pressedKeys = keyState.GetPressedKeys();

// work through each key that is presently pressed
for (int i = 0; i < pressedKeys.Length; i++)
{
    // set a flag to indicate we have not found the key
    bool foundIt = false;

    // work through each key that was previously pressed
    for (int j = 0; j < oldKeys.Length; j++)
    {
        if (pressedKeys[i] == oldKeys[j])
        {
            // we found the key in the previously pressed keys
            foundIt = true;
        }
    }
    if (foundIt == false)
    {
        // if we get here we didn't find the key in the old keys, so
        // add the key to the end of the message string
        messageString = messageString + pressedKeys[i].ToString();
    }
}

// remember the currently pressed keys for next time
oldKeys = pressedKeys;

base.Update(gameTime);
}
```

This version of `Update` takes each key in the `pressedKeys` array and searches the `oldKeys` array to see if that key is in there. If it doesn't find the key, it adds a description of the key to the message string. I've added quite a few comments (the lines that start with `//`) that should make the code easier to understand. Note that I am using a `bool` variable called `foundIt` to record whether a key has been found when the old key array is searched. If this flag is not set during a search, that key value is not present in the old array and must be a new key. The message string itself is drawn in the same way as it was in the previous program.

Don't worry if you find this code confusing at first; just remember the problem that it is trying to solve. The program has two lists of keys, an old list and a new list. It is trying to detect new arrivals (that is, those who are in the new list but not in the old one). You would use the same algorithm if you were in charge of greeting people arriving at a party. Every now and then, you would look around and try to spot any new faces that you hadn't seen before. If you were organized, you would keep a list of those people you have seen, and then look out for people not on that list. If you look at the code, you should find that it is doing exactly that.

Sample Code: First Message Display The MessageBoard project in the 02 First Message Display directory in the resources for this chapter contains a program that uses the Update method from this section to build and display a message from the keys that are pressed on the keyboard.

If you look closely at the code in Update, you find that at the end of the method, the value of `oldKeys` is set to refer to the `pressedKeys` array so that the next time that Update is called, it will have some old keys to check against. However, the very first time that Update is called, there are no old keys. This problem has been solved by making `oldKeys` refer to an empty array when the variable is declared:

```
// the keys that were pressed before - initially an empty array
Keys[] oldKeys = new Keys[0];
```

This declaration creates the `oldKeys` array reference and makes it refer to an array that contains zero elements. The program must do this because the Update method uses this reference to find the list of the keys that were pressed before. It turns out that this is a problem only if there is a key pressed the very first time that Update is called, which is not normally the case. However, I am confident that your younger brother would soon find this mistake.

The Great Programmer Speaks: Testing Is Vital Our Great Programmer reckons that good testers are worth their weight in gold. She might not include your younger brother in this category, but she does say that people who are good at breaking programs are very valuable. You might not think of asking the question, "I wonder what would happen if we ran the program with a key already held down?" but it is useful if someone tries this before the program is actually given to customers. The Great Programmer even goes as far as rewarding people who find faults in her programs so that she can identify and fix mistakes before they become faults. When you start thinking about selling your games (and XNA Creators Club now makes this viable), it is useful to find a bunch of people like your younger brother and offer them a free soda for every new bug they find in the program.

Using *break* to Improve Performance

The program that you've written works fine, but it's not as efficient as it could be. There's an additional feature of C# that you can use to improve it. The C# language provides a key word called `break` that you can use to abandon the execution of a loop. When you're searching through `oldKeys` to see if it contains a key that is currently pressed, as soon as you find a match, you need not look any further. You can use the `break` key word to break out of the search loop, as shown in bold type here:

```
// work through each key in that was previously pressed
for (int j = 0; j < oldKeys.Length; j++)
{
    if (pressedKeys[i] == oldKeys[j])
```

```
{  
    // we found the key in the previously pressed keys  
    foundIt = true;  
    // no need to look any further  
    break;  
}  
}
```

If the program reaches the `break` instruction, it abandons the loop and continues running at the statement after the loop.

Decoding Key Characters

You can now detect individual key presses, which is nice. However, at the moment, the text you get from the keys is not as useful as you might like. The letter keys seem to work okay, but keys like Shift and the spacebar do not produce the output you want. Figure 9-5 shows what happens if you try to type in “Hello World.” When you press Shift to get the uppercase characters, this is registered as a key, and the spacebar key doesn’t work properly, either.

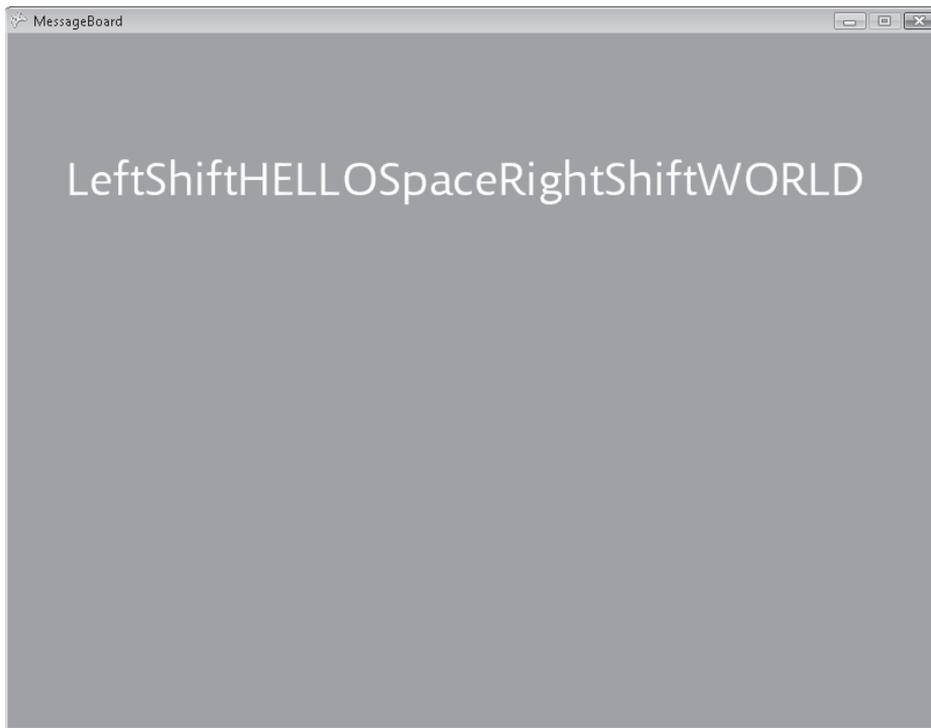


FIGURE 9-5 Some problems with typed text

What you need to do next is decode the keys into more useful strings. If you get the value `Keys.A`, you'd like to have "A," and so on. You could use a large number of `if` statements to do this, but C# provides a better way of doing this, called a `switch` statement:

```
string keyString = ""; // initially this is an empty string
switch (pressedKeys[i])
{
    // digits
    case Keys.D0:
        keyString = "0";
        break;
    case Keys.D1:
        keyString = "1";
        break;
    // rest of digits here

    case Keys.A:
        keyString = "A";
        break;
    case Keys.B:
        keyString = "B";
        break;
    // rest of alphabet here

    // punctuation characters
    case Keys.Space:
        keyString = " ";
        break;
    case Keys.OemPeriod:
        keyString = ".";
        break;
}
```

The `switch` statement selects a particular case based on the value of a *control expression*. In this case, the control expression is `pressedKeys[i]`, the value of the key you've discovered has just been pressed. Depending on this value, the code sets a string called `keyString` to the appropriate text. Once the string has been set, the code uses the C# `break` key word, causing the program to exit from the `switch` statement. You've seen `break` before when you used it to exit from a `for` loop. You can also use it to exit from a `switch` statement.

If the value in the control expression does not match any of the cases, the statement has no effect. The `switch` statement does not make anything possible that you couldn't do with a large number of `if` statements, but it does make programming easier in some situations.

Using the Shift Keys

If you use the previous code to decode your keys, you have a usable text reader, but at the moment, it doesn't use the Shift keys properly, so every letter that is typed is in uppercase.

However, it turns out that it's easy to fix this by adding the following code after your `switch` statement:

```
if (keyState.IsKeyUp(Keys.LeftShift) &&
    keyState.IsKeyUp(Keys.RightShift))
{
    keyString = keyString.ToLower();
}
```

I'm quite proud of this code. It tests the state of the two Shift keys on the keyboard. If both Shift keys are in the up position, the string that has been pressed is converted into the lowercase version of that text. This works because the string type provides a method called `ToLower` that provides a lowercase version of the string, which turns out to be exactly what you want. `ToLower` is clever in that it has no effect on characters other than letters, such as numbers and punctuation.

You could expand this code to allow the user to type in the shifted versions of the number keys. You could also create a flag variable to keep track of the Caps Lock key.

Editing the Text

The string type provides a huge number of methods that can be used to get a hold of processed versions of the string. It provides one called `ToUpper`, which produces a version of the string containing all uppercase letters; it also provides a method that can be used to chop out a certain number of characters from the string. You can use this to provide your user with simple text editing, as follows:

```
if (pressedKeys[i] == Keys.Back)
{
    if (messageString.Length > 0)
    {
        messageString = messageString.Remove(messageString.Length - 1);
    }
}
```

If the user presses the Back key, this code removes a key from the end of the `messageString`. It does this by using the `Remove` method, which removes characters from the end of the string. `Remove` is told the position to start removing from, so I give it the length of the string minus 1 to remove the last character. The code also checks to see if the length of the string is zero because if the string has zero length, there's nothing to remove.

The final enhancement that you need to add is the ability to take a new line in our string so that the user can create messages that are more than one line in size. A string can contain special *control characters* that control the layout of the text. The most useful of these is the newline character, which instructs whatever is processing the string to take a new line. It turns out that the `DrawString` method that you use to draw the text on the screen takes a new line when it sees this character in a message, so all you need to do is convert the Enter key

(which users press when they want a new line on the display) into a newline character. The convention in C# strings is that a control character is preceded by the backslash character (\). The following case is added to your `switch` statement to convert the Enter key into a string that causes `DrawString` to take a new line:

```
case Keys.Enter:  
    keyString = "\n";  
    break;
```

C# provides other special formatting characters, but for now, you use only the newline character.

Sample Code: Message Board Program The `MessageBoard` project in the 03 Full Message Display directory in the resources for this chapter contains a program that uses the previously mentioned code to implement a message display with a changing color background, 3-D text, and a clock.

Figure 9-6 shows the fully featured message board in action. The clock is always drawn on the line beneath the text.

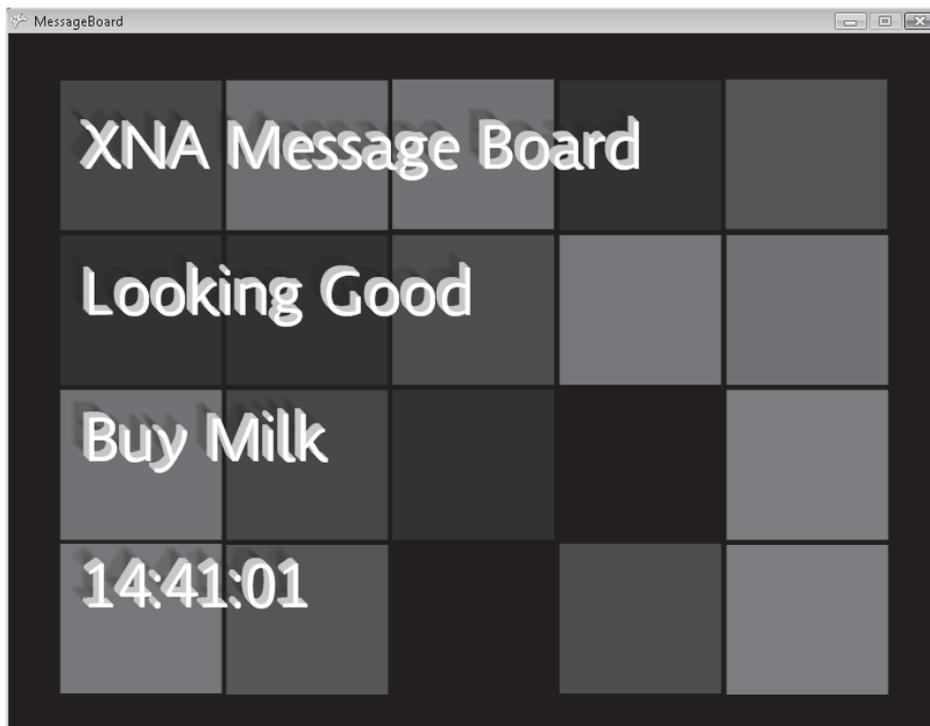


FIGURE 9-6 A message board with clock

You can experiment with the sample code for the Message Board program. You could try using different sizes of text to create different kinds of displays.

Conclusion

You now have a way that users can type text into your XNA program. This can be the basis of some interesting games, as you'll see in later chapters. You've also started to look at how data is stored and structured in C# programs and at the difference between value and reference types. You've used a new program structure, the `switch` statement, that lets a program select among a number of different options depending on the value of a particular expression. Finally, you've taken a look at the things you can do with strings.

Chapter Review Questions

And now the ever-popular chapter review. The questions are different, but the range of answers is still the same: true or false.

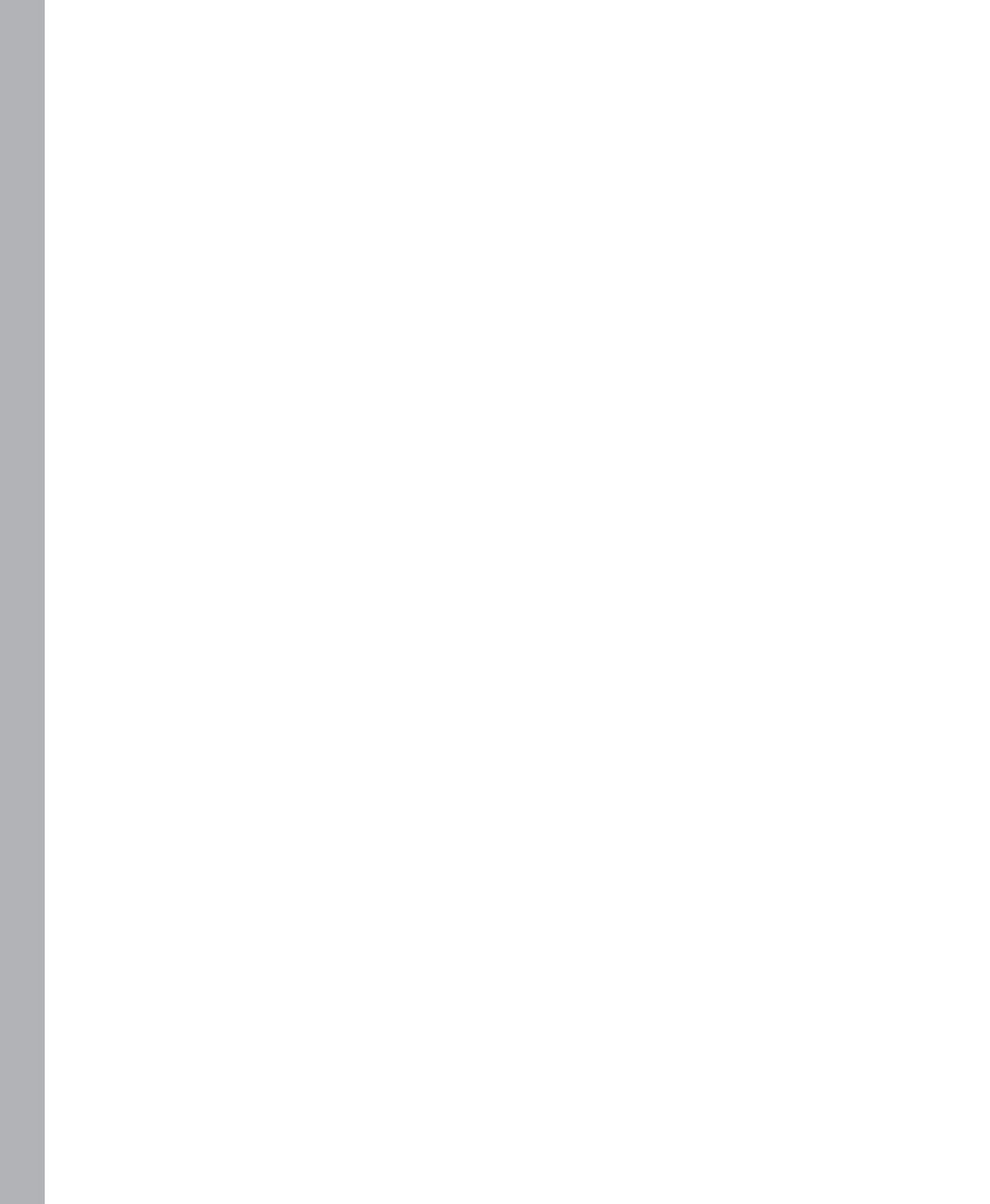
1. In XNA, a keyboard can register only one key at a time.
2. The `Keys` type holds a string.
3. There are separate `Keys` values for uppercase A and lowercase a.
4. The `Keys` type is an enumerated type.
5. A reference gives the location of an object in memory.
6. It's not possible for two references to refer to the same object in memory.
7. The garbage collector runs only when a program has finished.
8. The `break` key word causes your program to stop.
9. A `switch` statement is used to turn off the power to the computer.
10. The `string` class provides a method to produce an uppercase version of itself.
11. It's not possible to add two strings together.

Part III

Writing Proper Games

In this part:

| | |
|--|-----|
| Chapter 10: Using C# Methods to Solve Problems | 163 |
| Chapter 11: A Game as a C# Program | 189 |
| Chapter 12: Games, Objects, and State | 211 |
| Chapter 13: Making a Complete Game | 229 |
| Chapter 14: Classes, Objects, and Games | 249 |
| Chapter 15: Creating Game Components | 277 |
| Chapter 16: Creating Multiplayer Networked Games | 307 |



Chapter 10

Using C# Methods to Solve Problems

In this chapter, you will

- Use image manipulation to write a game you might like to play.
- Discover how to create and use your first C# methods.
- Take a look at test-driven development.
- Make some mistakes and discover how to fix them.

Introduction

Your programming skills are coming along. Your programs can store different kinds of numbers, do things with them, and even make decisions. You also know how to add image assets to your games and display them on the screen.

Now you create a game based on the image manipulation. To make your life easier, you create some C# methods of your own, and you also look at a development technique called *test-driven development*.

Playing with Images

In Chapter 4, “Displaying Images,” you discovered how to load images into your programs. Now you can start to have some fun with them. Up until now, the image drawing that you performed simply displays a texture on the screen in the same place each time the Draw method is called. It would be really nice to be able to move the picture around the screen and maybe even zoom in on it. You might even find that these abilities give you an idea for a game.

Zooming In on an Image

When you wrote your image display program, you created a variable called `jakeRect` of type `Rectangle`. This rectangle was the destination of the draw action. The size of the rectangle was set to the full screen in the `Initialize` method, as follows:

```
protected override void Initialize()
{
    gameSpriteBatch = new SpriteBatch(graphics.GraphicsDevice);
    jakeRect = new Rectangle(
```

```

        0,    // X position of top left hand corner
        0,    // Y position of top left hand corner
        GraphicsDevice.Viewport.Width, // rectangle width
        GraphicsDevice.Viewport.Height); // rectangle height

    base.Initialize();
}

```

When the Draw method ran, it drew the image texture in the `jakeRect` rectangle:

```

protected override void Draw(GameTime gameTime)
{
    graphics.GraphicsDevice.Clear(Color.CornflowerBlue);

    gameSpriteBatch.Begin();
    gameSpriteBatch.Draw(jakeTexture, jakeRect, Color.White);
    gameSpriteBatch.End();

    base.Draw(gameTime);
}

```

Now you change the way that the picture is drawn by changing the values in `jakeRect` as the program runs. XNA can resize the picture for you so that you can move and scale your picture very easily. You start by adding the following Update method to the display program:

```

protected override void Update(GameTime gameTime)
{
    // Allows the game to exit
    if (GamePad.GetState(PlayerIndex.One).Buttons.Back == ButtonState.Pressed)
        this.Exit();

    jakeRect.Height++;
    jakeRect.Width++;

    base.Update(gameTime);
}

```

Each time the Update method is called, the width and height fields of the rectangle are increased by one. These fields are the data members inside the rectangle that represent the rectangle dimensions. You get a hold of a field in an object by giving the identifier of the variable a period character (.) and then the name of the field you wish to use. Remember that this is the rectangle that describes where you want Jake to be drawn, so changing the size of this rectangle changes the size of the image on the screen.

Microsoft XNA does not care about the fact that you're "drawing off the screen" and simply shows you the part of the picture that fits on the screen. Figure 10-1 shows what the screen looks like after a program using this Update method has been running for a few seconds.

If you leave the program running a very long time, it only zooms in on a particular blade of grass, but it does show how you can change the way that images are placed on the screen.

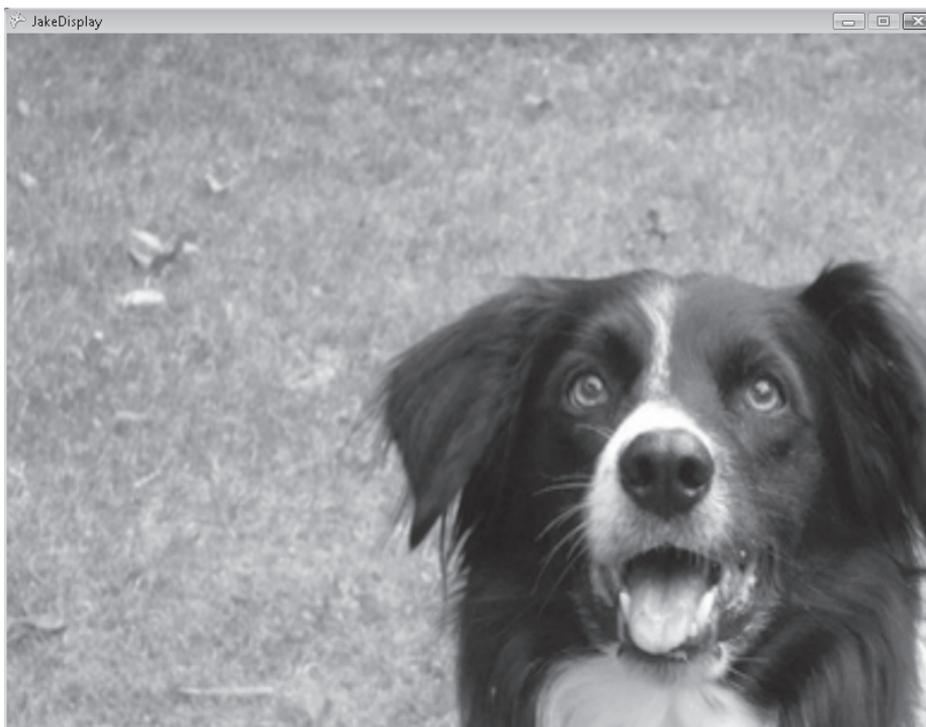


FIGURE 10-1 Stretching Jake

Sample Code: Jake Zoom All the sample projects can be obtained from the course instructor. The sample project in the 01 Jake Zoom directory in the resources for this chapter draws a picture of Jake and then slowly zooms in on it.

Game Idea: Super Zoom Out

You can use this zooming ability to create a game. Rather than starting with a picture and then zooming in on it, you could start with a zoomed image and slowly pull back (zoom out) to reveal more and more of the picture. The first person to correctly identify the picture wins the game. This game is quite fun, particularly if the images are ones that are familiar to the players.

Creating a Zoom-Out

The starting point of the game should be an enormous drawing rectangle that you reduce in size as the game continues, causing more and more of the image to be visible.

Updating the Drawing Rectangle

To make this work, you need to change the way that you set up the `Rectangle`, which describes the part of the image that you'll draw. Here's the code for that:

```
protected override void Initialize()
{
    gameSpriteBatch = new SpriteBatch(graphics.GraphicsDevice);
    jakeRect = new Rectangle(0, 0, 6000, 4500);

    base.Initialize();
}
```

This creates a rectangle that's 6,000 pixels wide and 4,500 pixels high, or 10 times the original image size and much bigger than the screen. Figure 10-2 shows the effect of using a rectangle like this. If you use this rectangle to control the draw process, the image is too large to fit on the display, so it shows only the top right corner.

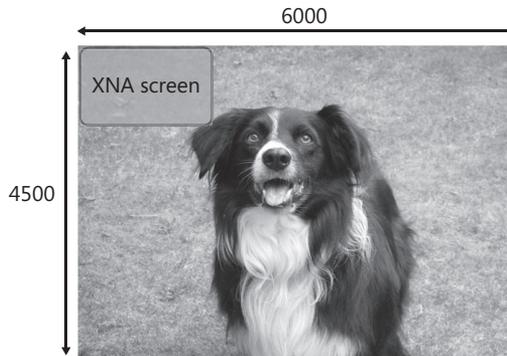


FIGURE 10-2 Jake in "Zoom"

The program then reduces the width and height of the rectangle each time `Update` is called:

```
protected override void Update(GameTime gameTime)
{
    // Allows the game to exit
    if (GamePad.GetState(PlayerIndex.One).Buttons.Back == ButtonState.Pressed)
        this.Exit();

    jakeRect.Height--;
    jakeRect.Width--;

    base.Update(gameTime);
}
```

The idea of this `Update` is that each time it's called, the width and height fields of the rectangle are reduced by one. This decreases the amount of zoom, meaning that more of the picture will be visible.

Sample Code: Jake Display Bad Zoom The sample project in the 02 JakeDisplay Bad Zoom Out directory in the resources for this chapter displays a zoomed-in image of Jake and then uses the Update method from this section to zoom out.

If you run the program, you find that although the zoom-out idea is a good one, the way it behaves is not quite what you want. Figure 10-3 shows what happens after you've run this program for a while.



FIGURE 10-3 Zooming out Jake, a first attempt

More of the picture is visible, but it seems to have been stretched for some reason. To understand what's happening, you need to think first about what you set out to do.

1. You wanted to display only part of the image on the screen. This allows you to show only part of the image so that the player has to guess what the picture is.
2. To achieve this, you made the draw rectangle enormous by multiplying its width and height by 10 so that only part of the drawn image was visible on the screen.
3. You then created an Update method that reduces the width and height of this rectangle by one each time it is called so that the amount of image in the screen increases progressively.
4. You've noticed that as this program "zooms out" of the image, it no longer looks right.

The problem is that each time you reduce the width and height, you're reducing them by the same amount (that is, both the width and the height get smaller by one). Figure 10-4 shows the path followed by the bottom left corner of the Jake image if you repeatedly reduce the width and height of the picture by one each time.

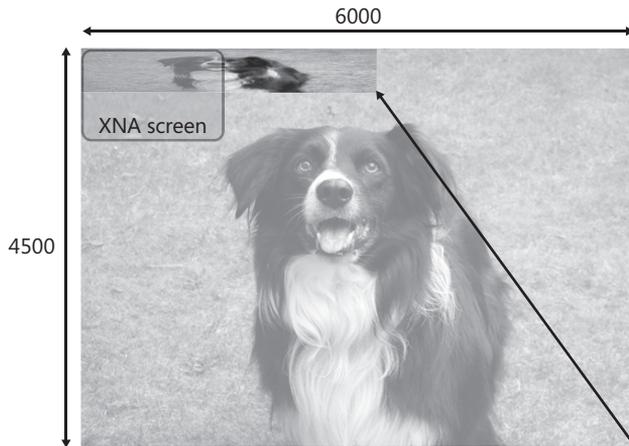


FIGURE 10-4 Zoom path behavior

The path does not follow the diagonal of the image; instead, it moves up too quickly and scrunches the height of the picture. This happens because you're reducing the height and width by the same amount each time. Because the picture is not as high (4,500) as it is wide (6,000), the height is "used up" more quickly, leading to a scrunched picture.

You can fix the problem by reducing each value by a percentage each time rather than by a particular value. For example, if you wanted to reduce the picture size by 1 percent, you would take 45 (1 percent of 4,500) off the height and 60 (1 percent of 6,000) off the width. This sounds a bit complicated, so let's ask the Great Programmer for advice.

The Great Programmer Speaks: Break Complicated Things Down The Great Programmer thinks that it's always a good idea to break more complicated things down into smaller chunks using methods. She says there are three reasons to do this:

- It makes the programming simpler.
- Perhaps you can find someone else to do that task (or maybe a method already exists to do that).
- You might end up with methods that you can use in other parts of your program.

In this case, you want to reduce the sizes by a particular percentage, so a good starting point is a method that works out percentages.

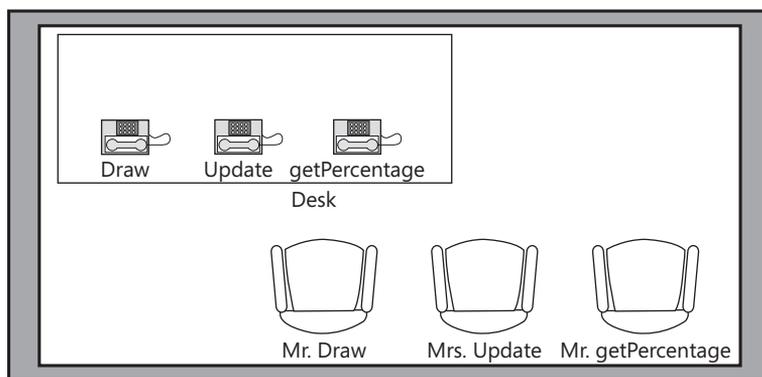
Because the Great Programmer is never wrong, you now have to find out how to use methods to help you solve your problem.

Creating a Method to Calculate Percentages

A method is a block of code that does something for you. Each method has an identifier that you use to refer to the method when you call it.

Putting a Method into Your Game Class

You've seen methods many times before. Mr. Draw and Mrs. Update are methods that were written by the XNA team for you to use. Now you create a method of your own. This means that you need to provide a name (identifier) for the method and a way that the method can tell you the result. You also need to provide a list of instructions for the method to use when it's asked to run. Figure 10-5 shows how this might work. You've given the method the name `getPercentage`, and Mr. `getPercentage` now has a chair and a telephone in the `Game1` office.



Game1 office

FIGURE 10-5 A new member of the *Game1* class

When the `getPercentage` telephone rings, Mr. `getPercentage` jumps up and answers it. He is told the number and the percentage required. He then needs to work out the answer, write it down on a piece of paper, and have the value sent back to the caller. The details of what information is passed into the method (the telephone call) and the result it delivers (what's written on the piece of paper) are written in C# as the method *header*. The details of what the method does is called the method *body*. Figure 10-6 shows how this would apply to a method called `getPercentage`.

This is not a very good `getPercentage` method in that it doesn't work out the result, but it does show how a C# method is made up of a header and a body.

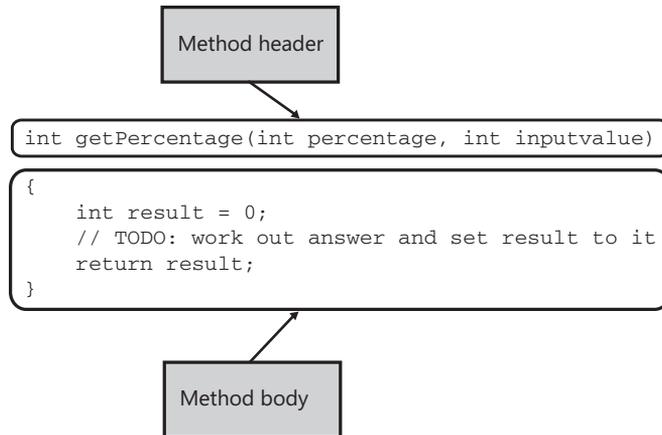


FIGURE 10-6 A `getPercentage` method header and body

The *method header* gives the identifier for the method, what type of result it returns, and the number and type of any parameters. A *parameter* is used to feed information into a method. It's how you told the Clear method the color to use when the screen was cleared way back in Chapter 1, "Computers, C#, XNA, and You." Once the compiler has the header of a method, it knows what the method "looks like" in that it can create the code to use the method. This description of a method is often called the *signature* of the method. The `getPercentage` method accepts two integer parameters and returns an integer result. When you create a method, you decide the type and number of the parameters that the method needs to do its job. Some methods have many parameters; others have none. The `Initialize` method does not accept any parameters; it's simply called to initialize the game program and does not need to be told anything.

The method header is followed by the method body, a block of statements that perform the task for which the method was created. The body can be a very large number of statements or only one or two. If the method delivers a result (which your `getPercentage` method needs to do), then the body must contain a statement that returns a value of the type specified in the method header. Once the compiler has the body of the method, it knows what statements need to be performed when the method is called. I've put a `TODO` in the place where the calculation needs to go. You haven't seen the `return` statement before, but it's the key word `return`, followed by the value the method is to send back to the caller.

Calling a Method

You've called methods many times in your programs. You use the `getPercentage` method as you would any other, but you need to make sure that you supply the right kinds of parameters, as follows:

```
height = height - getPercentage(1, height);
```

This line of code would use `getPercentage` to reduce the value of the variable called `height` by 1 percent. When a method call is made, the program does a number of things in sequence:

1. It makes a note of where it is in the program so that it can come back to the right place when the method finishes.
2. It gets the values of any parameters and sets them up for the method to use.
3. It jumps into the method body and performs the statements in the method body.
4. At the end of the method body, or when it reaches a `return` statement, it goes back and delivers whatever value was expected.
5. Then the program continues running at the statement following the method call.



Note You need to make sure that you call the method correctly. If you don't give the expected number of parameters, or one of them is not the correct type of data, the C# compiler shows you the errors and refuses to make a program that you can run.

Returning Nothing Using *void*

The `getPercentage` method must return a value, but sometimes a method need only perform a task. The `Draw` and `Update` methods are like this. Although they're given parameters to work on, they don't return an answer for the caller to use. Methods that don't return a result are given the return type `void`. This tells the compiler that the method does not deliver any information to the caller:

```
protected override void Draw(GameTime gameTime)
{
    graphics.GraphicsDevice.Clear(Color.CornflowerBlue);

    // game draw behavior here
    base.Draw(gameTime);
}
```

Methods that don't return anything don't have to contain a `return` key word to deliver a result. Instead, they return when the program reaches the end of the statements in the method body. Don't worry about the meaning of the `protected` and `override` key words. If you want a method to return before the end of the method block, you can use the `return` key word to cause a return at that point. If the method returns a value, the `return` key word must be followed by an expression that delivers a value of the required type.

It's up to you whether a method you create returns a value. Most of the methods that I write do return something, usually whether or not the method has worked correctly.

Creating a *getPercentage* Method

At this point, you know how to create methods. Now you need to make one that works for you. You started with an “empty” *getPercentage* method:

```
int getPercentage(int percentage, int inputValue)
{
    int result = 0;
    // TODO: work out answer and set result to it
    return result;
}
```

This code shows how the method works, and this compiles and runs. However, because it always returns 0, it won't do what you want. You need to add statements to the method body to get it to behave as you want.

Testing a Method

At this point, you've created a version of *getPercentage* that doesn't work properly, and this seems a bit silly. The Great Programmer tells you that it's quite sensible to create “broken” methods like this; you can use them to decide what the method looks like and then go back and fill in the statements later. You can also use them to write tests, as follows:

```
protected override void Draw(GameTime gameTime)
{
    if ( getPercentage(10, 800) == 80 )
    {
        graphics.GraphicsDevice.Clear(Color.Green);
    }
    else
    {
        graphics.GraphicsDevice.Clear(Color.Red);
    }
    base.Draw(gameTime);
}
```

This code is a test of the *getPercentage* method that turns the screen green if a call of the method works and red if it doesn't. Programmers usually use better ways to perform these tests, but it demonstrates the principle. This is a version of a professional development technique called *test-driven development*.

The Great Programmer Speaks: Test-Driven Development Is the Best Way to Write Programs

The Great Programmer likes test-driven development even more than she likes shoe sales, which is to say, a lot. She says that creating tests and then writing program statements that pass the tests is a very good way to develop software. But she warns that you should design your tests carefully.

Designing Tests for *getPercentage*

You could easily write a version of *getPercentage* that would pass the previously mentioned single test:

```
int getPercentage(int percentage, int inputValue)
{
    return 80;
}
```

This method would pass the one test that you've created but would not be a very good way to work out percentages. It does highlight a very important point, though: A test can prove only that a particular fault is not present. It can't prove that there are no faults in the code at all. The test that you wrote checks that your method could work out that 10 percent of 800 is 80. Even the original method that always returned 0 would work whenever you tried to work out 0 percent of something or any percentage of 0. If programmers claim that their code is "fully tested," usually what they really mean is that they can't think of a reason it shouldn't work, and this is not quite the same thing.

Testing computer programs is really difficult. If you want to test a design for a bridge over a river, you simply make a test bridge and put increasingly heavy things on it until it breaks. Then you know the heaviest thing that can go across that kind of bridge. Where computers are concerned, it doesn't work like this. A computer program might work with one value and then fail with another, slightly different one.

The good news (for most of you at least) is that your programs won't ever do anything that could be called "mission critical." However, if you end up writing programs for a living, you should take testing very seriously. It's what separates the Great Programmers from the merely good programmers.

I've come up with some C# code that gives your method a reasonable workout. It is not a particularly comprehensive test, but it will do for now:

```
protected override void Draw(GameTime gameTime)
{
    if ( (getPercentage(0, 0) == 0) && // 0 percent of 0
        (getPercentage(0, 100) == 0) && // 0 percent of 100
        (getPercentage(50, 100) == 50) && // 50 percent of 100
        (getPercentage(100, 50) == 50) && // 100 percent of 50
        (getPercentage(10, 100) == 10) ) // 10 percent of 100
    {
        graphics.GraphicsDevice.Clear(Color.Green);
    }
    else
    {
        graphics.GraphicsDevice.Clear(Color.Red);
    }
    base.Draw(gameTime);
}
```

Note that I'm using the `&&` (*AND*) operator to combine a bunch of conditions. You've seen the `//` (*OR*) condition before. I used to test if one thing *or* another was true. The `&&` condition lets me test if one thing *and* another is true. I want all the calls of `getPercentage` to work before I show the green screen. If any one of them fails, the `&&` condition returns `false`, and you'll get a red screen. This is not a very sensible way to manage large numbers of tests because if you get a red screen in this scenario, you have difficulty working out which test has failed. However, the principle is an important one. The objective now is to create a version of `getPercentage` that passes all the previously mentioned tests.

Creating the `getPercentage` Method Body

You now have a design for the method header and a set of tests for the method, so now you must create the method body. You could make it work like this:

1. Calculate the fraction of the amount that you want (this is the percentage divided by 100; in other words, 50 percent would give you 50/100, which is a half).
2. Multiply the incoming amount by this fraction to create the result.

The `getPercentage` method that uses this technique looks like the code shown here:

```
int getPercentage(int percentage, int inputValue)
{
    int fraction = percentage / 100;

    int result = fraction * inputValue;

    return result;
}
```

First, you work out the fraction; then you do the multiplication. The `/` operator can be applied between two *operands* (things that operators work on) and performs a division. The `*` operator is applied in the same way but performs multiplication.

Remember that when the method runs, the parameters `percentage` and `inputValue` are set to the values that they have in the call of the method:

```
int test;
test = getPercentage (10, 800);
```

The previous call would be performed with `percentage` set to 10 and `inputValue` set to 800:

```
int fraction = 10 / 100;
int result = fraction * 800;
```

If you plug the figures in and do the sums by hand, the result comes out fine. When you use this version of the method, though, you get a red screen, which is not good. Something is broken, and you need to fix it.

Sample Code: Percentage Test The sample project in the 03 Percentage Test directory in the resources for this chapter implements the `Update` method presented in this section. You won't ever use this project as the basis of a game, but you do use it to investigate the problems that you're having with the `getPercentage` method.

Debugging C# Programs

By now, you've probably started to wonder if zooming is worth all this effort. You've done lots of work and found out about methods, parameters, tests, and other stuff, but you have a red screen for your trouble. The good news is that the techniques you're learning are how all programs are written. The process of failing to get a picture of Jake to zoom properly is teaching you a lot about how programs are constructed. But now you need to learn some more things about how C# programs work and how to debug them.

Debugging with Breakpoints

You know that your program isn't working because the screen goes red when it runs. That means that at least one of the tests is failing. However, at the moment, you don't know which of the conditions is wrong. It would be really nice if you could stop the program and take a look at the values to see what's going on at that point. Fortunately, using the magic of XNA Game Studio you can do this by setting a breakpoint.

A *breakpoint* is a way of marking a particular statement in your program and saying to XNA Game Studio "When the program reaches this statement, pause it and let me take a look at stuff." This makes your game stop, so you use breakpoints not when you're playing the game, but only for debugging. Breakpoints are easy to set; you simply open the C# file in XNA Game Studio and click on the left margin in the position shown in Figure 10-7. XNA Game Studio highlights the line in brown, and a brown dot appears against the line. You want to stop the program when it has calculated a percentage, so the return statement is a good one to put the breakpoint on.

You can set lots of breakpoints in a program. The program stops at each one when it gets to that statement. Real programmers call this "hitting a breakpoint," so I suppose we should, too.

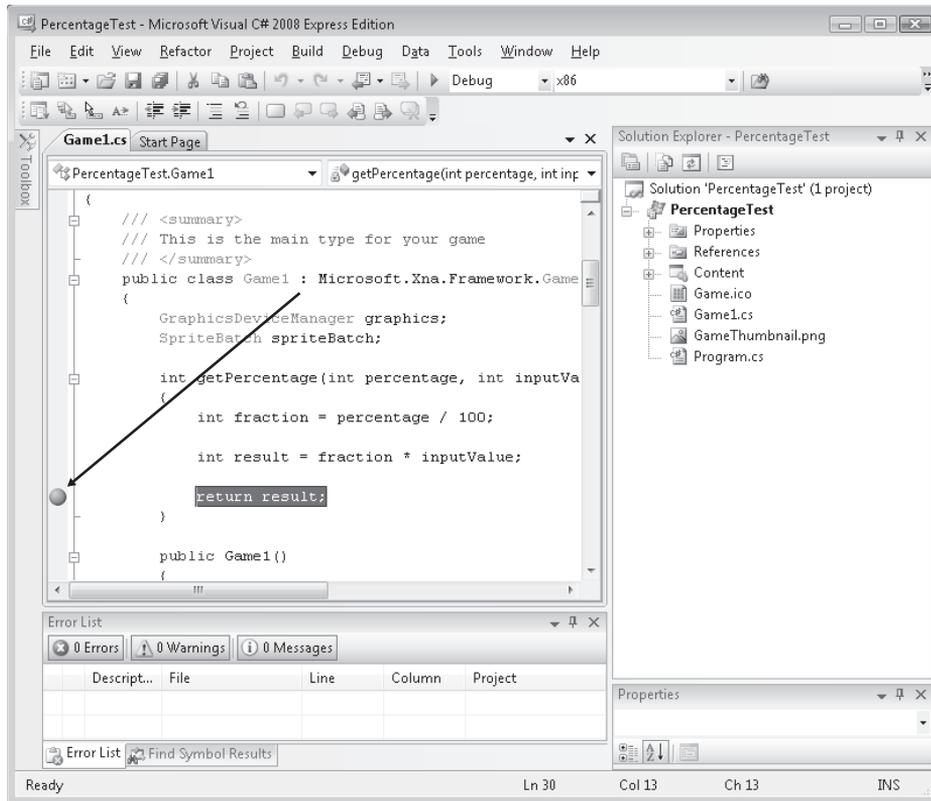


FIGURE 10-7 Setting a breakpoint in XNA Game Studio

Hitting a Breakpoint

If you now run the program, you see that when it gets to the line that you've marked as a breakpoint, it stops. This works whether you're using a PC, an Xbox, or a Zune for the development. This is impressive as a technical feat in that when you're using the Xbox or Zune, you're controlling the program remotely from XNA Game Studio but I guess that today it's okay to take these things for granted. When your program hits the breakpoint, it stops and gives you the display shown in Figure 10-8.

Viewing Variables

Now that the program has stopped, you can look at the values of the variables and see what's gone wrong. This is very easy to do; you simply rest the mouse pointer over the identifier of the variable in the code that you're interested in. A box pops up and tells you the value in that variable, as shown in Figure 10-9, where I placed the cursor over the `fraction` variable.

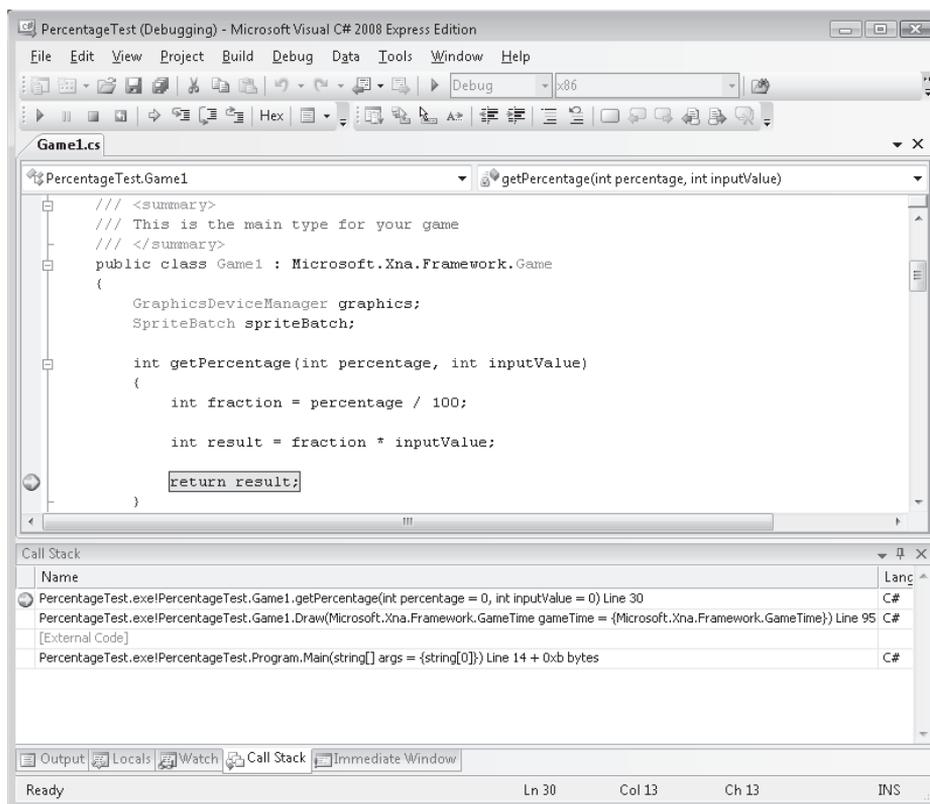


FIGURE 10-8 Hitting a breakpoint in XNA Game Studio

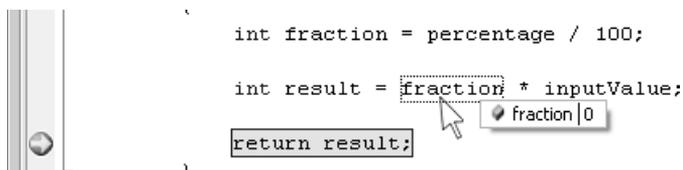


FIGURE 10-9 Viewing a variable value in XNA Game Studio

You can rest the cursor over any variable in the method to find out what it holds. If you do this the first time that the breakpoint is hit, all the values for `fraction`, `inputValue`, and `percentage` are 0. This is exactly what you'd expect. The very first call of `getPercentage` is as follows:

```
if ( (getPercentage(0, 0) == 0) & // 0 percent of 0
```

For these input values, the method is working correctly in that 0 percent of 0 is 0. It must be one of the later calls of `getPercentage` that's failing. This means that you need to run the program a bit further to find the problem. You can do this by pressing the green arrow in the program controls in the top left corner, as shown in Figure 10-10.

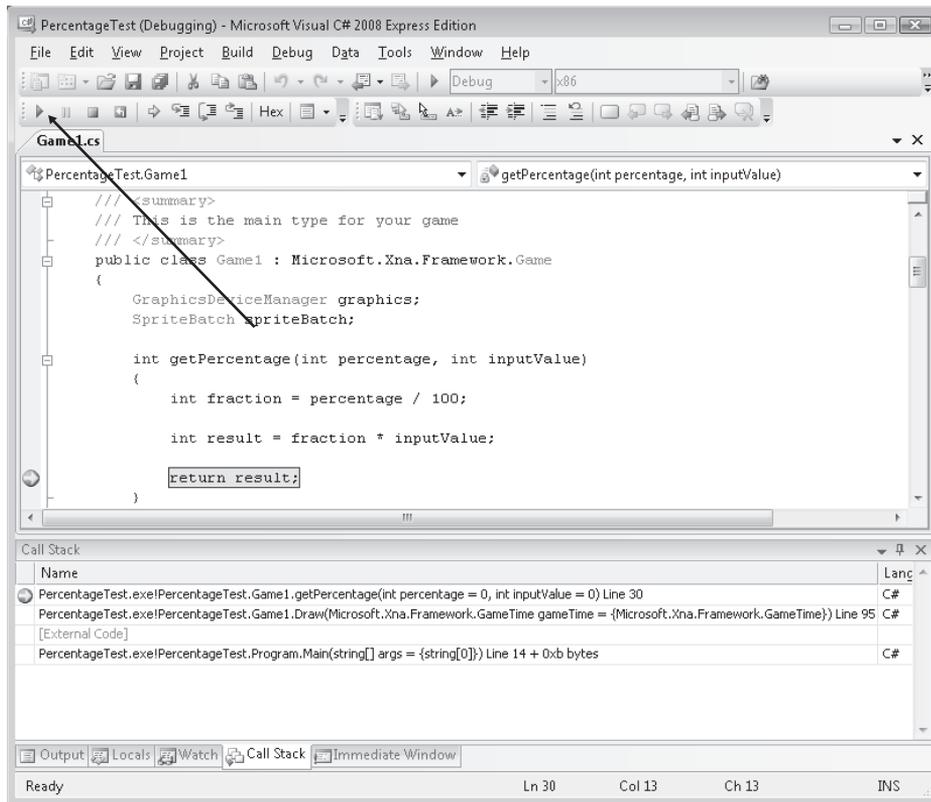


FIGURE 10-10 The continue button in the program controls

The program runs and hits the breakpoint again. This is the second call of `getPercentage`, which has been asked to work out 0 percent of 100. You can use the debugger to view the result value again, and you find that it is 0, which is correct. So you need to continue the program again. This time, you stop the third call of `getPercentage`, where you're trying to work out 50 percent of 100. This should work out to be half of 100, or 50. But when you use the debugger, you find that the result that's being calculated has the value of 0, which is wrong. If you dig a little further, you find that the value of `fraction` is also 0. This looks like the problem. If `fraction` is 0, when you work out the calculation `fraction * inputValue`, you get 0 because anything multiplied by 0 is 0. So you need to take a close look at how you calculate the value of `fraction`:

```
int fraction = percentage / 100;
```

The problem has to do with the `int` type, which is used to hold integer values. An integer does not have any fractional part. When you try to work out $50 / 100$, which should work out to 0.5 or a half, there's no place in the variable `fraction` to put this. Integers are used to store values that do not have any fractional part. It's reasonable to use them to count pixels because there's no such thing as half a pixel as far as the display is concerned. C# is quite happy to divide an integer by an integer, but it always produces an integer result when it does this, throwing away the fractional part.

However, for your program, you need to manipulate numbers that have that fractional bit; otherwise, the program won't work. Such numbers are called *real* or *floating-point* numbers. Therefore, you need a new type of data storage that can hold this type of number.

Using Floating-Point Numbers in C#

C# provides a variety of number storage options. For this task, you need to use the `float` type, which can hold floating-point numbers. These are so called because they have a decimal point that can "float" up and down the number, depending on the value being held.

A floating-point number is capable of holding the 0.5 value that you need to store. So you change the type of the fraction variable to `float` in your method:

```
int getPercentage(int percentage, int inputValue)
{
    float fraction = percentage / 100;

    int result = fraction * inputValue;

    return result;
}
```

However, when you try to build this method, things go horribly wrong. You now get an error message, as shown in Figure 10-11, because your program no longer compiles. The compiler has found something wrong with the code that you've written, and it can't produce an output program that runs.

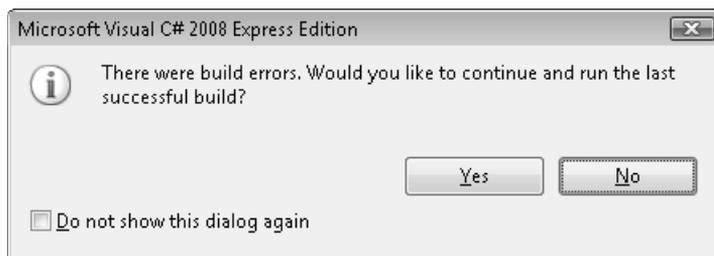


FIGURE 10-11 Build error message dialog box

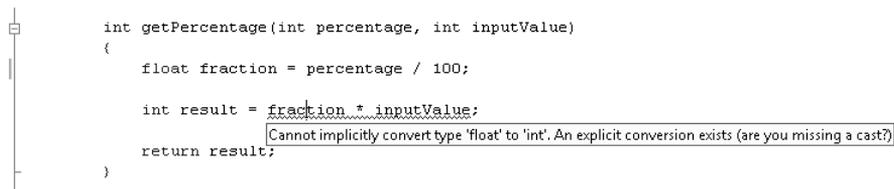
This is quite often how programming is. You think you've found the answer to the problem, you put in the fix, and the problem promptly gets worse. The Great Programmer can tell many tales of bugs that she's found and fixed, and she has lots of experience with this kind of thing. She also has some good advice at this point.

The Great Programmer Speaks: Don't Let It Get to You When you get to a snag like this, don't panic. It's probably a good time to go off and get a cup of coffee, walk the dog, do 20 pushups, or do whatever else to relax. The important point to remember is that you will find an answer to the problem, you will make it work, and you will understand what's going on.

People tell me things like “I spent five hours last night trying to fix a bug in a program,” as if that is supposed to impress me. Not so. If you can’t fix it after an hour or so, you should go and do something else. It doesn’t matter what that thing is; just don’t think too hard about the problem while you do it. When you come back to the code, it’s amazing how many times you can then fix the bug in an instant, as if the back of your brain has been working away on the problem, and suddenly up pops the answer for you.

The Compiler and C# Types

In this case, you’re having problems because you don’t know all about how C# works and what the compiler is having trouble with. If you go back and look at your method now that you have the error, you see that XNA Game Studio is trying to tell you something about the program. Some parts of the code are underlined in wavy blue lines. This indicates that the compiler is flagging some aspect of these statements for your attention. If you rest the cursor over the offending text, a message pops up that describes what the compiler has determined is wrong. Figure 10-12 shows what happens if you do this on your broken version of `getPercentage`.

A screenshot of a code editor showing a C# method named `getPercentage`. The code is as follows:

```
int getPercentage(int percentage, int inputValue)
{
    float fraction = percentage / 100;

    int result = fraction * inputValue;
    return result;
}
```

The line `int result = fraction * inputValue;` is underlined with a wavy blue line. A tooltip is displayed over this line with the text: "Cannot implicitly convert type 'float' to 'int'. An explicit conversion exists (are you missing a cast?)".

FIGURE 10-12 Compilation errors in `getPercentage`

The compiler is saying “Cannot implicitly convert type 'float' to 'int'. An explicit conversion exists (are you missing a cast?).” This is a technically correct description of the problem, but the compiler might as well be saying “Cannot put pizza in briefcase, but I can chop off a slice so it fits if you like” for all that this means at the moment. To understand what’s going on, you need to get into the compiler and work out what the problem in the code really is.

The compiler has the job of converting the C# that you’ve written into instructions that the computer can perform. Consider a C# statement that performs an addition:

```
greenIntensity++;
```

This statement increases by one the value of the variable `greenIntensity`. The compiler might produce a sequence of machine code statements a bit like this:

1. Fetch the value of `greenIntensity` from memory.
2. Add 1 to this value.
3. Store the result in the `greenIntensity` memory location.

So you can think of a compiler as somewhat of a translator, only rather than converting from English to French, it's converting from C# into machine instructions. At the same time, the compiler tries very hard to stop a programmer from doing stupid things. In this case, it's telling you that your program might lose data as it is. If you try to put a floating-point value (with a fractional part, say, the value 2.9) into a variable of type `int` (which doesn't have support for the floating bit), you are in danger of losing information. The line of code that you're looking at does just that:

```
int result = fraction * inputValue;
```

From your knowledge of math, you know that that if you multiply an integer value (`inputValue`) by a floating-point value (`fraction`), the result is a floating-point value. When you move that into the `result`, you're moving a floating-point value into an integer, which results in data loss. In programming terms, this is called *narrowing*. You're moving values from a data type with a wide range of values (floating point) into a type with a narrower range of values (integer). This is rather like trying to sail a high-masted sailboat under a low bridge. There's a danger that something might get chopped off in the process. You'd be heading for exactly the same trouble if you tried to put the value of an integer variable into a byte. The C# compiler has been designed to look for situations like this, where data might be lost by mistake, and to refuse to perform the conversion automatically.

Compilers and Casting

When the compiler sees a statement that narrows a value, it produces the error message, "Cannot implicitly convert type 'float' to 'int'." What it's saying is that the compiler won't produce output steps that perform the conversion unless you explicitly ask it to. This is because it thinks you might have made a mistake when you combined these two types.

The next part of the message gives you some more help. "An explicit conversion exists (are you missing a cast?)." This means that the compiler can perform such a conversion, but you need to use a cast to request that the action be performed. A *cast* is where you ask the compiler to produce code that converts a value from one type to another. You're saying, "We know what we're doing, so trust us on this and let the conversion take place." The cast you want looks like this:

```
int result = (int)(fraction * inputValue);
```

A cast is the name of the type you want (in parentheses). It precedes the value to be cast, which in this situation is the entire sum, which I've also put in parentheses. Now the compiler is quite happy to perform the narrowing since you've said that it's okay to do so.

Note that not all casts work. You can't convert from a `Color` to an `int` by using a cast because the compiler hasn't been told how to generate code to do this. For casting from

floating point to integer, though, the compiler knows just what to do. It generates code to throw away the fraction and put the integer part into the destination. This means that if what you are casting were 0.999999, the destination would be set to 0, something you might need to watch out for later. So, after all that, you now have a new, improved version of the method:

```
int getPercentage(int percentage, int inputValue)
{
    float fraction = percentage / 100;

    int result = (int)(fraction * inputValue);

    return result;
}
```

This version of the method compiles, so you can now run the program with your bug fix. And you get your red screen again—which seems very unfair.

Expression Types

At this point, you might be thinking that programming is not for you. Nothing seems to work. You started off trying to draw a picture on the screen. You got that working and decided to do some zooming, only to find that you need to do some serious messing about to make the picture stay the same shape. And it still doesn't work. If you put in some breakpoints and do some more digging, you'll find that the problem occurs when you work out the fraction:

```
float fraction = percentage / 100;
```

Even though you're storing the result of the division in a floating-point variable, for some reason the calculation is generating a result of 0 when you divide 50 by 100. You can blame the compiler again for this one. The compiler has the job of converting operators like / (divide) into the instructions that perform the division. There are two kinds of division: those that produce an integer result and those that produce a floating-point result. If the compiler sees an expression that divides an integer by another integer, it performs the integer division even if the result is being put into a floating-point variable.

There is actually method in this madness. You want your programs to run as fast as possible, and calculating the fractional portion of the result takes extra time, so it makes sense not to do the full division if you don't need to. However, you need to force the compiler to perform floating-point division, and the way you do that is to turn one of the things in the calculation into a floating-point value. You can do this by casting again:

```
float fraction = (float) percentage / 100;
```

This forces the compiler to regard the percentage variable as floating point so that it uses a floating-point division to get the correct result. This means that your `getPercentage` method now looks like this:

```
int getPercentage(int percentage, int inputValue)
{
    float fraction = (float) percentage / 100;

    int result = (int)(fraction * inputValue);

    return result;
}
```

If you put this into your program and run it, you find that you have a green screen. This means that this version of the method seems to work with the tests that you've created. So at this point, you can feel very pleased with yourself. You show your code to the Great Programmer. She wrinkles her nose, sits down at the keyboard, and types this:

```
int getPercentage(int percentage, int inputValue)
{
    return (inputValue * percentage) / 100;
}
```

This works fine as well and is much simpler than your version, which is annoying. However, both methods work okay, and unless you're performing many thousands of calls to your method, the user won't notice the difference between yours and the Great Programmer's. And anyway, you learned a lot writing your method, so there. The Great Programmer even has a point about this.

The Great Programmer Speaks: Don't Get Upset with Other Programmers If you end up writing programs for a living, you'll come up against programmers who are better than you (who you copy) and worse than you (who you help). It's important not to get upset when another programmer suggests a better way of doing something, finds something wrong with your code, or says something stupid. My experience has been that I am wrong as often as I am right, and the nicer I am about these situations, the more people want to work with me. Try to work in an "egoless" way if you can; it makes everyone happier in the long run. That's not to say that you shouldn't argue your corner when you think your ideas or opinions are the best way forward, but if the argument goes against you, accept this in good grace. In any project, what you're really working toward is a "happy ending." There are many ways you can get to the ending—just make sure that you get there happy.

Sample Code: Working Jake Zoom Program The sample project in the 04 Working Jake Zoom directory in the resources for this chapter uses the `GetPercentage` method that the Great Programmer wrote for us. It steadily zooms out of a picture of Jake. It is by no means a perfect program, though, because the picture gets smaller than the screen size and eventually stops zooming.

Stopping the Zoom

You need to find a way to stop the zoom when the image is the same size as the screen. It turns out that this is quite easy. You need only change the size of the sprite rectangle while it's wider than the screen. You've already seen that you can use the `Width` property of the device viewport to determine this value, so you simply need to add a condition as follows:

```
if (jakeRect.Width > graphics.GraphicsDevice.Viewport.Width)
{
    jakeRect.Width =
        jakeRect.Width - getPercentage(1, jakeRect.Width);
    jakeRect.Height =
        jakeRect.Height - getPercentage(1, jakeRect.Height);
}
```

The program now stops zooming, reducing the height and width of the drawing rectangle at the appropriate time.

Zooming from the Center

The zoom that you have at the moment starts off as zoomed in on the top left corner of the image. This is because when you create `jakeRect`, you set its position to `(0, 0)`, which is the top left corner of the screen. Figure 10-13 shows what's happening. The top left corner of the image is being displayed because the rectangle is positioned at the top left corner of the display area.



FIGURE 10-13 Zooming in on the top left corner of the image

If you want to zoom in on the center of the image, you need to move the top left corner of the draw rectangle upward and to the left, as shown in Figure 10-14, moving the display area into the middle of the image. Remember that XNA draws only the part of the rectangle starting at coordinate position (0, 0) and extending to the width and height of the screen's display area.

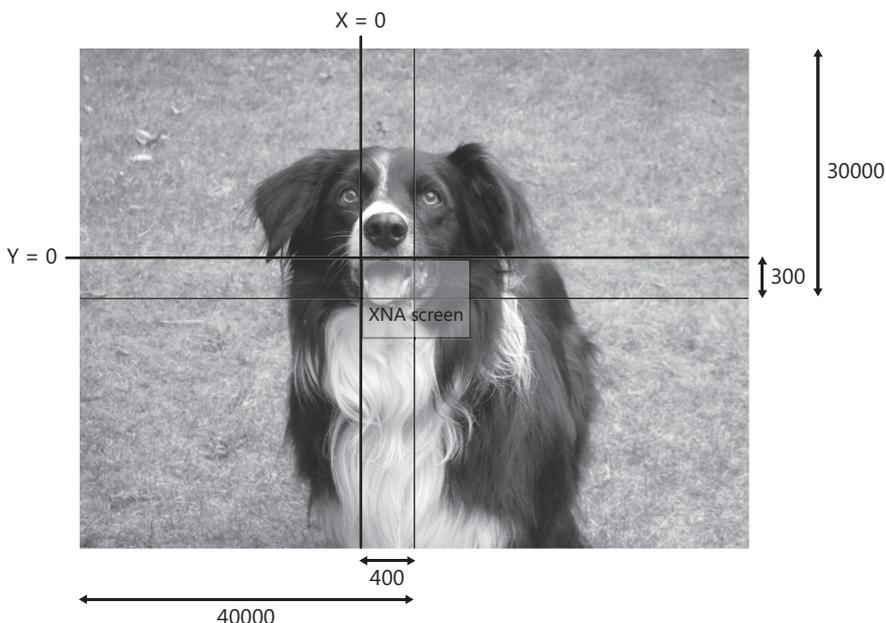


FIGURE 10-14 Zooming in on Jake's cheek

The thin lines on Figure 10-14 show both the center of the image of Jake and the center of the display area. To get the center of the image lined up exactly with the center of the display area, you must move the X (horizontal) position of the top left corner of the rectangle 40,000 (half the image width) to the left and then 400 (half the screen width) to the right. You then need to do the same thing with the Y (vertical) position. For the method to work properly, it has to know the width of the texture that is to be used, so all the work must be performed in the `LoadContent` method, as follows:

```
protected override void LoadContent()
{
    // Create a new SpriteBatch, which can be used to draw textures.
    spriteBatch = new SpriteBatch(GraphicsDevice);

    jakeTexture = this.Content.Load<Texture2D>("jake");

    int displayWidth = GraphicsDevice.Viewport.Width;
    int displayHeight = GraphicsDevice.Viewport.Height;

    int scaledWidth = jakeTexture.Width * 10;
    int scaledHeight = jakeTexture.Height * 10;
}
```

```

    jakeRect = new Rectangle(
        -(scaledWidth / 2) + (displayWidth / 2),
        -(scaledHeight / 2) + (displayHeight / 2),
        scaledWidth, scaledHeight);
}

```

To make this code clearer, I've created some extra variables that hold the width and height of the scaled image and the width and height of the display area. Note that you can make a number (or an expression) negative simply by putting a minus sign in front of it.

Now that you've put the viewing rectangle in the center of the screen, you need to move the draw position each time you scale the image. It turns out that if the width of the rectangle changes by X -amount, the position of the top left corner must move to the right by half of X to keep the rectangle centered with respect to the display area. The code to do this is as follows:

```

int widthChange = getPercentage(1, jakeRect.Width);
int heightChange = getPercentage(1, jakeRect.Height);
jakeRect.Width = jakeRect.Width - widthChange;
jakeRect.Height = jakeRect.Height - heightChange;
jakeRect.X = jakeRect.X + (widthChange / 2);
jakeRect.Y = jakeRect.Y + (heightChange / 2);

```

This code works out the change in width, updates the width and height of the rectangle, and then moves the X and Y positions of the rectangle to keep the drawing centered correctly. To get a good understanding of what's happening here, you can try some values and sketch some diagrams based on Figure 10-14. I often find it very useful to draw out what needs to happen on graph paper (that's how I worked out what the previous code must do).

Sample Code: Broken Jake Center Zoom Program The sample project in the 05 Broken Jake Center Zoom directory in the resources for this chapter uses the code given so far in this section to zoom out of the picture and keep it in the center. The name doesn't particularly inspire confidence, though, and when you run it, you find that it doesn't work properly.

The problem with this zoom program is that although it works fine, when the zoom finishes, the image is not lined up properly with the display. If you add some breakpoints and do some digging, you find that the X and Y draw positions, which should be 0 when you've fully zoomed out of the image, still hold negative values at the end of the zoom. The problem lies with the following two statements:

```

jakeRect.X = jakeRect.X + (widthChange / 2);
jakeRect.Y = jakeRect.Y + (heightChange / 2);

```

You know that you want to move these positions by half the change in the width and height. Unfortunately, you're dividing integers. This means that you can get only an integer result; in other words, if the width change were 101, the change to the value of X would be 50, not 50.5. This calculation is repeated many times, and eventually this lack of precision leads to an answer that's incorrect. The only way to solve this problem is to change the data type

you're using to hold all the values. Rather than using the integer values that are stored in the `jakeRect`, you need to create floating-point variables and use them instead. Floating-point values have a fractional part, meaning that they are better for representing a smooth transition from one coordinate to another. Here are the updated variable declarations:

```
float displayWidth;  
float displayHeight;  
float rectWidth;  
float rectHeight;  
float rectX;  
float rectY;
```

These variables are set up by the `LoadContent` method. The new variables are used in all the calculations and are transferred into the `jakeRect` to position the drawing as follows:

```
float widthChange = getPercentage(1, rectWidth);  
rectWidth = rectWidth - widthChange;  
rectX = rectX + (widthChange / 2);  
  
float heightChange = getPercentage(1, rectHeight);  
rectHeight = rectHeight - heightChange;  
rectY = rectY + (heightChange / 2);  
  
jakeRect.Width = (int)rectWidth;  
jakeRect.Height = (int)rectHeight;  
jakeRect.X = (int)rectX;  
jakeRect.Y = (int)rectY;
```

Sample Code: Float Jake Center Zoom Program The sample project in the 06 Float Jake Center Zoom directory in the resources for this chapter uses floating-point values to keep track of the size and position of the draw rectangle. Note that it also contains a floating-point version of `getPercentage`.

It's not uncommon for games—and indeed other programs—to have problems with the precision of numeric calculations. The `float` and `double` data types provided by C# can hold numbers to very high levels of precision, but you need to remember that updates to the variables in games may take place many millions of times a second. Errors in values that build up over time, sometimes called *cumulative errors*, are something that programmers often need to address.

Conclusion

This has been another very busy chapter. You began with a simple idea for a game and then got diverted into program design and structure. You made your first simple method, which worked on numbers that you gave it and returned a result. You also looked at the test-driven programming technique, which you can use to make sure the methods you create work correctly. Finally, you saw how to manage the draw position of an item on the screen and discovered why game programs need to use values stored to high levels of precision.

Chapter Review Questions

If chapter reviewing is what you want to do, you've come to the right place. See if you can outperform a penny with heads for true and tails for false.

1. You use an XNA Rectangle to draw a texture on the screen.
2. Only the creators of XNA are allowed to make methods.
3. Methods are created inside classes.
4. The body of a method is made up of C# statements.
5. Methods must return a result.
6. A method can contain only one return.
7. A method must have at least one parameter.
8. The C# compiler automatically fills in the value of any missing parameters when a method is called.
9. Test-driven development means that you do all the testing when the program is finished.
10. You can set breakpoints only when your program is not running.
11. The C# compiler automatically converts a float value into an int value.
12. The C# compiler lets you move an integer into a double precision variable.
13. A cast requests that data be converted from one type into another.
14. You can cast a string into an integer.

Chapter 11

A Game as a C# Program

In this chapter, you will

- Find out how Microsoft XNA games are actually C# programs.
- Start to create a game from the contents of a grocery bag.
- Make your game display fit correctly on the screen.
- Get the first components of a game running.

Introduction

At the moment, you know quite a lot about how XNA works and how to use C# language constructions to control the facilities that XNA gives you. You have created games by investigating what you need to do inside the game class to get the effects that you want on the screen. Now it's time to step back a little and consider how the XNA Framework and the C# language fit together and just what a C# program is. This helps you understand how to construct games of your own and also how you can make programs other than games. If you like, you can think of this as "lifting the hood" on the C# process and looking at how the engine and transmission work underneath. You consider what makes up a C# program and how it is started and given control.

To do this, you create a brand-new game from scratch, using the contents of a grocery bag. You start by creating some simple game behaviors and then combine them until you get something that might be fun to play.

Game Idea: Bread and Cheese

Game ideas are tricky things. The way I see it, there are two ways that you can make a great game:

You can wake up one morning with the idea perfectly formed in your head and then sit down and write the game program. Alternatively, you can start off playing with a few pieces of program code and then tinker with them until you get something interesting.

You take the second approach for your game, using as your inspiration the contents of a grocery bag. The Great Programmer has been out getting some food and has come back with some bread, some cheese, some tomatoes, and a green pepper. She wonders if you might like to use these things in your game. She suggests that you get the cheese bouncing around the screen, maybe add the bread as a bat to hit the cheese around, and see where this takes you. For now, you decide to call the game BreadAndCheese and to find a use for the tomatoes and peppers later.

Creating Game Graphics

In a large-scale game development, you have the graphics created for you by the art department, but for this one, we are going to do all the work ourselves. I created the graphics for the game by taking a well-lit picture of each item against a white background. I then cut the central image out of the picture and pasted it onto a transparent background (see Figure 11-1). To do this, I used a free graphics editing program called "Paint .NET," which can be downloaded from www.getpaint.net. I then ate the cheese on the bread, and it was delicious. If you want to do something similar to create your game objects, it's very easy. You could use model cars, candy, toy soldiers, or anything else that's easy to photograph. When you take the pictures, ensure that the objects are as evenly lit as possible; ideally, take the pictures outside on a cloudy day. If you have a friend who is good with a camera, you might like to ask them to give you a hand.

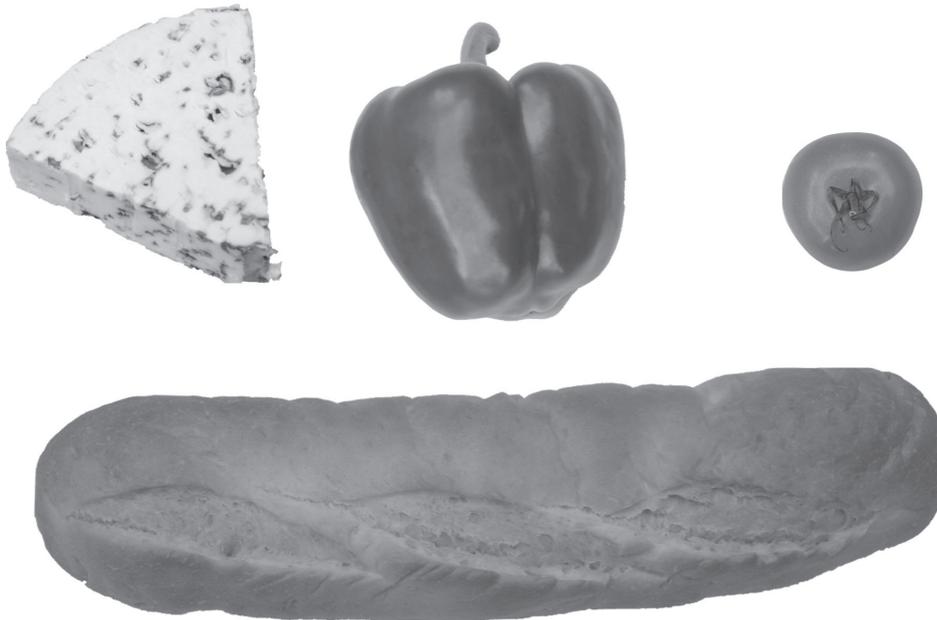


FIGURE 11-1 Your game objects

You add these images to the project in the same way that you added Jake to your first image-drawing program in Chapter 4, “Displaying Images.”

Projects, Resources, and Classes

You start by making a new game project using XNA Game Studio and call the project BreadAndCheese. Before you go any further, it’s worth spending some time discovering how an XNA program fits together and actually gets to run. You can use this knowledge to tidy up your solution and allow you to understand better how C# programs are structured.

XNA Game Studio Solutions and Projects

You know that when you make a new project, XNA Game Studio creates a solution, a project, and some C# class files. Figure 11-2 shows how these appear in Solution Explorer. Some programmers call a solution a *workspace*, but I am going to use the word *solution* throughout this book.

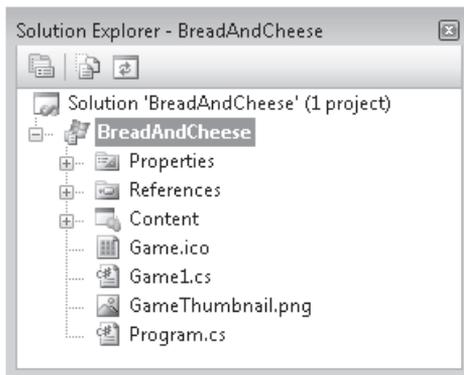


FIGURE 11-2 The BreadAndCheese solution and project

In Chapter 4, you saw that when you create a new project, you get a new solution as well. An XNA Game Studio solution can contain a number of projects. Each project brings together C# program source files and resources.

Projects and Folders

Whenever you write a program, you need to consider how things will be organized. At the moment, all the files related to a particular game program are stored in a single directory in the file store of the PC. You should be familiar with using directories, or *folders* as they are sometimes called. Microsoft Windows provides folders for your documents and pictures so that you can group documents and pictures together easily. When XNA Game Studio creates a new XNA project, it makes a new folder that holds all the information for a particular solution. This folder contains other folders, reflecting the way that XNA Game Studio organizes things.

Because you're about to add a whole bunch of image files to the BreadAndCheese project, it makes sense to put these all together in a particular place. You can get XNA Game Studio to create such a location. You create an images folder and put all the images into it. When you add sound to the game, you can then put all the sounds in a different place, thus keeping everything nice and tidy.

The Great Programmer Speaks: Tidy Is Good If you take a peek at the Great Programmer's desk, you might notice what a mess it is. There are bits and pieces everywhere, used concert tickets, old photos, and even the occasional stuffed toy. However, if you look inside the organization of her projects, you find everything perfectly tidy, with images in graphics folders, sounds in audio folders, and all items having a name that reflects exactly what it is used for. She reckons she does not have time to keep her desk tidy (and actually doesn't particularly want to), but she knows that keeping her project and resource files well organized pays huge dividends when she needs to find something important.

Figure 11-3 shows how you can use XNA Game Studio to create a new content folder. Start by right-clicking the Content item in the BreadAndCheese project in the Solution Explorer and find your way to the New Folder option as shown.

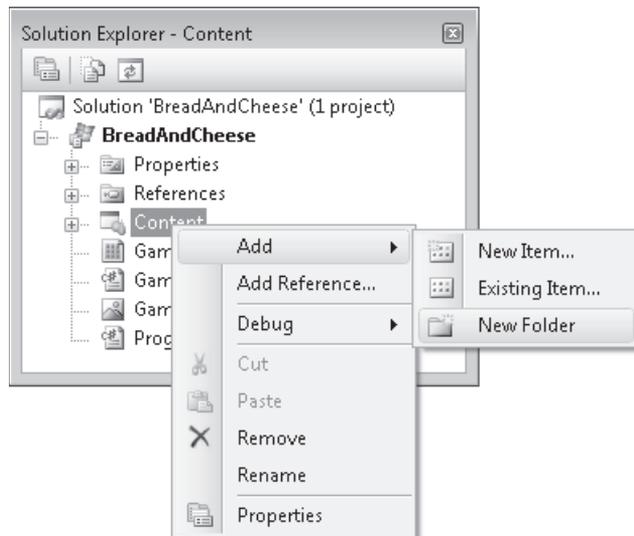


FIGURE 11-3 Creating a new content folder in XNA Game Studio

XNA Game Studio creates a new folder with the original name New Folder. You can overtype this with a more appropriate name; I'd suggest Images. Once you've created the new directory, it takes its place in Solution Explorer for the project, as shown in Figure 11-4.

This has created a new directory, and the next step is to get your image files and put them into that directory. You can do this in exactly the same way as you added the picture of Jake

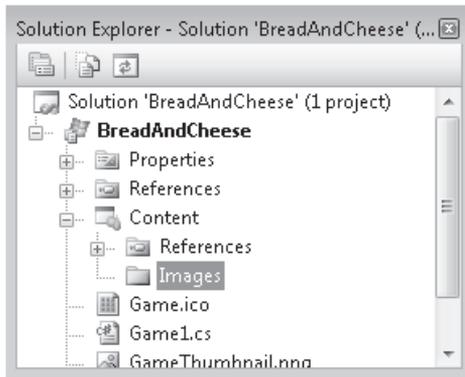


FIGURE 11-4 The new Images folder in Solution Explorer

in Chapter 4, only rather than adding them to the Content directory, you can add them to the Images directory instead. Figure 11-5 shows how this should appear once two image files have been added.

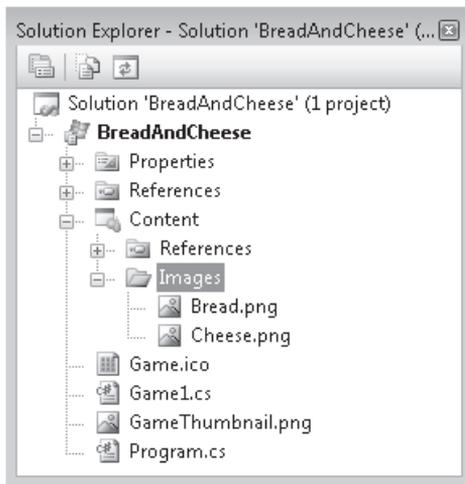


FIGURE 11-5 An Images folder with Bread and Cheese images in it

The Content Manager needs to be told to look in the folder for the resource when it tries to load it. This means that the name of the folder holding the resource must be used when it is loaded, as shown in the LoadContent method here:

```
protected override void LoadContent()
{
    // Create a new SpriteBatch, which can be used to draw textures.
    spriteBatch = new SpriteBatch(GraphicsDevice);

    breadTexture = Content.Load<Texture2D>("Images/Bread");
    cheeseTexture = Content.Load<Texture2D>("Images/Cheese");
}
```

The name of the folder is given, separated from the asset name by the forward slash / character. It is perfectly possible to create folders inside folders, so that you could have a folder inside Images that contained backgrounds, another that contained enemy sprites, and so on. The Great Programmer thinks this kind of organization is a really good idea. It is particularly useful if you have different teams working on the same game project and you don't want to have problems with name clashes.

The Game Program Files

Now that you know how best to organize the assets in a game, it is time to take a look at the program files that XNA Game Studio has created for you.

You're already familiar with the Game1.cs file, which contains the program that provides all the game behaviors, including the Update and Draw methods. However, this is not where your program starts running. To discover how this happens, you need to look in the Program.cs source file.

The Program.cs File

The Program.cs file is created automatically by XNA Game Studio when you make a new game project. You don't have to change this file, but the Great Programmer (who is at the moment rather cross because I seem to have eaten all the cheese that she bought) reckons that you really should know how programs work if you're going to call yourself a programmer. If you take a look at the Program.cs file in XNA Game Studio, you find that it's quite small:

```
using System;

namespace BreadAndCheese
{
    static class Program
    {
        /// <summary>
        /// The main entry point for the application.
        /// </summary>
        static void Main(string[] args)
        {
            using (Game1 game = new Game1())
            {
                game.Run();
            }
        }
    }
}
```

The job of the C# code in this file is to create an instance of the game class and then start the game running. A C# program is started by the call to the program's Main method. You can see the Main method in the Program class shown previously, but there are also some words that you have not seen before, and now you must consider what they mean.

Namespaces and Programs

At the top of the Program.cs file, there's the statement that tells the compiler to use the System namespace:

```
using System;
```

The word `using` has two meanings in C#. In this statement, it's used as a *compiler directive*. In other words, it's a message to the compiler and doesn't directly generate machine language instructions for the program the compiler is creating. You use directives to tell the compiler what to do. In this case, you want to tell the compiler to use the System namespace.

A *namespace* is a space where names have meaning. You can think of it as a directory of services. The System namespace contains descriptions of lots of classes provided by .NET that you might want to use in your program. You've already used one class from the System namespace; the DateTime class is described there. You used this to obtain the current time for the clock, as described in the section entitled "Getting the Date and Time," in Chapter 5, "Writing Text."

Whenever you use a name that the compiler hasn't seen before, it looks in all the namespaces that it has been told about to see if it can find a resource that matches that name. If the name is found, the compiler generates code that uses that resource. If the name is not found, the compiler states that it doesn't know about the item. As an example, consider what would happen if your program contained the following statement:

```
dateTime d;
```

The statement is intended to create a DateTime variable, but the name has not been typed correctly. When the program is compiled, this statement produces the following compilation error:

```
Error 1 The type or namespace name 'dateTime' could not be found (are you missing a using directive or an assembly reference?)
```

The compiler is saying that it can't find anything called `dateTime`. It even suggests that you might need to add a `using` directive to identify the namespace that holds this item. (Of course, in this case it is wrong, in that you have misspelled something, rather than forgotten to tell the compiler where to look for it—but at least the compiler is trying to help).

As far as programmers are concerned, a namespace is a way they can make sure that when they invent an identifier for an object, it's unique in their namespace and won't be confused with an identically named resource in any other namespace. In fact, the next line of Program.cs sets up a namespace for your solution:

```
namespace BreadAndCheese
{
    // Program class in here
}
```

XNA Game Studio automatically creates a namespace to hold all your classes. The namespace is given the same name as the solution. If other C# programmers want to refer to the `Game1` class that is in your namespace, they could insert `using BreadAndCheese` at the top of their program source files. If you use two namespaces that contain a class with identical names, the compiler asks you to use the fully qualified form of the name, as in this example:

```
BreadAndCheese.Game1 myGame = new BreadAndCheese.Game1();
```

A *fully qualified* name includes the namespace in which the object is declared, followed by the name of the class required.

A namespace can contain other namespaces, so programmers can build a tree of namespaces that can be used to hold different categories of resources. The designers of XNA have created several namespaces that describe resources you've used in your programs. The `using` directives at the top of `Game1.cs` include the following:

```
using System;
using System.Collections.Generic;
using System.Linq;
using Microsoft.Xna.Framework;
using Microsoft.Xna.Framework.Audio;
using Microsoft.Xna.Framework.Content;
using Microsoft.Xna.Framework.GamerServices;
using Microsoft.Xna.Framework.Graphics;
using Microsoft.Xna.Framework.Input;
using Microsoft.Xna.Framework.Media;
using Microsoft.Xna.Framework.Net;
using Microsoft.Xna.Framework.Storage;
```

The features of XNA that you've used are described in appropriate namespaces; for example, the `Texture2D` class is described in the `Microsoft.XNA.Graphics` namespace.



Note It's important to remember that the namespace information is used by the compiler to identify the resources that are to be used. The resources themselves are loaded and used when the program runs and your solution must have a reference to them. A solution contains a list of references that it is using; you can see the `References` folder in Figure 11-2, just above the `Content` folder.

You'd create namespaces of your own if you wanted to use some classes in more than one solution. For example, you might create some classes that deal with high scores in a game. For this, you might create a `HighScores` namespace that stores and displays a high-score table.

Static Classes and Methods

The next line in `Program.cs` describes a class called `Program`:

```
static class Program
{
    // content of the class goes here
}
```

The class has been made `static`. You haven't seen the word `static` before, but it means "always there." In the programs you've written up until now, you've had to create instances of classes using `new`. When a class is made `static`, it means that there's always one and only one instance of that class present when the program is running. When a C# program starts up, before the code that you've written is given control, any `static` classes are created automatically. This means that there's no need to ever create an instance of the `Program` class by using `new` because it's always there when your program starts.

The next line of the program declares a method called `Main` in the `Program` class:

```
static void Main(string[] args)
{
    // content of the Main method goes here
}
```

The `Main` method has also been made `static`. This is because it must exist before your program begins to run. When you run a C# program, the operating system loads the program file into memory, creates all the `static` classes, and then finds and calls the `Main` method. One and only one of the classes in a program must contain a `Main` method so that the operating system knows where to start. Imagine you misspell the name of the method, for example you write the following:

```
static void main(string[] args)
{
    // content of the Main method goes here
}
```

The compiler produces an error message saying that the program cannot be started, as follows:

```
Program 'BreadAndCheese.exe' does not contain a static 'Main' method suitable for an
entry point
```

The compiler is trying to make an executable output (one that can be run as a program), and if the `Main` method isn't present, it literally doesn't know where to start the program.

Making Methods Static

Methods are made `static` so that they can be used without needing to have an instance of the class present. Static methods can be ones that are used to perform a particular task and are not part of a class instance. The `getPercentage` method that you created in Chapter 10, "Using C# Methods to Solve Problems," could be made `static` because it simply works out a calculation and returns the result.

Main Method Parameters

When the `Main` method is called to start the program, it's provided with a parameter called `args`, which is an array of strings. This parameter gives the `Main` method any arguments that have been supplied to the program when it starts. An argument is a way of giving a program

instructions when it runs. If a program is run from the command prompt (in other words, you type in a command to make the program run), you can provide arguments simply by typing them after the program command. For example, the Windows command `del` (for delete) is followed by a list of arguments that give the names of the files that are to be deleted, like this:

```
del notes.txt oldImage.png
```

In this case, a program that implements the delete behavior is provided with two strings, which are the names of two files to be deleted. Because XNA games are usually started from within Windows or directly by the target device, you won't be providing arguments to the `Main` method, so you can ignore these parameters.

The C# *Using* Statement

The `Program.cs` file contains a second use of the keyword `using`. This is a bit confusing because I've just described `using`, but this is a different use of the same keyword. Previously, you saw that `using` was a directive to the compiler meaning, "Look in here if you want to find out about something." Once you get inside the C# program itself, however, the word has a different meaning: "Use this object and then dispose of it when you are finished." It's a way of explicitly telling the run-time system how long you need an object. You've seen that the garbage collector is continuously searching for objects that it can remove from memory. If you want to speed up this process and make sure that an object is disposed of as soon as the program has finished with it, an object should be used within a block of code following a `using` statement. As an example, consider how you'd use a class called `HugeObjectUsedForSums` in this program:

```
using ( temp = new HugeObjectUsedForSums() )
{
    // do things with temp to work out the answer
}
```

You need to make an instance of `HugeObjectUsedForSums` to perform some calculations, after which you want it removed as quickly as possible. The previous code does this. As soon as the program leaves the block following the `using` statement, the system knows that `temp` is no longer required, and the resources that it uses can be recovered.

The *Main* Method in an XNA Game

In an XNA game, the job of the `Main` method is to create an instance of the `Game1` class and then make it run. Look at the following code:

```
static void Main(string[] args)
{
    using (Game1 game = new Game1())
    {
        game.Run();
    }
}
```

The designers of XNA wanted to make sure that the instance of the game class created to run the game is destroyed as soon as it's no longer needed, so they place it within a block of code after a `using` statement.

The `Run` method runs your game. When `Run` is called, it calls the `Initialize` and `LoadContent` methods and then repeatedly calls the `Update` and `Draw` methods. When the game finishes, the `Run` method ends, the game class is destroyed, and the program finishes.

Renaming the *Game1* Class

The Great Programmer doesn't like using the names that XNA Game Studio creates. She suggests that rather than calling the game class `Game1`, you might want to call it something else, perhaps `BreadAndCheeseGame`. This makes it easier for other people to understand what your program does. At the moment, the `Game1` class is held in a file called `Game1.cs`. The C# language doesn't insist that the file and the class it holds have the same name, but it would seem sensible to make the two names line up.

You can rename the `Game1.cs` file from within XNA Game Studio. One way to do this is to right-click the filename in Solution Explorer and select `Rename` from the menu that appears, as shown in Figure 11-6.

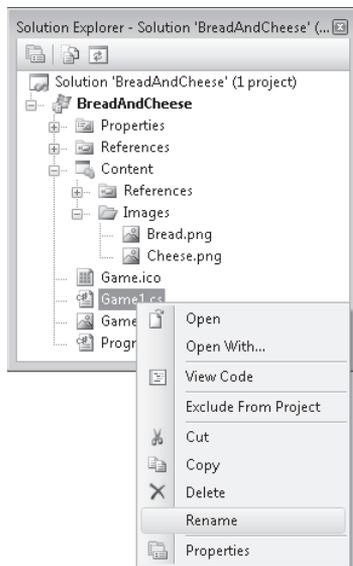


FIGURE 11-6 The `Rename` command for a source file

When you select Rename, you can type a new name, as shown in Figure 11-7.

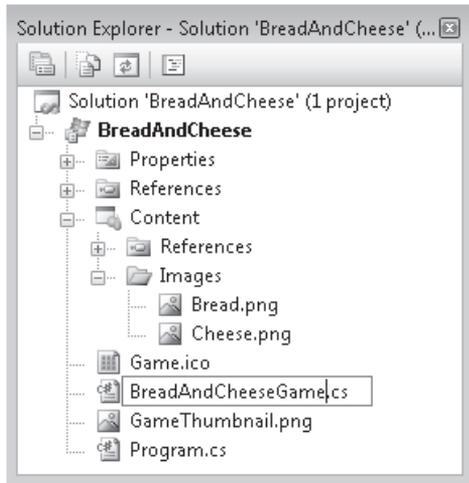


FIGURE 11-7 Renaming a class file

You need to make sure that you don't remove the ".cs" from the end of the filename. This is the filename extension, and it is how XNA Game Studio and the rest of Windows know that the file contains a C# program. One really nice feature of XNA Game Studio is that when you finish typing the new name and press Enter, the dialog box shown in Figure 11-8 appears.

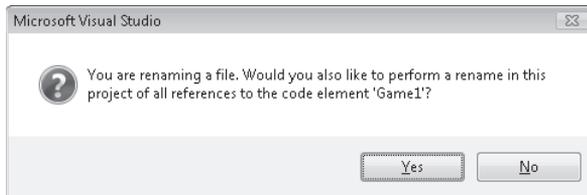


FIGURE 11-8 Renaming a class globally

XNA Game Studio detects that you're renaming the file and offers to rename the class throughout all your files for you. To accept this useful offer, you simply click OK, and the Game1 class is now renamed BreadAndCheeseGame in all your source files. This renaming process is a lot subtler than you might think. The class is renamed in the BreadAndCheeseGame.cs file and also where it's used in the Program.cs file.

The Great Programmer Speaks: Refactoring Is Good What you've done is called "refactoring," which means changing the code you've written to make it better. If you find that a block of statements needs to be made into a method, you can use the refactoring support in XNA Game Studio to do this for you. If you invent a better name for a variable than the one that you originally came up with, you also can use XNA Game Studio to change the name for you. Before we had tools like XNA Game Studio, it was very difficult to do this, so programmers tended to be stuck with bad decisions made at the beginning of a project. Today, it's very easy to make these changes. The Great Programmer is very keen on refactoring; she says that as you write a program, your understanding of the problem improves, and you'll need to make these changes.

You can access the refactoring support in XNA Game Studio by selecting the item you want to refactor and right-clicking the selection. You can then select Refactor from the menu that appears. Of course, you can rename only the items that you've created yourself; for example, it would not be sensible to try to rename the Update method.

Creating Game Objects

Now that you have a good understanding of your classes and how a game program fits together, you can start making objects to be used in your game. You begin with the graphical items to be drawn on the screen. To start, you draw the cheese and make it move, and then you implement the bread bat.

Sprites in Games

Graphical objects in a game are often called *sprites*. A sprite can be a very small image, such as a spaceship viewed from far away, a missile, or a piece of cheese. It can also be very large. The background of your screen can be a single sprite. Sprites have graphical content and a position on the screen. Your sprites are drawn with a particular texture and have a position specified by a rectangle, as follows:

```
// Game World
Texture2D cheeseTexture;
Rectangle cheeseRectangle;
```

When the game starts, you load the texture from the image content, set the size of the draw rectangle, and draw the texture using techniques that we first saw in Chapter 4. Your finished game will contain a great many sprites.

Managing the Size of Game Sprites

Owners of Xbox consoles can choose from a variety of screen-size and screen-resolution settings. They can also select between standard and wide screen shapes. Your game must work correctly on any of these sizes and give the player the same game-play experience on each. If you do this correctly, it should even be possible to play the game properly on the tiny Zune screen. This means that your game must automatically set the size of the objects that you draw, depending on the display in use. The game must also adjust the speed at which the objects in the game move; otherwise, a game that works on a small TV might be unplayable on a large display.

You've seen in the section entitled "Filling the Screen" in Chapter 4 that you can get the dimensions of your screen from the display adapter viewport properties. However, getting a hold of these is a rather laborious process, so you create two data fields in your game that

hold these values for you to use. The best place to set these variables is in the `Initialize` method, which is called once when your game first starts running:

```
// Display settings
float displayWidth;
float displayHeight;

protected override void Initialize()
{
    displayWidth = GraphicsDevice.Viewport.Width;
    displayHeight = GraphicsDevice.Viewport.Height;
    base.Initialize();
}
```

Working with Floating-Point Values and Integers

The previously mentioned `displayWidth` and `displayHeight` variables have been declared as floating-point, although the `display` properties themselves are integers. This is because all your calculations involving the width and height of items need the fractional part that floating-point variables give you, so that they are sufficiently accurate.

However, all the properties of your display rectangle are integers, so you need to convert these floating-point values into integers when you want to position the sprites. You know that you can use casting to convert from one type to another, but you also need to allow for the fact that casting always truncates; in other words, if the floating-point input were 1.99999, it would still be converted to 1, which would be inaccurate. You can make sure that the converted value is as accurate as possible by adding 0.5 to the floating-point value before you truncate it so that 1.99999 would turn into 2.4999 and then be truncated down to 2. You can see this in action in the `scaleSprites` method later in this chapter.

Double Precision Floating-Point Values

C# and XNA can use two different types to hold floating-point values. One of these is called `float` and holds a number with seven digits of precision. This means it could hold the mathematical constant pi (an endless decimal) as 3.141593. The other is called `double`. It uses twice as much memory to hold each value and is good for around 16 digits of accuracy, and could hold pi as 3.14159265358979. Very high levels of precision can be important in video games because values are being updated thousands of times a second, so errors accumulate quickly. For the purpose of your game, you can use floating-point variables. However, you need to remember that when you give a real number value (one with a decimal point) in the program text, the C# compiler assumes that it's a double precision one. This means that the following statement causes a compilation error:

```
float pi = 3.14159;
```

This is because 3.14159 is compiled as a double precision value, and you know that the C# compiler reacts badly when you perform an action that might result in a loss of data (which is what could happen if you put a double value into a float variable). There are two ways around this: you can cast the double value to floating-point, or you can change the value in the program to be a floating-point value, as shown here:

```
float pi = 3.14159f;
```

Putting the letter "f" after a decimal value tells the compiler that you're writing a floating-point value, not a double precision value.

Drawing and Aspect Ratios

When an image is drawn, you need to be careful to preserve its *aspect ratio*. The aspect ratio of an image is the ratio of the width to the height. For your cheese, this is just about one because the texture is square, but for your bread, it's quite different. Figure 11-9 shows the effect of getting the aspect ratio wrong when you draw the bread bat.

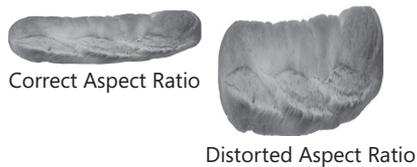


FIGURE 11-9 The effect of aspect ratio on drawing

The bread has an aspect ratio of around 4 to 1; in other words, it is around four times as wide as it is high. The program can get the aspect ratio of the original image from the dimensions of the texture:

```
float aspectRatio =  
    (float) cheeseTexture.Width / cheeseTexture.Height;
```

The program can now use the aspect ratio to calculate the correct height of a sprite given the width that we want it to have.



Note The variable `aspectRatio` is being declared and used in the program to hold a value that is going to be used in one particular part of the code. This is called a *local variable* because it is used in only one place in the code and has no need to be visible anywhere else.

Sprite Sizing

Next, you need to decide how large to make the cheese sprite. This depends on the game you're creating. Do you want to have a big cheese or a little cheese? In some games, the objects change size as the game progresses so that you can start with large sprites and then

reduce their size and increase their speed to make the game more challenging. You think that having the cheese take up around one-twentieth of the screen width would work well, but you're not sure. You ask the Great Programmer for advice because it was her cheese that you used for the game.

The Great Programmer Speaks: Flexibility Should Be Designed into Your Programs

The Great Programmer has no idea what size cheese makes a good game. She suggests that you have no idea either. Therefore, you need to make sure that when you create the game, you make it as easy as possible to change the size of the cheese and all the other game sprites. Your program could use variables to represent the scale values, so that rather than using the literal value of one-twentieth (0.05) to represent the fact that you want the width of the cheese to be one-twentieth of the screen, you use a variable called `cheeseWidthFactor` instead. Then you can easily change the value everywhere it's used just by changing the value of `cheeseWidthFactor`. Your program could also use methods. If you create a method called `scaleSprites`, you can then call it to perform the scaling. If you decide that you need to change the size of the sprites during the game, you simply need to call this method again.

With these points in mind, you create a method called `scaleSprites` and some variables to hold the width factors. You can call the `scaleSprites` method from `LoadGraphicsContent` when the cheese texture has been loaded. It sets the size of the draw rectangle to match the display you're using, as follows:

```
void scaleSprites()
{
    cheeseRectangle.Width = (int)((displayWidth * cheeseWidthFactor) + 0.5f);
    float aspectRatio = (float) cheeseTexture.Width / cheeseTexture.Height;
    cheeseRectangle.Height = (int)((cheeseRectangle.Width / aspectRatio) + 0.5f);
}
```

This `scaleSprites` method performs the required calculations. Note that you need to use casting to convert the floating-point results into integers that can be used to set up the `cheeseRectangle`.

Moving Sprites

Now that you have your cheese sprite, you need to make it move. You use two floating-point variables to hold the draw positions and two more floating-point variables to hold the speed at which the cheese is moving:

```
float cheeseX;
float cheeseXSpeed;
float cheeseY;
float cheeseYSpeed;
```

Each time that Update is called in your game, you update the X and Y properties of `cheeseRectangle`, causing the cheese to be drawn in a different position and so appear to move:

```
protected override void Update(GameTime gameTime)
{
    // Allows the game to exit
    if (GamePad.GetState(PlayerIndex.One).Buttons.Back == ButtonState.Pressed)
        this.Exit();

    cheeseX = cheeseX + cheeseXSpeed;
    cheeseY = cheeseY + cheeseYSpeed;
    cheeseRectangle.X = (int)(cheeseX + 0.5f);
    cheeseRectangle.Y = (int)(cheeseY + 0.5f);
    base.Update(gameTime);
}
```

Each time this Update is called, it adds the speed values to the current position of your cheese, causing it to appear to move across the screen. It's important that the cheese appears to move at the same speed on every kind of game display, so you need to calculate appropriate values for `cheeseXSpeed` and `cheeseYSpeed`. You know that the Update method is called 60 times a second. If `cheeseXSpeed` were set to one-sixtieth of the width of the screen, this would mean that the cheese would take around a second to cross the screen. If you want your cheese to take around 2 seconds to cross the screen, the position of the cheese must change by half that (1/120 of the screen) each time. At this point, you remember what the Great Programmer said. She said that you should make important values into variables so that they are easy to change. With that in mind, you modify the `scaleSprites` method to calculate speed values as well as sizes:

```
float cheeseWidthFactor = 0.05f;
float cheeseTicksToCrossScreen = 200.0f;

void scaleSprites()
{
    cheeseRectangle.Width = (int)((displayWidth * cheeseWidthFactor) + 0.5f);
    float aspectRatio = (float) cheeseTexture.Width / cheeseTexture.Height;
    cheeseRectangle.Height = (int)((cheeseRectangle.Width / aspectRatio) + 0.5f);

    cheeseX = 0;
    cheeseY = 0;
    cheeseXSpeed = displayWidth / cheeseTicksToCrossScreen;
    cheeseYSpeed = cheeseXSpeed;
}
```

The interval between calls of Update is sometimes called a "tick." The variable `cheeseTicksToCrossScreen` sets the number of ticks that the cheese takes to move across the screen. The larger this number, the slower the cheese moves. It turns out that 200 ticks is a reasonable number. Note that the value of `cheeseYSpeed` has been made the same as

cheeseXSpeed. This means that the cheese moves at 45 degrees down the screen rather than along the diagonal of the screen.

Sample Code: Moving Cheese All the sample projects can be obtained from the course instructor. The sample project in the 01 Moving Cheese directory in the resources for this chapter draws a piece of cheese that flies down the screen and vanishes off the bottom.

Bouncing the Cheese

What you really want to do is have the cheese bounce around the screen. To do this, you need to reverse the direction of movement of the cheese when it reaches the edge. This is what happens when things bounce. To reverse a direction of movement, you simply need to multiply the speed value by -1 . You can use the size of the screen and the size of your draw rectangle to determine when you've reached an edge:

```
if (cheeseX + cheeseRectangle.Width >= displayWidth)
{
    cheeseXSpeed = cheeseXSpeed * -1;
}

if (cheeseX <= 0)
{
    cheeseXSpeed = cheeseXSpeed * -1;
}
```

This code performs two tests. The first one checks to see if the cheese has gone off the right of the screen. If the X position plus the width of the cheese is greater than the width of the display, it's time for the cheese to change direction. If the X position is less than or equal to 0, the cheese must change direction again. You need to perform the same tests for the Y movement so that you can get your cheese to bounce properly.

Sample Code: Bouncing Cheese The sample project in the 02 Bouncing Cheese directory in the resources for this chapter draws a piece of cheese that bounces around the screen.

Dealing with Display Overscan

The previously mentioned sample program runs correctly on the Xbox or a desktop PC. However, some Xbox owners find a game based on this code rather hard to play. If they're using an older display device or a TV screen, they complain that the cheese goes off the screen at the edges. This is because TV displays use what is called *overscan*. Figure 11-10 shows the problem. The cheese has managed to disappear almost completely from the TV picture.

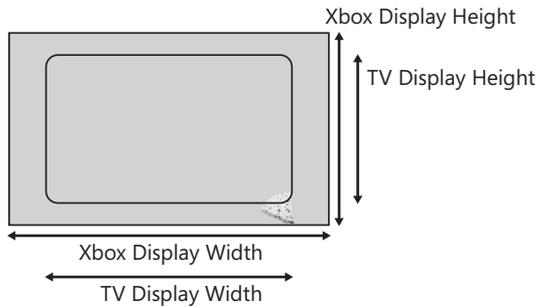


FIGURE 11-10 A drawing extending off the visible screen

The problem arises because a TV does not show the entire Xbox display; it shows only a central region. This is because glass TV tubes cannot be made to align precisely with the edge of the picture they are showing, so TV signals have an area of overscan where program makers must be careful not to put important parts of a scene. If you let your game objects go into the overscan area, there's a danger that players won't be able to see them, and this would be very bad for game play.

The amount of overscan (in other words, the amount of the display that you lose) varies from one display to another. It's usually expressed as a percentage, perhaps 10 percent or 20 percent. The bigger the number, the greater the amount of screen that's lost. You need to calculate the range of the available screen coordinates that you can use to place items on display if you want them to be visible. You can do this when you set up the scaling values, and you can use a floating-point version of your `getPercentage` method from Chapter 10 to help you, as follows:

```
// Display settings
float displayWidth;
float displayHeight;
float overScanPercentage = 10.0f;
float minDisplayX;
float maxDisplayX;
float minDisplayY;
float maxDisplayY;

float getPercentage(float percentage, float inputValue)
{
    return (inputValue * percentage) / 100;
}

private void setupScreen ()
{
    displayWidth = graphics.GraphicsDevice.Viewport.Width;
    displayHeight = graphics.GraphicsDevice.Viewport.Height;
    float xOverscanMargin =
        getPercentage(overScanPercentage, displayWidth) / 2.0f;
    float yOverscanMargin =
        getPercentage(overScanPercentage, displayHeight) / 2.0f;
```

```
minDisplayX = xOverscanMargin;  
minDisplayY = yOverscanMargin;  
  
maxDisplayX = displayWidth - xOverscanMargin;  
maxDisplayY = displayHeight - yOverscanMargin;  
}
```

The `setupScreen` method is called by the `Initialize` method when the game starts running. It calculates the width and height values based on a particular overscan percentage. It does this by working out the margins required around the screen and then creating maximum and minimum values for the X and Y coordinates. It also provides the game with minimum and maximum values, which can be used to place the cheese on the screen at the start of the game and also in the code that bounces the cheese. Look at the following:

```
if (cheeseX + cheeseRectangle.Width >= maxDisplayX)  
{  
    cheeseXSpeed = cheeseXSpeed * -1;  
}  
  
if (cheeseX <= minDisplayX)  
{  
    cheeseXSpeed = cheeseXSpeed * -1;  
}
```

This code uses the new boundary values to ensure that the cheese never leaves the visible part of the screen.

Sample Code: Overscan Bouncing Cheese The sample project in the 03 Overscan Bouncing Cheese directory in the resources for this chapter draws a piece of cheese that bounces around the screen and stays within a 10 percent overscan boundary.

You now have some bouncing cheese that provides the same gaming experience on any platform. You can now take any image of yours and make it bounce around the screen. In the next chapter, you'll add the bread bat and start hitting the cheese about with it.

Conclusion

In this chapter, you've learned a lot. For the first time, you've taken a look at how a game application is structured. You've seen how it's spread over more than one class and how the `Program.cs` file gets the game running. You've also learned the meaning of some more C# key words. Now you know how one program can be given information provided from another by means of the `using` compiler directive. You've seen how the `static` key word can make methods and classes that are created when your application runs without your needing to explicitly create them, and you've looked at the `Main` method, which is how C# programs are started. You completed your investigation into how C# programs work with a look at the

using key word. You moved on to creating your game and found out how to ensure that games work correctly on different types, sizes, and resolutions of the display device. Then you created a sprite and got it moving around the visible portion of the display.

Chapter Review Questions

If you're thinking that you're due for another chapter review about now, you're right. As usual, true or false?

1. Images for use in games must be bought from a special XNA image bank.
2. An XNA Game Studio project contains a solution.
3. You need to create your own Program.cs file to run your programs.
4. The Program.cs source file does not contain your game program.
5. Namespaces are used in a program to locate resources.
6. The main method is called to start the program.
7. If something is made static, it means it can't be moved around in memory.
8. The C# using statement is provided to help the garbage collector work more effectively.
9. The cast from floating-point to integer value automatically rounds up values with a fractional value greater than 0.5.

Chapter 12

Games, Objects, and State

In this chapter, you will

- Discover a better way to structure your programs.
- Add some bread that you can use to bash the cheese around on your screen.
- Give yourself some targets to hit the cheese at.

Introduction

You have the basis of a little game at the moment. You know how to place objects on the screen and manage their movement. You also know how to make sure that the games you create work with different display sizes and resolutions. In this chapter, you develop the game play further, add some more sprites, and create a game that has proper game-play.

Adding Bread to Your Game

You can continue working on the 03 OverScan Bouncing Cheese sample code that you were using in Chapter 11, “A Game as a C# Program.” You need to add some bread to your game. The bread will be the bat that the player uses to hit the cheese around the screen. You think that tomatoes might make good targets, but first you need to get the bread working.

You need to store all the same information about the bread as you do about the cheese. It has a position, a texture, and a speed. The only difference is in the Update behavior. Whereas the cheese travels in a particular direction each time it’s updated and bounces off the edges of the playing field, the bread is controlled by one of the thumbsticks on gamepad 1. In the game, you need to store the same information for the cheese and bread, so you could go ahead and create all the class member variables for them as follows:

```
Texture2D cheeseTexture;  
Rectangle cheeseRectangle;  
float cheeseX;  
float cheeseXSpeed;  
float cheeseY;  
float cheeseYSpeed;  
float cheeseWidthFactor = 0.05f;  
float cheeseTicksToCrossScreen = 200.0f;
```

```
Texture2D breadTexture;  
Rectangle breadRectangle;  
float breadX;
```

```
float breadXSpeed;  
float breadY;  
float breadYSpeed;  
float breadWidthFactor = 0.05f;  
float breadTicksToCrossScreen = 200.0f;
```

This code simply has a copy of all the cheese variables, but renamed for bread. However, from a programming point of view, this is not really the best way to do it. The Great Programmer would certainly not approve. She doesn't like it when you have lots of separate variables all relating to one thing. She reckons that all the information about a particular item should be grouped together in one place. There should be a "cheese group" and a "bread group."

You've seen this "grouping together" in Microsoft XNA ever since you started writing programs. For example, you know that XNA holds Co₁or information in the form of a structure with fields that represent the red, green, and blue intensities of a particular color. For your bread and cheese, you'd like to group all this information together in the same way.

Using a Structure to Hold Sprite Information

C# provides a kind of object called a *structure* to allow programmers to group things together. Structures are like classes, in that they can contain methods and data, but they are managed by value. You found out about values and references in the section entitled "Working with Arrays, Objects, and References," in Chapter 9, "Reading Text Input." The fact that structures are managed by value makes them ideal for holding small lumps of data that we want to treat as a whole. You can design a structure that holds all the information about a sprite on the screen as follows:

```
struct GameSpriteStruct  
{  
    public Texture2D SpriteTexture;  
    public Rectangle SpriteRectangle;  
    public float X;  
    public float Y;  
    public float XSpeed;  
    public float YSpeed;  
    public float WidthFactor;  
    public float TicksToCrossScreen;  
}
```

Each of the items in the structure is a field. If you compare the fields of the structure `GameSpriteStruct` with the variables you used in the original bouncing cheese program, you find that it holds all the information you need for a sprite: the texture, the rectangle in which to draw the sprite, the current position of the sprite, the speed at which the sprite moves, and the size and speed settings. Once you've created this structure, you can declare variables of this type for use in your game:

```
GameSpriteStruct cheese;  
GameSpriteStruct bread;
```

When you declare a `GameSpriteStruct` variable, you get a structure that contains all the fields grouped together in it. You can then use the fields in the structure as follows:

```
cheese.SpriteTexture = Content.Load<Texture2D>("Images/Cheese");  
bread.SpriteTexture = Content.Load<Texture2D>("Images/Bread");
```

These statements set the textures for the bread and cheese to ones loaded from images placed in your project content. You can get hold of any of the fields in your structure by following the name of the structure variable with a period (.) and then the name of the field. This works because you've made the fields *public*. If you look back to the declaration of `GameSpriteStruct`, you see that each field has the C# keyword `public` in front of it. Words placed in front of fields like this are called *modifiers*. There are a number of different modifiers in C#; `public` is an "access modifier," in that it determines the level of access to a field. Fields marked as `public` can be used by code outside the class or structure. You can make fields `private` so that code in methods outside the class or structure can't read or write the value in the field. For now, though, `public` fields are fine because they are easy to use and you don't have any particular need for security. Now that you have your bread and cheese structures, you can set the values in them:

```
void scaleSprites()  
{  
    cheese.TicksToCrossScreen = 200.0f;  
    cheese.WidthFactor = 0.05f;  
  
    cheese.SpriteRectangle.Width =  
        (int)((displayWidth * cheese.WidthFactor) + 0.5f);  
    float aspectRatio =  
        (float)cheese.SpriteTexture.Width / cheese.SpriteTexture.Height;  
    cheese.SpriteRectangle.Height =  
        (int)((cheese.SpriteRectangle.Width / aspectRatio) + 0.5f);  
    cheese.X = minDisplayX;  
    cheese.Y = minDisplayY;  
    cheese.XSpeed = displayWidth / cheese.TicksToCrossScreen;  
    cheese.YSpeed = cheese.XSpeed;  
  
    bread.WidthFactor = 0.15f;  
    bread.TicksToCrossScreen = 120.0f;  
  
    bread.SpriteRectangle.Width =  
        (int)((displayWidth * bread.WidthFactor) + 0.5f);  
    aspectRatio =  
        (float)bread.SpriteTexture.Width / bread.SpriteTexture.Height;  
    bread.SpriteRectangle.Height =  
        (int)((bread.SpriteRectangle.Width / aspectRatio) + 0.5f);  
    bread.X = displayWidth / 2;  
    bread.Y = displayHeight / 2;  
    bread.XSpeed = displayWidth / bread.TicksToCrossScreen;  
    bread.YSpeed = bread.XSpeed;  
}
```

This version of `ScaleSprites` sets the width, height, speed, and initial position of the bread and the cheese sprites. It makes the bread take up slightly more of the width of the screen and allows it to move a bit faster than the cheese. The `ScaleSprites` method also sets the initial position of the bread at the middle of the screen and places the cheese at the top left corner of the display area.

Using the Gamepad Thumbsticks to Control Movement

You've decided that the player will control the bread and use it as a bat to hit the cheese. To make the bread move, you need to add some statements to the `Update` method. This turns out to be very easy. The Xbox gamepad has two thumbsticks that can be used to control games. These generate floating-point values that you can use to direct the movement of the bread bat. Figure 12-1 shows the range of values that the thumbstick produces. If it's pushed all the way to the left, it will generate -1.0 for the X value. If it's pushed halfway to the left, it will generate -0.5 . If the thumbstick is left in the center, the X and Y values are zero.

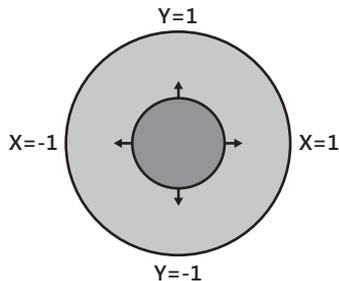


FIGURE 12-1 Thumbstick values

You've used the `GamePadState` structure before to read the state of buttons on a gamepad. It also provides a `ThumbSticks` property that contains two vectors (one for each thumbstick) that allow your program to read the current thumbstick values. Version 2.0 of the Zune (the devices with a Zune pad) map input from the pad onto the left thumbstick.

To get the amount of movement of the bread, you simply need to take the values from the left thumbstick and multiply them by the speed values for your bread sprite. The farther the thumbstick is moved, the bigger the values and the faster the bread moves across the screen:

```
GamePadState gamePad1 = GamePad.GetState(PlayerIndex.One);
// Allows the game to exit
if (gamePad1.Buttons.Back == ButtonState.Pressed)
    this.Exit();

// Move the bread

bread.X = bread.X + (bread.XSpeed * gamePad1.ThumbSticks.Left.X);
bread.Y = bread.Y - (bread.YSpeed * gamePad1.ThumbSticks.Left.Y);
bread.SpriteRectangle.X = (int)bread.X;
bread.SpriteRectangle.Y = (int)bread.Y;
```

This code is placed in the Update method and updates the position of the bread rectangle according to the setting of the left thumbstick. Note that the code must subtract the speed value from the Y coordinate. This is because the Y coordinate goes down the screen, with 0 at the top. If the speed value was added to the Y coordinate, the bread would go down the screen when the thumbstick is moved up, making it harder to control. This version of the bread movement does not restrict the bread to the screen, so it is possible for the player to move the bread right off the screen.

Sample Code: Bread and Cheese All the sample projects can be obtained from the course instructor. The sample project in the 01 Bread and Cheese directory in the resources for this chapter draws cheese bouncing around the screen and a bread bat that you can move around the screen with the left thumbstick. It works very well, and the feeling of control that you get is very impressive for such a simple program. The bread doesn't yet interact with the cheese; you'll add that later.

Improving Programs Using Methods

The Great Programmer has just been around and has taken a look at your code. She purses her lips when she sees something she doesn't like, and she's doing that now. The bit of code she doesn't like is the `scaleSprites` method where you set up the bread and cheese sprites:

```
void scaleSprites()
{
    cheese.TicksToCrossScreen = 200.0f;
    cheese.WidthFactor = 0.05f;

    cheese.SpriteRectangle.Width =
        (int)((displayWidth * cheese.WidthFactor) + 0.5f);
    float aspectRatio =
        (float)cheese.SpriteTexture.Width / cheese.SpriteTexture.Height;
    cheese.SpriteRectangle.Height =
        (int)((cheese.SpriteRectangle.Width / aspectRatio) + 0.5f);
    cheese.X = minDisplayX;
    cheese.Y = minDisplayY;
    cheese.XSpeed = displayWidth / cheese.TicksToCrossScreen;
    cheese.YSpeed = cheese.XSpeed;

    bread.WidthFactor = 0.15f;
    bread.TicksToCrossScreen = 120.0f;

    bread.SpriteRectangle.Width =
        (int)((displayWidth * bread.WidthFactor) + 0.5f);
    aspectRatio =
        (float)bread.SpriteTexture.Width / bread.SpriteTexture.Height;
    bread.SpriteRectangle.Height =
        (int)((bread.SpriteRectangle.Width / aspectRatio) + 0.5f);
    bread.X = displayWidth / 2;
    bread.Y = displayHeight / 2;
    bread.XSpeed = displayWidth / bread.TicksToCrossScreen;
    bread.YSpeed = bread.XSpeed;
}
```

For a start, she reckons that the name is no longer correct. The method doesn't only scale the sprites; it also sets their initial position on the screen and their speed of movement. So you promise to go through and change the name of the method, using the Refactor technique you used in Chapter 11. The next thing she doesn't like to see is the same piece of code repeated. Rather than perform exactly the same sequence of statements for the bread as for the cheese, she suggests that you make a method called `setupSprite` that sets up a sprite. You then call this for every sprite you want to set up. You know that you'll have tomato sprites later, so this seems like a sensible, time-saving plan. You can pass the `setupSprite` method parameters that give it all the information it needs to work on, so you begin to write the method:

```
void setupSprite(
    GameSpriteStruct sprite,
    float widthFactor,
    float ticksToCrossScreen,
    float initialX,
    float initialY)
{
    sprite.WidthFactor = widthFactor;
    sprite.TicksToCrossScreen = ticksToCrossScreen;
    sprite.SpriteRectangle.Width = (int)((displayWidth * widthFactor) + 0.5f);
    float aspectRatio =
        (float)sprite.SpriteTexture.Width / sprite.SpriteTexture.Height;
    sprite.SpriteRectangle.Height =
        (int)((sprite.SpriteRectangle.Width / aspectRatio) + 0.5f);
    sprite.X = initialX;
    sprite.Y = initialY;
    sprite.XSpeed = displayWidth / ticksToCrossScreen;
    sprite.YSpeed = sprite.XSpeed;
}
```

The method is given the sprite to set up, along with the width factor, the time taken to cross the screen, and the initial start position of the sprite. You can then set up the cheese and bread by making two calls of the method:

```
void setupSprites()
{
    setupSprite(cheese, 0.05f, 200.0f, minDisplayX, minDisplayY);
    setupSprite(bread, 0.15f, 120.0f, displayWidth / 2, displayHeight / 2);
}
```

This looks much neater, and you're really pleased with the code that you've written. You feed all your setup values into the method call, and it calculates the content of the `gameSpriteStruct` that needs to be set up. The only problem is that it doesn't work. The method call doesn't seem to have any effect on the bread or cheese sprite value.

Value and Reference Parameters

It turns out that your program doesn't work because the parameters in your method are passed by *value*. A parameter is the means by which you can pass information into a method.

When a method is called, the value given in the call is copied into the parameter. This means that when code in a method assigns a value to the parameter, the copy is changed, but not the original. In other words, the statement `sprite.X = initialX;` changes the value of a copy of the `GameSpriteStruct` that was supplied as a parameter. When a method ends, all the parameter copies are discarded, and the updated values are lost.

Passing value parameters into method calls is fine when you want to tell a method something, but it is less useful when you want the method to change the parameter. To make the method useful, you need to find a way of pointing the method at the variable you want it to change. It turns out that you have a way to do this, and you've seen it before. The device you'll use is called a *reference*. If you give the method a reference to the thing you want it to change, it can follow the reference and make changes to your actual bread and cheese objects rather than to copies. In Chapter 9, in the section entitled "Working with Arrays, Objects, and References," you discovered that some variables are managed by value and some by reference. C# structures are managed by value, which is why the values of the cheese and bread sprites get copied when the method is called. To tell C# to manage a particular parameter as a reference, you need to change the header of the method:

```
void setupSprite(  
    ref GameSpriteStruct sprite,  
    float widthFactor,  
    float ticksToCrossScreen,  
    float initialX,  
    float initialY)  
{  
    // method goes here  
}
```

The `ref` modifier before the `GameSpriteStruct` parameter in the method header tells the compiler to pass a reference to the parameter's location in memory rather than copying a value stored in that memory location. You also need to use the `ref` modifier, as shown here in bold, when you make a call to the method:

```
setupSprite(ref cheese, 0.05f, 200.0f,  
            minDisplayX, minDisplayY);  
setupSprite(ref bread, 0.15f, 120.0f,  
            displayWidth/2, displayHeight/2);
```

Now, when `setupSprite` runs, it is given the values of the rest of the parameters that it needs to work with and a reference to the `GameSpriteStruct` object that needs to be changed. You don't need to change any code in the body of the method itself; the compiler makes sure that the instructions it produces follow the reference and update the correct values in memory rather than updating a copy of the values.

Sample Code: Bread and Cheese with Setup Method The sample project in the 02 Bread and Cheese with Setup Method directory in the resources for this chapter uses a `setupSprite` method to set up the sprites.

Handling Collisions

You have a bread bat and some cheese, and you can move the bread around the game and chase the cheese, but nothing happens when you hit the cheese with the bread. You now need to add the interaction between these two sprites. The first thing the game needs to do is detect when the bread and the cheese collide. The best way to do this is to use the rectangles that define the size and position of the two sprites on the screen. When these two rectangles intersect (that is, both of them cover the same part of the screen), it means that a collision has taken place. Figure 12-2 shows how this works.

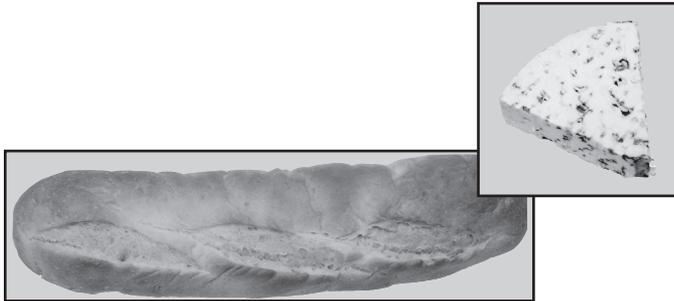


FIGURE 12-2 A sprite collision

What you need is a method that you can use to detect when this happens. Fortunately, the designers of XNA have provided just such a method using the `Rectangle` type. The method, called `Intersects`, is used as follows:

```
if (cheese.SpriteRectangle.Intersects(bread.SpriteRectangle))
{
    // we have a collision
}
```

You call the `Intersects` method on one rectangle and feed it the other one to compare with it. It returns `true` if the two rectangles intersect. Note that in the previous code, it is necessary to get the rectangle value of the bread and cheese sprites.

Making the Cheese Bounce off the Bat

Now that you can detect when the cheese and the bread collide, you need to make the cheese “bounce” off the bat. Because the bread is horizontal, it makes sense to bounce the cheese up and down the screen so that whenever the cheese hits the bat, it reverses its movement in the Y direction. The code to achieve this is very simple; you do the same thing with the `YSpeed` as you do when the cheese hits the top or bottom of the game region:

```
if (cheese.SpriteRectangle.Intersects(bread.SpriteRectangle))
{
    cheese.YSpeed = cheese.YSpeed * -1;
}
```

This code can be placed at the end of the Update method to cause the cheese to bounce off the bat.

Sample Code: Cheese and Bread Bat The sample project in the 03 Cheese and Bread Bat directory in the resources for this chapter lets players hit the cheese up and down the screen with the bread bat.

Strange Bounce Behavior

When you run the game, you find that it works well, and you can guide the cheese around the screen successfully. However, you make the mistake of letting your younger brother have a go, and he's soon complaining that there's a bug in your game. Sometimes the cheese gets "stuck" on the bread. You ask him to show you what happens, and it turns out that he's right. It seems to happen when the bread is moving when it hits the cheese. The cheese travels along the bread, vibrating up and down as it moves. After some thought, you work out what's causing the problem. Figure 12-3 shows what's happening.

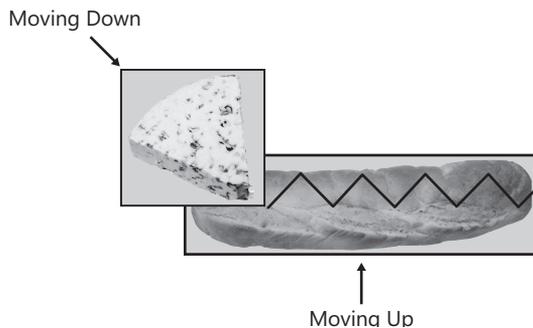


FIGURE 12-3 Cheese that gets stuck on the bread

When the cheese rectangle and the bread rectangle intersect, the program reverses the direction of movement of the cheese. Normally, this means that the next time the position of the cheese is updated, it moves away from the bread, and the rectangles no longer intersect. However, if the cheese is moving down and the bread is moving up when they collide, the cheese goes so far "in" to the bread that, even after the cheese has been updated, the bread and cheese rectangles still intersect. If this is the case, the Update method reverses the vertical direction of movement of the cheese, causing the cheese to move back into the bread. This continues as the cheese moves along the bread, following the path shown in Figure 12-3, until it finally escapes off the end. There are a number of ways you can solve this problem:

1. When the cheese collides with the bread, the program could stop detecting collisions for a while, giving the cheese a chance to move clear of the bread. To implement this, you need to add a variable to count a certain number of ticks after the collision and not allow collisions until after that number of ticks.

2. The program could move the cheese away from the bread after a collision so that the two sprite rectangles no longer intersect at the next update. To implement this, you need to know which direction the cheese is moving so that you can move it appropriately.
3. You could change the rules of the game and tell the player about this special trick shot where a skillful player can send the cheese in a particular direction by making it stick to the bat in this way. This would require no additional programming at all.

The important thing to remember is that because you own the game universe, including what you say the game is supposed to do, you can change the rules to suit what your program does. The Great Programmer doesn't have this freedom; usually she's paid a large sum of money to create a solution that does what the customer wants. However, quite a few games have turned out the way they are because of the way the programmer made them work or because of a bug that turned out to make the game more fun. In this case, you decide to use the third approach and tell your younger brother that the game is meant to work like that, and he has found a secret feature.

Strange Edge Behavior

Your younger brother is now very pleased with himself and with you. He is pleased with you for making a game that rewards clever play and pleased with himself for finding this new trick in the game. However, this doesn't last long because he soon comes back and tells you that he's found a proper bug in the game. He can make the cheese go right off the screen and not come back. You ask him to show you, and sure enough, if he uses the bread to chase the cheese right to the top of the screen, he can send the cheese right off the screen. This is definitely a bug, and you can't pass it off as a feature.

Debugging a Running Program

One of the great things about XNA Game Studio is that you can stop the game and take a look at what's happening. Once you've persuaded your younger brother to make the problem happen, you can put a breakpoint into the program and stop it so that you can look at the values of the variables. You can do this even as the program is running, either on the Xbox, Zune or Windows PC. You've used breakpoints before in the section entitled "Creating a Method to Calculate Percentages," in Chapter 10, "Using C# Methods to Solving Problems," where you were debugging the `getPercentage` method. Now you use them again to find out how your cheese is escaping from the screen.

You can put a breakpoint in the `Update` method by clicking next to the line at which you want it to stop. XNA Game Studio indicates that a breakpoint has been set by highlighting the line, as shown in Figure 12-4.

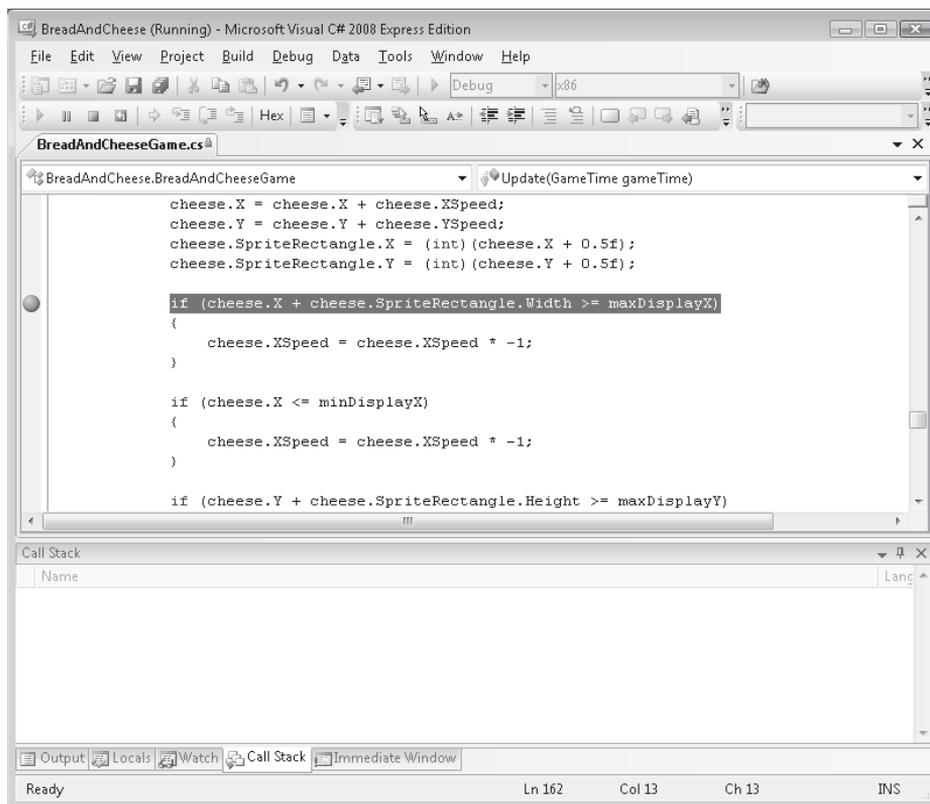


FIGURE 12-4 Adding a breakpoint to the program

The next time the program reaches this statement, it stops, and XNA Game Studio enters debugging mode. You can then look at the values of the variables to see what's going wrong. You did this in Chapter 10 as well. You add the breakpoint, and the program stops at that line. When you take a look at the values in the cheese sprite, you find that the X coordinate value is fine, but the Y coordinate is -50 , which is very wrong. The cheese Y coordinate should never get as low as this because the direction of the cheese movement should reverse when it reaches an edge. You take another look at the code that does this, and it looks sensible:

```
if (cheese.Y <= minDisplayY)
{
    cheese.YSpeed = cheese.YSpeed * -1;
}
```

If the cheese Y value becomes less than the minimum it's allowed to have, the direction of movement is reversed to bring it back onto the screen. The program does this by multiplying the speed of the cheese by -1 , which made perfect sense when you wrote it. You take a look at the cheese YSpeed and find that for the size of the screen you are using it has been calculated as 4. This means that next time the cheese is updated, the Y position of the cheese will be changed to -46 (which is still much lower than it's supposed to be). The result is that

the same condition triggers again, reversing the direction of the YSpeed and sending the Y position of the cheese back to -50. So the cheese remains forever off the screen, dancing backward and forward just out of view. The problem happens because the bread collision testing is performed after the cheese has been made to bounce when it hits the edge of the screen, so if the cheese repeatedly bounces off the bread when it's on the edge of the screen, it can be made to vanish like this.

There are a number of ways you can fix this bug. You can stop the bread from going too close to the edges so that it can't harass the cheese like this, or you can fix the bouncing problem of the cheese. You can't really say that this behavior is a feature, although you could create a completely different game where the aim was to push all the objects off the screen, perhaps something called "Herd the Cheese" or "Sweep the Table." However, you decide to fix the problem.

The problem lies with the use of multiplication by -1 to change the direction of movement. If the next update brings the cheese back into the required range, then all is well, but if by some mischance it doesn't, you get the dancing behavior that you've just uncovered.

The best way to fix this is to set the direction of movement of the cheese explicitly to the one in which you need it to go. Rather than bouncing, where you simply reverse the sign of the speed value, you should say, "If the cheese Y position is less than the limit, then make the movement positive so that this always brings the cheese back onto the screen." Even if the cheese Y position remains less than the limit next time, the movement will still be correct and result in the cheese heading in the right direction.

This turns out to be easy. You can use a method called `Abs`, which is provided by `.NET`. The `Abs` method is held in the `Math` class and returns the absolute value or magnitude of a number. The absolute value of a number is simply its value, if the number is zero or positive, or the opposite of its value if the number is negative. For example, the absolute value of -4 is 4. The `Math` class provides a number of static methods (which are always available) for use in your programs. The `Math` class is in the `System` namespace, so you can use it without having to add any `using` directives to your program. The code to deal with the Y position of the cheese ends up looking like this:

```
if (cheese.Y + cheese.SpriteRectangle.Height >= maxDisplayY)
{
    cheese.YSpeed = Math.Abs(cheese.YSpeed) * -1;
}

if (cheese.Y <= minDisplayY)
{
    cheese.YSpeed = Math.Abs(cheese.YSpeed) ;
}
```

If the cheese is too high, you make it move downward. If the cheese is too low, you make it move upward. Now there's no way the cheese can get stuck off the screen.

Unfortunately it is still possible to move the bat off the screen, To solve this, you have to add code to limit the movement of the bread.

Sample Code: Absolute Cheese Bouncing The sample project in the 04 Absolute Cheese Bouncing directory in the resources for this chapter has the updated cheese bouncing behavior so that the cheese cannot be forced off the screen.

Adding Tomato Targets

Your younger brother has become adept at balancing the cheese on the bat, but he wants something to aim at, so now's the time to provide some targets. You decide to use tomatoes for this, so you need to add them to your program. You want to have lots of tomatoes, so you need to create an array of `GameSpriteStruct` instances to hold all of them:

```
Texture2D tomatoTexture;  
GameSpriteStruct[] tomatoes;  
int numberOfTomatoes = 20;
```

These are the fields that you have to create to hold tomato information. Note that although I've created an array reference called `tomatoes`, I haven't yet created the array itself. You'll load the tomato texture from your image into a single `Texture2D` object which will be loaded with the rest of the content for the game:

```
protected override void LoadContent()  
{  
    // Create a new SpriteBatch, which can be used to draw textures.  
    spriteBatch = new SpriteBatch(GraphicsDevice);  
  
    cheese.SpriteTexture = Content.Load<Texture2D>("Images/Cheese");  
    bread.SpriteTexture = Content.Load<Texture2D>("Images/Bread");  
    tomatoTexture = Content.Load<Texture2D>("Images/Tomato");  
    setupSprites();  
}
```

Textures are classes, and are managed by reference, not value, so each of your tomatoes contains a reference to the same tomato texture:

```
void setupSprites()  
{  
    setupSprite(ref cheese, 0.05f, 200.0f, minDisplayX, minDisplayY);  
    setupSprite(ref bread, 0.15f, 120.0f, displayWidth / 2, displayHeight / 2);  
    tomatoes = new GameSpriteStruct[numberOfTomatoes];  
  
    float tomatoSpacing = (maxDisplayX - minDisplayX) / numberOfTomatoes;
```

```

    for (int i = 0; i < numberOfTomatoes; i++)
    {
        tomatoes[i].SpriteTexture = tomatoTexture;
        setupSprite(
            ref tomatoes[i],
            0.05f, // 20 tomatoes across the screen
            1000, // 1000 ticks to move across the screen
            minDisplayX + (i * tomatoSpacing), minDisplayY);
    }
}

```

The `setupSprites` method creates the `tomatoes` array and contains a `for` loop that works through each tomato sprite and sets its size and position. Your first version of the game has the tomatoes evenly spaced in a line along the top of the screen. To make this work, the method uses a local variable called `tomatoSpacing` that's set to the width of the display divided by the number of tomatoes that you're using in the game. Note that you're following the advice of the Great Programmer in that it is very easy to change the number of tomatoes in the game; you need only change the value of one variable.

At the moment, you won't be making the tomatoes move, so the `Update` method only needs to copy the X and Y positions of the tomato into the rectangle for that sprite:

```

for (int i = 0; i < numberOfTomatoes; i++)
{
    tomatoes[i].SpriteRectangle.X = (int)tomatoes[i].X;
    tomatoes[i].SpriteRectangle.Y = (int)tomatoes[i].Y;
}

```

The last thing you need to do is add the code to draw all the tomatoes. This is placed in the `Draw` method as follows:

```

protected override void Draw(GameTime gameTime)
{
    graphics.GraphicsDevice.Clear(Color.CornflowerBlue);

    spriteBatch.Begin();
    spriteBatch.Draw(cheese.SpriteTexture, cheese.SpriteRectangle, Color.White);
    spriteBatch.Draw(bread.SpriteTexture, bread.SpriteRectangle, Color.White);
    for (int i = 0; i < numberOfTomatoes; i++)
    {
        spriteBatch.Draw(tomatoes[i].SpriteTexture,
            tomatoes[i].SpriteRectangle, Color.White);
    }

    spriteBatch.End();

    base.Draw(gameTime);
}

```

The `Draw` method contains another `for` loop that draws each of the tomatoes in turn. Figure 12-5 shows the display produced with your 20 tomatoes along the top.

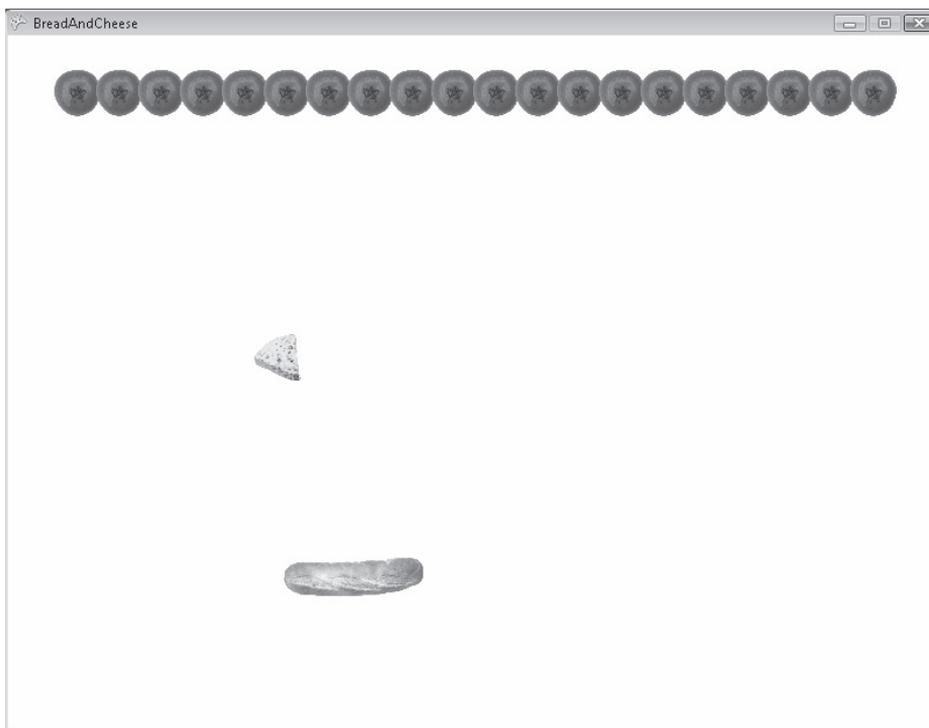


FIGURE 12-5 Bread, cheese, and 20 tomatoes

Sample Code: Adding Tomatoes The sample project in the 05 Adding Tomatoes directory in the resources for this chapter draws 20 tomatoes along the top of the screen.

Zune Image Sizes

The Zune will run XNA games quite happily, but it does not have as much available memory as the Xbox 360 or Windows PC. Up until now I have been using quite high resolution images of the bread, tomatoes, and cheese. However, these images have been so large that if we add too many the Zune is unable to hold them. (And the Zune screen is so small that images made up of fewer pixels are quite acceptable anyway.) For this version of the game I have re-sized the textures so that they look acceptable on the Xbox and Windows PC, but will also fit into the Zune memory. When you create game resources you must be careful to make sure that the images you produce are of the appropriate size and resolution.

Tomato Collisions

The idea of the game is that when the cheese hits a tomato, the tomato vanishes. This means that you need a way of making the tomatoes disappear. You can't make them vanish as such, but you can decide not to draw them.

Controlling Sprite Visibility

The game must have some way of deciding when a particular sprite shouldn't be drawn. This turns out to be easy; you need only add an extra field to the `GameSpriteStruct` structure:

```
struct GameSpriteStruct
{
    public Texture2D SpriteTexture;
    public Rectangle SpriteRectangle;
    public float X;
    public float Y;
    public float XSpeed;
    public float YSpeed;
    public float WidthFactor;
    public float TicksToCrossScreen;
    public bool Visible;
}
```

The `Visible` field is set to `true` if the sprite is to be drawn on the screen.

Setting the Initial Visibility State

The initial value of `Visible` can be set by the `setupSprite` method, which is now given an additional parameter that is used to set the initial visibility of the sprite:

```
void setupSprite(
    ref GameSpriteStruct sprite,
    float widthFactor,
    float ticksToCrossScreen,
    float initialX,
    float initialY,
    bool initialVisibility)
{
    // original setup code here
    sprite.Visible = initialVisibility;
}
```

Initially, it's set to `true` for all the tomatoes, the cheese, and the bread in the `setupSprites` method:

```
void setupSprites()
{
    setupSprite(ref cheese, 0.05f, 200.0f, 200, 100, true);
    setupSprite(ref bread, 0.15f, 120.0f, displayWidth / 2, displayHeight / 2, true);

    tomatoes = new GameSpriteStruct[numberOfTomatoes];

    float tomatoSpacing = (maxDisplayX - minDisplayX) / numberOfTomatoes;

    for (int i = 0; i < numberOfTomatoes; i++)
    {
        tomatoes[i].SpriteTexture = tomatoTexture;
        setupSprite(
```

```
        ref tomatoes[i],
        0.05f, // 20 tomatos across the screen
        1000, // 1000 ticks to move across the screen
        minDisplayX + (i * tomatoSpacing), minDisplayY,
        true // initially visible
    );
}
}
```

This `setupSprites` method also sets the initial position of the cheese a bit further into the screen so that it does not initially collide with any tomatoes.

Using the *Visible* Field When Drawing

You use the value of the `Visible` field when you draw the sprites in the `Draw` method:

```
for (int i = 0; i < numberOfTomatoes; i++)
{
    if (tomatoes[i].Visible)
    {
        spriteBatch.Draw(tomatoes[i].SpriteTexture,
            tomatoes[i].SpriteRectangle, Color.White);
    }
}
```

Only tomatoes that have the `Visible` field set to `true` are drawn on the screen. To make a tomato vanish, you simply set its `Visible` property to `false`. You do this in the `Update` method:

```
for (int i = 0; i < numberOfTomatoes; i++)
{
    if (tomatoes[i].Visible)
    {
        if (cheese.SpriteRectangle.Intersects(tomatoes[i].SpriteRectangle))
        {
            tomatoes[i].Visible = false;
            cheese.YSpeed = cheese.YSpeed * -1;
            break;
        }
    }
}
```

The `for` loop looks through all the tomatoes and tests to see if any of the tomato rectangles intersect with the cheese. If it finds an intersection, it sets the `Visible` property of the tomato to `false` and then reverses the direction of the cheese movement to make it “bounce” off the tomato it has just destroyed. Once it has removed one tomato, it stops looking for any more because the `break` statement causes the `for` loop to end at that point. This is important because otherwise, the cheese might collide with and destroy more than one tomato at a time, making the game too easy.

Sample Code: Tomato Killer The sample project in the 06 Tomato Killer directory lets a player steer the cheese around the screen and use it to destroy tomatoes.

Conclusion

You're now starting to make games that look like "proper" ones. You're building your understanding of how C# lets you structure the data in your programs so that it's easier to work with. You've also discovered how to use references so that methods can change the content of variables passed as parameters, and you've found another use for the XNA Game Studio debugger.

Chapter Review Questions

Here's the twelfth chapter review. You know the procedure by now: true or false?

1. Structures are held in fields.
2. Structures let programmers group things together in their programs.
3. Structures are managed by reference.
4. Making a member of a class `public` stops code in other classes from using that item.
5. The absolute value of a number is always negative.
6. By default, parameters to a C# method are passed by copying their values into the method.
7. You can't put a breakpoint in a running program.
8. The `Abs` method is static, so you don't need an instance of the `Math` class to use it.
9. You can't change the name of a method once you've created it.

Chapter 13

Making a Complete Game

In this chapter, you will

- Finish off the game play in your game.
- Add some features to make the game more exciting.
- Discover how to improve the structure of the game program itself.
- Find out how to use state machines to add a title screen to the game.

Introduction

You can now create programs with all the behaviors required to create a “proper” game. You know how to place objects on the screen and manage their movement. You also know how to make sure that the games you create work on different display sizes. You can also display text and produce sounds. In this chapter, you develop the game play further, add some more sprites, and create a game that has proper game-play states.

Making a Finished Game

You now have the basis of a single-player tomato-killer game. The game play is simple—you use the bread to steer the cheese around at the tomatoes—but even your younger brother, who is easy to amuse, quickly finds it boring. Thus, you need to add some additional game-play elements: scores, survival, and progression.

Adding Scores to a Game

Even a simple game can be made addictive by adding a score component. It gets even more interesting when you add a high score so that the player always has something to beat. The game score is another integer variable that’s set to 0 when the game starts and increases each time a tomato is killed. You’ve decided that tomatoes are worth 10 points, so each time the cheese crashes into a tomato, the score goes up by 10. The code that manages the cheese and tomato collisions is in the Update method:

```
if (cheese.SpriteRectangle.Intersects(tomatoes[i].SpriteRectangle))
{
    cheese.YSpeed = cheese.YSpeed * -1;
    score = score + 10;
    tomatoes[i].Visible = false;
    break;
}
```

You could make the game even more interesting by making the value of the tomatoes change over time so that the longer the player takes to destroy them, the less they're worth, but for now, you'll simply give the player 10 points for every tomato destroyed.

Drawing Text in the Game

Now that you have a score value to display you need some code to write it on the screen so that the player can see it increasing. The best way to do this is to create a general-purpose method for drawing text. You can then use the method to draw text whenever you need to display a message. The method needs to be given the text to be displayed, the position of the text, and the color of the text. It uses a font resource that is loaded by `LoadContent` and draws using the `spriteBatch` that is set up by the game:

```
void drawText(string text, Color textColor, float x, float y)
{
    int layer;
    Vector2 textVector = new Vector2(x, y);

    // Draw the shadow
    Color backColor = new Color(0, 0, 0, 20);
    for (layer = 0; layer < 10; layer++)
    {
        spriteBatch.DrawString(font, text, textVector, backColor);
        textVector.X++;
        textVector.Y++;
    }

    // Draw the solid part of the characters
    backColor = new Color(190, 190, 190);
    for (layer = 0; layer < 5; layer++)
    {
        spriteBatch.DrawString(font, text, textVector, backColor);
        textVector.X++;
        textVector.Y++;
    }

    // Draw the top of the characters
    spriteBatch.DrawString(font, text, textVector, textColor);
}
```

The `drawText` method is the same code you used to draw the clock in Chapter 5, "Writing Text." However, it's been packaged as a method that you can use whenever you want to put text onto the screen. It is supplied with the string to be displayed, the color of text that's required, and the position on the screen to draw it. The font that is to be used must have been loaded by the `LoadContent` method. To draw the score on the screen, you simply need to call the `drawText` method within the `Draw` method:

```
protected override void Draw(GameTime gameTime)
{
    graphics.GraphicsDevice.Clear(Color.CornflowerBlue);

    spriteBatch.Begin();
```

```

spriteBatch.Draw(cheese.SpriteTexture, cheese.SpriteRectangle, Color.White);
spriteBatch.Draw(bread.SpriteTexture, bread.SpriteRectangle, Color.White);
for (int i = 0; i < numberOfTomatoes; i++)
{
    if (tomatoes[i].Visible)
    {
        spriteBatch.Draw(tomatoes[i].SpriteTexture,
            tomatoes[i].SpriteRectangle, Color.White);
    }
}

drawText(
    "Score : " + score.ToString(),
    Color.White,
    minDisplayX,
    maxDisplayY - 50);

spriteBatch.End();

base.Draw(gameTime);
}

```

This Draw method draws all the game objects and then puts the score on last. This means that the score values are shown “on top” of all the other game items. You can call the drawText method several times if you want to draw multiple messages.

Adding Survival

At the moment, the player is under no particular pressure during the game. If the player makes a mistake, it doesn’t cost anything. You need to add some bad news to the game. Later, you could add deadly peppers and the killer tangerines, but for now, just cause the player to lose a life if the cheese hits the bottom of the screen. The life counter is just another variable in the game. There seems to be a tradition in computer games that you always start with three lives and that each time something bad happens, you lose a life. When you have no lives left, your game ends. The Update method contains the code that checks for the cheese hitting the bottom of the screen; you need only add some code that updates the life counter when this happens. The life counter must be reduced only when the player has some lives left, so the program must test for this, as follows:

```

if (cheese.Y + cheese.SpriteRectangle.Height >= maxDisplayY)
{
    cheese.YSpeed = Math.Abs(cheese.YSpeed) * -1;
    if (lives > 0)
    {
        lives--;
    }
}
}

```

Next, you need to stop the game from continuing when the number of lives reaches 0. The best way to do this is to exit from the Update method after you've moved the cheese but before you update the bread and look for tomatoes to collide with. This code uses the fact that C# lets a program return from a method at any point during the method:

```
protected override void Update(GameTime gameTime)
{
    ...
    // code to move the cheese and update the life counter
    ...
    if (lives <= 0)
    {
        return;
    }

    ...
    // Code to update the bread position
    // Code to check for the cheese hitting the tomatoes
    ...
}
```

The effect of this code is that when all the lives are used up, the cheese continues bouncing around the screen, but the score does not change, and the player is unable to control the bread.

You need to display the number of lives left alongside the player score. You can do this by adding this information to the string displayed by Draw:

```
protected override void Draw(GameTime gameTime)
{
    ...
    // Code to clear the screen and draw the game elements
    ...

    drawText(
        "Score : " + score.ToString() + " Lives : " + lives.ToString(),
        Color.White,
        minDisplayX,
        maxDisplayY - 50);

    ...
    // Code to finish off the Draw method
    ...
}
```

Adding Progression

Once the player has killed all the tomatoes, your game becomes very boring in that there's nothing left to do. Many games are built around the idea of successive levels, with each one being progressively more difficult than the last. The task of the player is to survive as long as possible, building up the highest score possible before all the lives are used up. One way

you can achieve progression is by redrawing the tomatoes each time all of them have been destroyed. To make the game more difficult, you can redraw them lower down the screen so that the player has less time to react with each passing level.

To achieve this, you need to detect when all the tomatoes have been destroyed. One way to do this is to use a flag that's set when a tomato is found, as shown in the following code:

```
bool noTomatoes = true;

for (int i = 0; i < numberOfTomatoes; i++)
{
    if (tomatoes[i].Visible)
    {
        noTomatoes = false;
        if (cheese.SpriteRectangle.Intersects(tomatoes[i].SpriteRectangle))
        {
            cheese.YSpeed = cheese.YSpeed * -1;
            score = score + 10;
            tomatoes[i].Visible = false;
            break;
        }
    }
    tomatoes[i].SpriteRectangle.X = (int)tomatoes[i].X;
    tomatoes[i].SpriteRectangle.Y = (int)tomatoes[i].Y;
}

if (noTomatoes)
{
    resetTomatoDisplay();
}
```

The `noTomatoes` flag is set to `false` if a visible tomato is found in the list. If the loop completes and `noTomatoes` is still `true`, the program must call the `resetTomatoDisplay` method to put the tomatoes back on the screen again. The method moves the tomato draw height down the screen and then uses a loop to update the draw height of each tomato and make the tomato visible again:

```
void resetTomatoDisplay()
{
    tomatoHeight = tomatoHeight + (displayHeight * tomatoStepFactor);

    if (tomatoHeight > tomatoHeightLimit)
    {
        tomatoHeight = minDisplayY;
    }

    for (int i = 0; i < numberOfTomatoes; i++)
    {
        tomatoes[i].Visible = true;
        tomatoes[i].Y = tomatoHeight;
    }
}
```

The `resetTomatoDisplay` method cannot move the tomatoes down the screen indefinitely; otherwise, they would eventually fall off the bottom of the display. To prevent this, the method imposes a limit on how far down the screen tomatoes can be drawn. Once this limit is reached, the tomatoes are moved back to the top of the screen again. The limit value is set when the game starts, in the method that sets up the tomatoes:

```
void setupTomatoes()
{
    tomatoHeight = minDisplayY;
    tomatoHeightLimit = minDisplayY + ((maxDisplayY - minDisplayY) / 2);
    tomatoes = new GameSpriteStruct[numberOfTomatoes];
    float tomatoSpacing = (maxDisplayX - minDisplayX) / numberOfTomatoes;

    for (int i = 0; i < numberOfTomatoes; i++)
    {
        tomatoes[i].SpriteTexture = tomatoTexture;
        setupSprite(
            ref tomatoes[i],
            0.05f, // 20 tomatoes across the screen
            1000, // 1000 ticks to move across the screen
            minDisplayX + (i * tomatoSpacing), minDisplayY,
            true // initially visible
        );
    }
}
```

Sample Code: Bread and Cheese Game All the sample projects can be obtained from the course instructor. The sample project in the 01 Bread and Cheese Game directory in the resources for this chapter is a fully working version of the game. Use the bread bat to hit the cheese at the tomato targets. When you've destroyed a complete row, the tomatoes are all redrawn. If you let the cheese hit the bottom of the screen, the life counter is reduced. Once all three lives have been used up, you cannot control the bread, and the score does not update.

Figure 13-1 shows a Bread and Cheese game in progress. This game is actually quite easy to play; it would be interesting to see how much better it would be made by adding a clock that timed the disposal of each level, or some additional forms of player jeopardy.



Note There are some game-play issues with this design that your younger brother might notice, particularly the way that after a level is redrawn, the cheese often collides instantly with one of the tomatoes and gets above the tomato row, bouncing about and making a huge score. If you decide that this is a problem, there are a number of ways you could fix it. I'll leave it to you to sort it out.



FIGURE 13-1 Simple Bread and Cheese game

Improving Code Design

In Chapter 11, “A Game as a C# Program,” in the section entitled “Renaming the *Game1* Class,” you changed the name of the class to one that better reflects the game that’s being created. Now you consider other ways that your programs can be better structured. At the moment, you haven’t given much thought to the structure of the game program itself. When you have needed extra code, you simply added it where it seemed to do the job. However, this is not very good design practice.

It’s much easier if code is structured into well-defined areas. If you think about it, all the cheese, bread, and tomato game elements are used in the same way. The game program performs a number of fundamental actions with these elements during a game:

1. The game elements are set up at the beginning of the game.
2. The game elements are updated during the game.
3. The game elements are drawn during the game.

At the moment, these actions are performed in a piecemeal fashion in the game methods that perform these tasks. However, it makes very good sense to bring the code for each

element together so that they're easier to manage. Rather than having bits of behavior for all the elements in the Update method, you can change the Update method so that it instead calls a method for each game element type:

```
protected override void Update(GameTime gameTime)
{
    gamePad1 = GamePad.GetState(PlayerIndex.One);

    if (gamePad1.Buttons.Back == ButtonState.Pressed)
        this.Exit();

    updateCheese();

    if (lives <= 0)
    {
        return;
    }

    updateBread();

    updateTomatoes();

    base.Update(gameTime);
}
```

The same pattern could be used in the Setup and Draw methods. Note that these changes won't make the game program run more quickly (in fact, the method calls slow things down very slightly), but it makes things much easier for the programmer, as shown next. You might remember that the process of tidying up a program like this is known as refactoring. You first saw this in Chapter 11, where you changed the name of elements in your game to better reflect what they were used for. XNA Game Studio provides some useful refactoring features to help you organize your program and perform refactoring.

Refactoring by Creating Methods from Code

The refactoring support in XNA Game Studio makes it easy to create a method from a block of statements. First, you need to highlight the statements to be placed in the new method. Then right-click the block of code to bring up the Context menu, select Refactor, and then select Extract Method from the Refactor menu, as shown in Figure 13-2.

The Extract Method dialog box now appears, as shown in Figure 13-3. Enter the name of the method to be created and click OK.

XNA Game Studio creates a method with the name you've entered, puts the selected code into the method, and places a call to the method where the code used to be. You could have performed all these tasks yourself, but the automation makes it much easier.

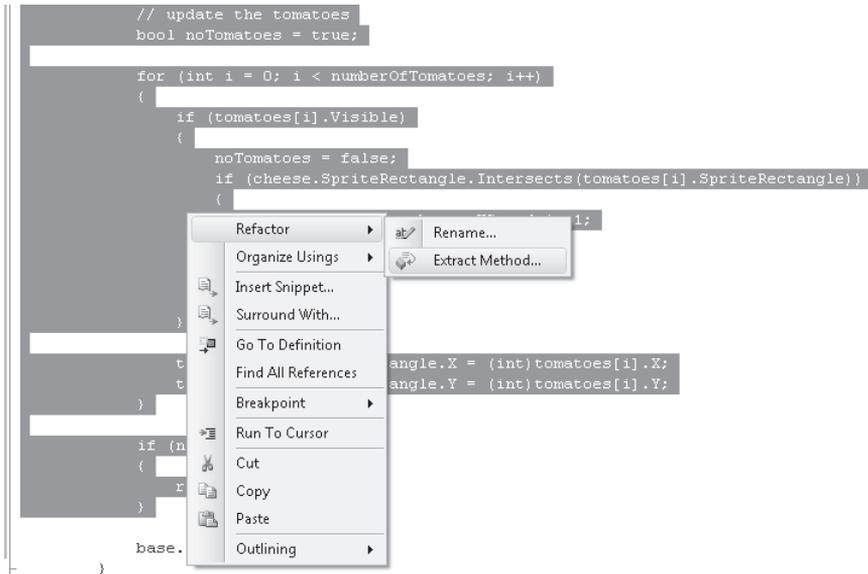


FIGURE 13-2 Opening the Extract Method dialog box

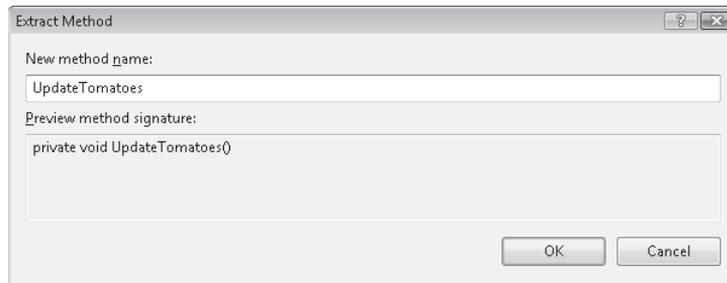


FIGURE 13-3 Creating a method



Note If the statements that you have extracted use variables that are local to the block of code from which the statements were taken, you will find that extracting a method stops your program from compiling correctly. You would need to fix the problem by declaring parameters for the new method and passing the variables as arguments.

Refactoring by Changing Identifiers

Frequently it's necessary to change identifiers as a program is developed. This happens because the purpose of the variables and methods changes as you gain a better understanding of the problem you're solving. At the start of the development, you created a method called `setupSprites`, which set up all the sprite settings for the elements in the

game. However, this method now has other responsibilities; it must also set the score and life counters. If the purpose of a method changes, you should make sure to change the name of the method to reflect its purpose. This means that the name of the method should change to `setupGame`. The refactoring support in XNA Game Studio makes this easy. To rename an identifier, right-click the identifier you want to rename and select the appropriate refactoring command, as shown in Figure 13-4.

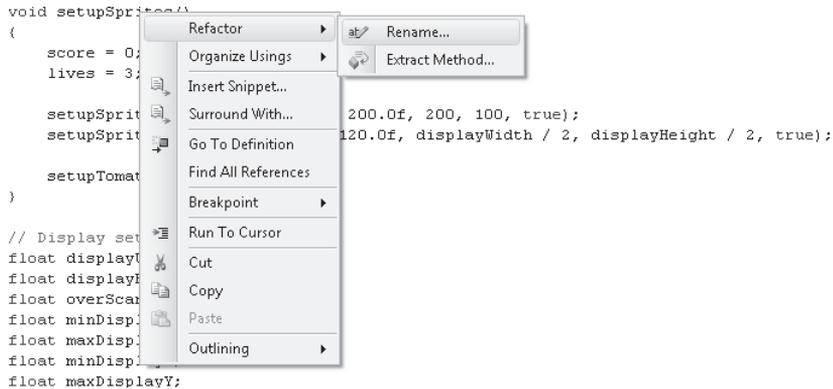


FIGURE 13-4 Selecting the rename operation

The Rename dialog box now appears, as shown in Figure 13-5. You can type in the new name of the method and select options to control the renaming process. If you've created comments or text strings that refer to the method, you can ask XNA Game Studio to update these, too.

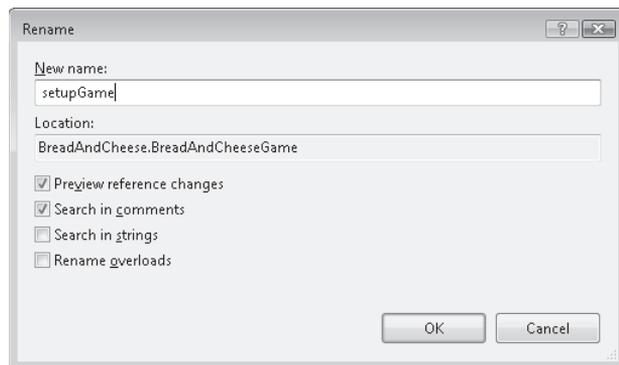


FIGURE 13-5 Renaming a method

By default, the Preview Reference Changes check box is selected so that you are given a chance to see the names that are about to be changed, as shown in Figure 13-6. You can control which changes are to be made by selecting the check box next to each change.

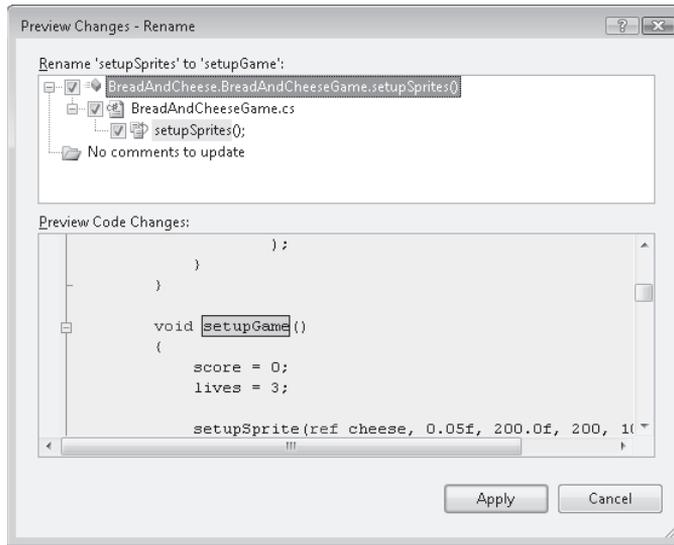


FIGURE 13-6 Previewing name changes

When you click OK, the changes that you have requested are applied, and the program source code is updated. When renaming items, you must be careful that you don't break your program. Figure 13-7 shows the warning that XNA Game Studio displays if it detects that you're about to rename something that's used in other parts of the program.

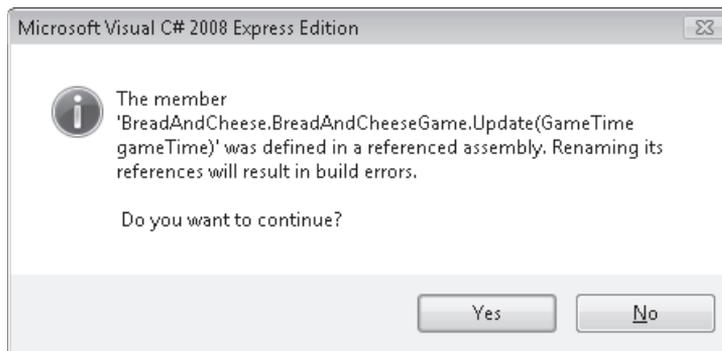


FIGURE 13-7 Warning of invalid name changes

If you ignore this warning and perform the changes anyway, it's very likely that you'll prevent your program from compiling. The good news here, though, is that you can always use the Undo command in XNA Game Studio to remove the changes that you've made. Figure 13-8 shows where the command is on the Edit menu; you can also invoke it by pressing the left looping arrow on the toolbar or by using the key combination Ctrl+Z or Alt+Backspace.

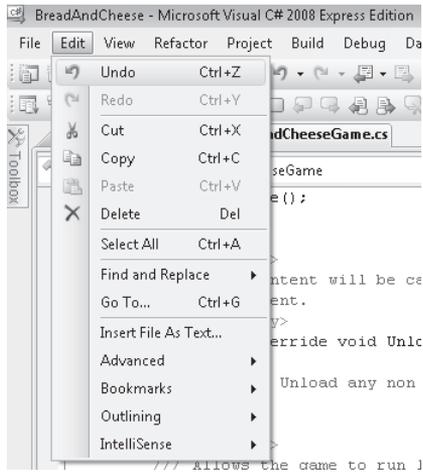


FIGURE 13-8 The Undo command

Creating Code Regions

Another way to make program listings easier to understand is to use regions. A region is an area of the code that you can expand or collapse. For example, you can expand or collapse the view of your code by clicking on the plus (+) or minus (-) signs at the top of a method. You can also create regions that can be expanded or collapsed by enclosing related code in `#region` compiler directives, as shown in Figure 13-9. This shows a region around the collapsed methods that were created to manage the tomatoes in the game.

```

-
    #region Tomato code and data

    Texture2D tomatoTexture;
    GameSpriteStruct[] tomatoes;
    int numberOfTomatoes = 20;
    float tomatoHeight;
    float tomatoStepFactor = 0.1f;
    float tomatoHeightLimit;

+
    private void loadTomatoContent() {...}
+
    void setupTomatoes() {...}
+
    void resetTomatoDisplay() {...}
+
    void updateTomatoes() {...}
+
    void drawTomatoes() {...}

-
    #endregion
  
```

FIGURE 13-9 Creating code regions

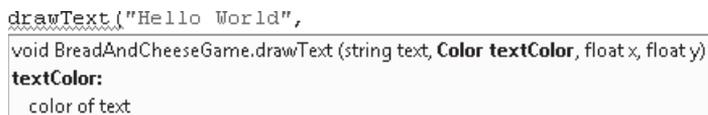
Regions can be placed inside other regions to make it easier for other programmers to find their way around your programs.

Creating Useful Comments

You've seen that Microsoft Visual Studio provides a feature called *Intellisense* when you're writing a program. When you're typing a statement that contains a method call, the structure of the method call is described to you automatically using Intellisense. Some of this information is obtained from specially formatted comments that have been added to the method itself. You first saw comments in Chapter 2, "Programs, Data, and Pretty Colors." They provide a way that you can leave notes in your program that the compiler ignores. If you give comments in a particular format, they can be used by the compiler to provide Intellisense to other programmers. As an example, consider the `drawText` method. Each of the parameters has a particular purpose, and you can add comments to describe them:

```
/// <summary>
/// Draws text on the screen
/// </summary>
/// <param name="text">text to write</param>
/// <param name="textColor">color of text</param>
/// <param name="x">left edge of text</param>
/// <param name="y">top of text</param>
void drawText(string text, Color textColor, float x, float y)
{
    // Draw statements
}
```

The comments are formatted so as to provide XNA Game Studio with Intellisense information so that now when you start coding a call of the method, the extra information is displayed. Figure 13-10 shows how the information is displayed when a call of `drawText` is being coded.



The screenshot shows a code editor with the following text: `drawText("Hello World",`. A tooltip box is displayed below the opening parenthesis, containing the signature `void BreadAndCheeseGame.drawText (string text, Color textColor, float x, float y)`. Below the signature, the parameter `textColor` is highlighted, and its description, `color of text`, is shown below it.

FIGURE 13-10 Using Intellisense comments

The structure of the Intellisense comments has to be exactly right; otherwise, no help is displayed. You can create these by hand, or you can use XNA Game Studio to create a template for you to fill in. To obtain the template, you type three forward slash (`/`) characters in succession in the editor immediately above the item to which you wish to add the comment.

The Great Programmer Speaks: A Great Program Is a Work of Art The Great Programmer reckons that, just as there is artistry in the design of a bridge or other great engineering work, well-written code is a thing of beauty. She regards code that uses properly chosen identifiers and appropriate methods and that is broken down into regions as being as worthy of admiration as any other work of art. She always tries to make sure that her code looks good.

Sample Code: Refactored Bread and Cheese Game The sample project in the 02 Refactored Bread and Cheese Game directory in the resources for this chapter is a refactored version of the game. From the player's point of view, it's exactly the same. However, if you look at the source code of this program, you find that the code has been organized into a set of methods and separated into regions. You should find it much easier to locate particular items of code in the source file.

Adding a Background

At the moment, the game is played on the blue background that is provided by XNA. This is okay, but it doesn't look very special. To improve things, you could add a texture that's drawn behind the game. You can do this by following the same pattern that was used for the other graphics items. The set of background methods shown in this next code block match those that are provided for the bread, cheese, and tomatoes. You need only put calls to the following methods into the appropriate game methods, and you have a game with an attractive background image:

```
#region Background code and data

GameSpriteStruct background;
private void loadBackgroundContent()
{
    background.SpriteTexture =
        Content.Load<Texture2D>("Images\\Background");

    background.SpriteRectangle =
        new Rectangle(
            (int) minDisplayX, (int) minDisplayY,
            (int) (maxDisplayX - minDisplayX),
            (int) (maxDisplayY - minDisplayY)
        );
}
private void updateBackground()
{
}

private void drawBackground()
{
    spriteBatch.Draw(background.SpriteTexture,
        background.SpriteRectangle, Color.White);
}

#endregion
```

The background texture is drawn in an area that fills the playfield. This makes it easier for the player to determine when the cheese is going to bounce.

Note that there's an `updateBackground` method, but it is empty at the moment. Later, you might want to make the background flutter in the breeze or change color as the player approaches the high score. Leaving the method blank makes it easy to add code to do this.

Sample Code: Bread and Cheese with Background The sample project in the 03 Bread and Cheese with Background directory in the resources for this chapter is a version of the game with a rather snazzy tablecloth in the background. Note that although this program runs correctly on a Zune, the graphics in the title and background screens look a little stretched and the text spills off the edge of the screen. This is because the Zune graphics are drawn in “portrait” orientation where the screen is higher than it is wide. If you want to make a proper Zune version of the game you will have to change the font size and perhaps use different textures.

The use of this technique makes it much easier to add new elements to the game program. It also makes it easier to swap one element for another. If other programmers wanted to create a different type of background, you could tell them what methods they would need to provide, and then their code would plug directly into the game code. In later chapters, you will see ways to make genuinely “pluggable” software components that can be added to a game easily.

Adding a Title Screen

At the moment, the game starts when you run the program and then finishes when the last life has been used up by the player. This is not how real games work. If you watch a real video game, you might notice that it has an “attract” mode, where it shows a screen intended to entice the player into playing the game. You can create a simple version of this by adding a title screen like the one shown in Figure 13-11.



FIGURE 13-11 A tasteful title screen

This screen is displayed when the game is not active. You create a title, `GameSpriteStruct`, and all the associated methods in the same way as you created a background earlier in this chapter.

Games and State

To make the title screen appear correctly, the program must manage the *state* of the game. The best way to do this is to create an enumerated type that has values to represent the states that the game can occupy. You first saw enumerated types in Chapter 9, “Reading Text Input.” Each of the possible keys that the keyboard can generate is represented by a value of the enumerated type `Keys`. You create an enumerated type to hold the state of the game. This type has only two values, representing a state when the title screen is displayed and a state when the game is being played. Once the type has been created, you can make a variable of that type to hold the state of the game, setting it initially to the title screen state as follows:

```
enum GameState
{
    titleScreen,
    playingGame
}
```

```
GameState state = GameState.titleScreen;
```

If there are only two states the program can occupy, you might think that this is overkill. You could have just used a Boolean type, perhaps called `gameActive`, and make it `true` to indicate a game in progress and `false` to indicate that the title screen should be displayed. However, you might decide later to add other game states, perhaps one where the high-score table is displayed. This enhancement is easier to implement if you use an enumerated type instead of a Boolean type because you simply need to add a new value to the enumerated type to represent this state.

Using the State Values

The state variable in the game controls what happens in the Draw and Update methods. When the game is in the title screen state, the title screen needs to be drawn. When the game is in the `playingGame` state, the background, cheese, bread, and tomatoes need to be drawn. The following code accomplishes this:

```
protected override void Draw(GameTime gameTime)
{
    spriteBatch.Begin();

    switch (state)
    {
        case GameState.titleScreen:
            drawTitle();
            break;
        case GameState.playingGame:
            drawBackground();
            drawCheese();
    }
}
```

```
        drawBread();
        drawTomatoes();
        drawScore();
        break;
    }

    spriteBatch.End();

    base.Draw(gameTime);
}
```

The Update method in the game contains a similar switch construction that would be used to select the appropriate behavior:

```
protected override void Update(GameTime gameTime)
{
    gamePad1 = GamePad.GetState(PlayerIndex.One);

    if (gamePad1.Buttons.Back == ButtonState.Pressed)
        this.Exit();

    switch (state)
    {
        case GameState.titleScreen:
            updateTitle(); // changes state to playingGame when A pressed
            break;
        case GameState.playingGame:
            updateCheese(); // changes state to titleScreen when game ends
            updateBread();
            updateTomatoes();
            break;
    }

    base.Update(gameTime);
}
```

Building a State Machine

Now that you've identified the states that the game occupies, you need to consider what causes the game program to move from one state to another. In professional programming, this is shown using a state diagram, as shown in Figure 13-12.

A state diagram shows the entry point (the black filled-in blob) and then arrows that show transition from one state to another. Some of the arrows have "guard conditions" on them that identify things that must happen for the transition to take place. The diagram shows that when the game starts, it moves into the "Title Screen" state, and then, if the A button is pressed, it moves into the "Playing Game" state. Once the player has no lives left, it moves back onto the title screen.

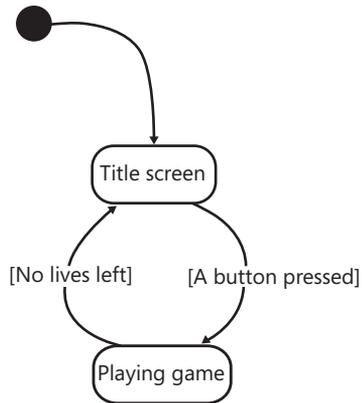


FIGURE 13-12 A game state diagram

State diagrams are useful in showing how a program behaves. They tell the programmer that at certain points, the program must behave in a certain way; for example, in the previous game state machine, there's no need to test the A button when the player is playing the game. State diagrams are used often in games when game items have a range of possible states. Once you've identified the states, you need to create some methods that manage the transition from one state to another. You need one method to start the game and one that's called when the game is over. The methods must set up all the variables as required and then change the state of the game. Look at the following code:

```

#region Game state management

void startGame()
{
    score = 0;
    lives = 3;
    startCheese();
    startBread();
    startTomatoes();
    state = GameState.playingGame;
}

void gameOver()
{
    if (score > highScore)
    {
        highScore = score;
    }
    state = GameState.titleScreen;
}

#endregion

```

The `startGame` method clears the score, sets the number of lives left to three, and begins the game. It also calls a method for each of the game elements to reset it to a known position

before the game starts running. This makes sure that the bread is sensibly placed on the screen and the cheese isn't so near the edge that the player loses a life as soon as the game starts, which wouldn't be very fair.

The `gameOver` method updates the high score if it's been beaten and then puts the game back to the `titleScreen` state. Now all you need to do is call these methods at the appropriate times to change the states in the game state machine. When the player presses the A button, the game must call the `startGame` method. The test for this should be placed in the `updateTitle` method, which updates the title screen:

```
if (gamePad1.Buttons.A == ButtonState.Pressed)
{
    startGame();
}
```

A game ends when the last life is used up. The test for this should be placed in the `updateCheese` method:

```
if (cheese.Y + cheese.SpriteRectangle.Height >= maxDisplayY)
{
    cheese.YSpeed = Math.Abs(cheese.YSpeed) * -1;
    lives = lives - 1;
    if (lives <= 0)
    {
        gameOver();
    }
}
```

Sample Code: Bread and Cheese with Title Screen The sample project in the 04 Bread and Cheese with Title Screen directory in the resources for this chapter is a version of the game that operates using a state machine to provide a title screen.

Many games show different displays during their "attract mode." It's easy to get your game to do this by making the program change from one state to another over time. The game code can do this by counting the number of times that `titleUpdate` has been called and then moving to another state when the counter reaches a particular value.

The Great Programmer Speaks: State Machines Are a Great Way to Write Programs The Great Programmer uses state machines a lot in her code. They let her programs "remember" where they are so that they can respond correctly when an event happens. She starts off by working out what states her program must occupy and identifying the events that cause the states to change. Once she has done this and drawn her state diagram, she can go ahead and write the code.

Conclusion

At last, you've created what might be regarded as a finished game. It has some rough edges and is rather simple to play, but it should keep your younger brother quiet for an hour or so. You've seen how the way a program is structured and laid out in the source file can have a huge impact on how easy it is to work with the code. You've also discovered some fundamentals of game program behavior by finding out how a state machine can be used to manage the operation of a game.

Chapter Review Questions

I don't know a better way to end a chapter than with some review questions. I really don't.

1. A program returns from a method only when it reaches the end of that method block.
2. Refactoring is how you change the type of the variables.
3. Method names can't be changed once a program has been written.
4. Each code region in a program is stored in a separate source file.
5. Intellisense information is retrieved from code regions.
6. A state machine can have only two possible states.

Chapter 14

Classes, Objects, and Games

In this chapter, you will

- Find out about making programs using software objects.
- Learn some software engineering terms and what they mean when we write programs.
- Use objects to add some new elements to our game easily.

Introduction

In this chapter, you learn something about the craft of programming and how writing a good solution to a problem is all about organization. You also see how a well-organized program is simple to extend and modify, and how to create software components that make it possible to create code mashups very easily.

The Great Programmer is very keen on this chapter. You might not be quite so enthusiastic, but it has to be said that objects do make software construction much easier. The whole of Microsoft XNA is built around objects, so to get a complete understanding of how the framework fits together, you really have to know about objects and how a system is built using them.

Design with Objects

We have seen that if we want to store a block of information about a particular item, we can bring all this together in a structure. We used this technique when we created the `GameSpriteStruct` structure in Chapter 12, “Games, Objects, and State.” Structures are useful, but we would like to be able to solve other problems when we create large programs:

- We want to make sure that a given item in our program cannot be placed into an invalid state; that is, we don’t want to have tomatoes that can be positioned off the display screen.
- We want to be able to separate a large system into distinct and isolated parts that can be developed independently and made to work together; that is, we want to get one team of programmers working on game backgrounds, another on the cheese, another on animated bread, and so on.
- We want to make sure that the effort involved with making new types of game elements is as small as possible; that is, if we decide to introduce a new “killer tomato” we want to be able to make use of the existing tomato code as much as we can.

To do all these things, we are going to have to start to consider programs from the point of view of object-based design. This section should come with some kind of a health warning along the lines of "Some of these ideas might hurt your head a bit at the start." But the following points are also very important:

- Objects don't add any new behaviors to our programs—we know just about everything we need to know to write programs when we know about variables, statements, loops, conditions, and arrays.
- Objects are best regarded as a solution to the problem of design. They let us talk about systems in general terms. We can decide which objects we need and then go back and refine how the objects actually do their tasks once we have decided how they fit together.

You can write just about every program that has ever been written just by using the technologies that we have seen so far. But objects allow you to work in a much nicer way. And so you are going to have to get the hang of them, like it or not.

An Object Refresher Course

At this point, it is probably worth reminding ourselves what a software object is. An object is a collection of data (fields) and behaviors (methods) that a programmer creates for a particular purpose. An XNA game is an object. It contains data such as the `GraphicsDevice` (which describes the display system our game can use) and methods such as `Draw` (which provides the draw behavior for the game). You have created the beginnings of an object with your `GameSpriteStruct` structure, which brings together information about an item to be displayed on the game screen.

In this chapter, you find out what makes a full-fledged object and how systems are designed using them. To learn how objects can be used in the design and construction of a game, you rebuild the Bread and Cheese game program, this time using objects. Then, in the payoff at the end, you find out how easy an object-based design makes it to add a new game element in the form of the "deadly pepper," which provides a new hazard for the player to deal with. You learn some of the software engineering principles that the Great Programmer seems to know, and how they can be used to improve the design of the game program.

Cohesion and Objects

Cohesion is a term used by software engineers to express how "together" an object is. A "together" object is a bit like those people who are always very organized and always have everything sorted. If you went camping with a "together" object, you would find that it would always know what to do and have the tools with it to do the job. It would not be the one borrowing a can opener from the people in the tent next door so that it could open the can of beans for breakfast. It would have a "can opener" behavior built in, along with everything else it needed to be able to do.

The `GameSpriteStruct` type is not very “together”; all the data inside it has been made public so that the outside world can get hold of its contents and use the values. Although this has been quite convenient, it is not the best way to create reliable programs. At the moment, it is possible for any code to access the value of `SpriteRectangle` that the `GameSpriteStruct` uses to position itself on the screen. This means that a naughty programmer could change the location of the sprite to a random place, which is not good. This would be even more dangerous if you were designing objects to hold bank account information, where you want to protect the account balance and control how money is paid in and out.

Creating a Cohesive *BatSpriteStruct*

Rather than having one generic type of sprite structure, you must now think about each kind of sprite in turn. You can start with the bat, which in the previous game was drawn as a piece of bread. Once you make a bat sprite, you have something that can be moved around the screen by the player. This might come in very handy in any game you might create later that needs any kind of bat. What you want is a `BatSpriteStruct` that can look after itself and keep its internal data private. It should be able to behave as a bat, and it should not be possible for other programs to upset this behavior. To do this, you need to protect the data inside the bat object, so that programs outside can't see or change the values that control how the bat behaves.

Protecting Data Inside Objects

The C# language provides a means by which data in an object can be made private, so that only methods inside the object can access the data. Of course, once the data has been made private, it is impossible for the outside world to use the data to interact with the bat, so you must add some public behaviors (methods) so that the bat can be asked to do things. Public members of a class can be used by code in any other class. When creating objects with high cohesion, the data in the object should be private and the methods should be public. You select whether or not a member is private or public by putting the appropriate C# keyword in front of the class member when you declare it. From now on you will take care to make sure that only members of a class that need to be used by other classes are made public, and that all other members are made private.

BatSpriteStruct Behaviors

The early part of the design of an object focuses on what it needs to do. Then you can consider the data that the object needs to hold to perform the required actions. There are four things we want the bat to be able to do for our game:

- **Load its content** Load the texture to be used to draw the object itself on the screen.
- **Start a new game** Set up the rectangle for drawing the bat and set the initial position and speed at the start of a game.
- **Update itself** Update the bat position during the game.
- **Draw itself** Draw the bat at its required position.

There might be other methods that we need later, but these are a start. You can create a method for each of these actions. If this looks like you are taking the different methods out of the regions that were set up when we refactored the program and putting them inside the bat object, that is exactly what you are doing. The methods that make a bat behave like a bat are now being moved into a bat structure. These methods work on data held privately inside the object, so that any code outside the bat is not able to put it in the wrong place on the screen by directly changing the member variables that hold its position:

```

struct BatSpriteStruct
{
    private Texture2D spriteTexture;
    private Rectangle spriteRectangle;
    private float x;
    private float y;
    private float xSpeed;
    private float ySpeed;

    public void LoadTexture(Texture2D inSpriteTexture)
    {
        spriteTexture = inSpriteTexture;
    }

    public void StartGame(
        float widthFactor,
        float ticksToCrossScreen,
        float inDisplayWidth,
        float initialX,
        float initialY)
    {
        spriteRectangle.Width = (int)((inDisplayWidth * widthFactor) + 0.5f);
        float aspectRatio =
            (float)spriteTexture.Width / spriteTexture.Height;
        spriteRectangle.Height =
            (int)((spriteRectangle.Width / aspectRatio) + 0.5f);
        x = initialX;
        y = initialY;
        xSpeed = inDisplayWidth / ticksToCrossScreen;
        ySpeed = xSpeed;
    }

    public void Draw(SpriteBatch spriteBatch)
    {
        spriteBatch.Draw(spriteTexture, spriteRectangle, Color.White);
    }

    public void Update()
    {
        GamePadState gamePad1 = GamePad.GetState(PlayerIndex.One);
        x = x + (xSpeed * gamePad1.ThumbSticks.Left.X);
        y = y - (ySpeed * gamePad1.ThumbSticks.Left.Y);
        spriteRectangle.X = (int)x;
        spriteRectangle.Y = (int)y;
    }
}

```

This is all that is needed to make a working bat. The world outside the bat knows it only by the methods it exposes, and everything about how the bat works is hidden inside and can't be damaged by the outside world.

Objects and Encapsulation

Another software engineering term we can use at this point is *encapsulation*, the approach where everything relating to a particular part of a system is placed in a single object. If you think about it, this is how a lot of appliances work. Your MP3 player contains a computer and some very complicated software, but as far as you are concerned, it just has buttons that you press to select music tracks and play them. You don't know (or even care) how it works internally. You just know which buttons to press to get sound out.

Users of the bat sprite can work the same way. They don't need to know how the bat manages internal state, what variables it contains, or how the methods actually work, they just know what each method does and how to use it. Any game can now contain a `BatSpriteStruct` value and call the methods at the appropriate points to add a bread bat to the game.

Sample Code: Bat Sprite Structure All the sample projects can be obtained from the course instructor. The sample project in the 01 Bat Sprite Structure directory in the resources for this chapter contains a `BatSpriteStruct` structure that implements a self-contained bat. This is then used to provide a bread bat that can be steered around the screen.

The next step is to consider how the bread bat can be made to work with other objects to create a working game.

The Great Programmer Speaks: Cohesion Is Good The Great Programmer is going to be talking a lot in this chapter. She really likes cohesion. She likes the way that the bat is now "master of its own destiny." There is no chance that any other part of the program can affect the behavior of the bat. They have to use the four methods described in this section to drive it, and they cannot damage the data inside it. She could give this implementation of the bat to a customer knowing that they could not break it, which for her is a very good thing.

Coupling Between Objects

Now that you have a bat object, you need to connect it to the other game objects. You start with the cheese object, which is acting as the ball in the game and needs to be able to find the location of the bat so that it can make the ball change direction when it hits the bat. Software engineers like the Great Programmer call this kind of object linkage *coupling*. She carefully manages the amount of coupling in her programs because a lot of coupling in a program is bad. If all the objects in a program are coupled together, this makes it much harder to change one component because you have to worry about how the change might affect everything else.

This is a bit like organizing a party. The more people you have to organize, the harder it is to find a free evening. If you are inviting (coupled to) only one or two people, then you can sort out things like the date of the party really quickly. However, if you have lots of friends, and they have lots of friends that they want to bring, too, it can be very hard to agree on a date.

The fewer objects that are coupled, the easier it is to manage change in a program. It is also easier to manage change if the way that the objects are coupled is restricted to a few well-defined connections. Rather than letting the ball structure have access to all the data inside the bat, it makes sense for the bread bat to provide a method that lets the ball ask if it has collided with it. If this is the only form of communication between the ball and the bat, any other changes to them (for example, an animated trail of crumbs behind the bread bat) can be added without fear of changing the way this part of the game works. Good program design is all about making sure that the amount of coupling between different program elements is as small as possible.

The Great Programmer Speaks: Proper Design Is Vital This all sounds like a lot of work. Your game seems to be getting more complicated for no good reason. You make this point to the Great Programmer, who just shrugs and starts up a copy of "Halo Wars" on her Xbox. She gets to a point where her forces are attacking an enemy base. The screen is alive with troops, spartans, warthogs, and gunfire. Then she pauses the game and reminds you that the program behind the scenes must be keeping track of every battlefield element, every vehicle, character, bullet, and flash of light. There must be hundreds of different objects on the screen, all interacting with each other and doing their own thing to make up the game world. A team of programmers must have worked on these objects, with one group doing the vehicles, another the characters, a third the bullets, and so on.

She tells you that if the objects in the game were not carefully organized, it would have been impossible to create the game program. She reckons that modern computer games are among the most complicated software around, and so you need to use these techniques to make sure that the programs are properly structured and the development can be managed across a team of people.

Creating a Link Between the Bread Bat and the Cheese Ball

You will implement the coupling between the bat and ball by providing a method in the `BatSpriteStruct`. The method is called `CheckCollision`:

```
public bool CheckCollision(Rectangle target)
{
    return spriteRectangle.Intersects(target);
}
```

Next, the ball has to be provided with a way that it can find the bat sprite when the game is running. The best way is to provide the `Update` method in the cheese with a reference to the `BreadAndCheeseGame` game object that represents the running game. The ball can then get hold of data items in the game, including the bat sprite. This link also allows the ball to tell the game itself that lives have been lost if the ball hits the bottom of the display. This information is provided as a parameter to the call of `Update` in the ball as follows:

```

public struct BallSpriteStruct
{
    // ...
    // All the other members for the ball
    // ...

    /// <summary>
    /// Update the ball position. Handle collisions with the bat.
    /// </summary>
    /// <param name="game">Game the ball is part of</param>
    public void Update(BreadAndCheeseGame game)
    {
        x = x + xSpeed;
        y = y + ySpeed;

        // Set the sprite rectangle to the new position
        spriteRectangle.X = (int)(x + 0.5f);
        spriteRectangle.Y = (int)(y + 0.5f);

        // Check to see if the ball has hit the bat
        if (game.BreadBat.CheckCollision(spriteRectangle))
        {
            // bat has hit the ball.
            ySpeed = ySpeed * -1;
        }

        // Other updates here
    }

    // ...
    // Rest of ball members
    // ...
}

```

When the game is running, the ball can now check for collisions with the bat and behave correctly when it hits it. When the game calls the Update method in the ball, it needs to provide a reference to the game object. C# provides a key word called `this`, which allows an object to get hold of a reference to itself, shown in bold here:

```

// Update method for the BreadAndCheeseGame
protected override void Update(GameTime gameTime)
{
    GamePadState gamePad1 = GamePad.GetState(PlayerIndex.One);

    if (gamePad1.Buttons.Back == ButtonState.Pressed)
        this.Exit();

    BreadBat.Update(this);
    CheeseBall.Update(this);

    base.Update(gameTime);
}

```

The `this` key word means “a reference to me.” When used within the `BreadAndCheeseGame` class, it means the currently executing instance of the game class. This is exactly what the ball needs, so that it can get the `bat` variable out of the game and use it to check for collisions. The ball can also use this reference to tell the game when a life has been lost because the ball has hit the bottom of the screen.

Designing Object Interactions

It is important to manage carefully what each of the game objects is responsible for, what it needs to interact with, and what it needs from what it interacts with. There are several objects in our game, and for each of them, you need to work out what methods it needs to have and who uses them. You can draw these out in tables like Table 14-1.

TABLE 14-1 Methods in *BatSpriteStruct*

| Method | Description | Users |
|-----------------------------|--|---------------------------------|
| <code>LoadTexture</code> | Loads the texture into the bat | <code>BreadAndCheeseGame</code> |
| <code>StartGame</code> | Calculates the bat size and positions it for the start of the game | <code>BreadAndCheeseGame</code> |
| <code>Draw</code> | Draws the bat | <code>BreadAndCheeseGame</code> |
| <code>Update</code> | Updates the bat | <code>BreadAndCheeseGame</code> |
| <code>CheckCollision</code> | Checks for collision with the bread bat | <code>Ball</code> |

This looks very much like the list of bat methods we saw earlier, but there is now the additional method to check for collisions. This table tells us what objects the bat interacts with. For example, you can see that the design of the game does not need the bat to interact with the tomatoes. You can make changes to the bat behavior without affecting how the tomato works, and vice versa.

Software designers draw up tables like these when they are trying to decide what each thing in a system should do. I’m not suggesting that you should create such tables every time you write a program, but they do help you think about the way your solution should be structured.

Objects and Messages

The bat object is one of the simplest ones, but some of the objects need to change the state of the game. Every time the ball hits the bottom of the screen, it needs to tell the game that a life has been lost, and when the ball hits a tomato target, this causes the game score to increase. This makes the game itself a kind of “fourth object,” after the bat, ball, and tomato targets. Table 14-2 lists methods for a game object.

TABLE 14-2 Methods in *BreadAndCheeseGame*

| Method | Description | Users |
|------------|---------------------------|-------|
| LoseLife | Lose a life | Ball |
| AddToScore | Adds a value to the score | Ball |

The ball object needs to use a reference to the game it is part of, so that it can call methods in the game to send these messages. When the ball is updated, it is given such a reference so that it can call the methods at the appropriate times.

Messages and Organization

At this level, designing a program sounds a lot like an organizational problem, and it is. Consider the example of a ship: The captain gives orders to the mate to set sail in a particular direction. But the captain must also respond to messages from those on the ship. The captain tells the lookout to scan the horizon for pirates. If the lookout spots a suspicious ship, the lookout calls out to the captain, who sends out further orders to the crew to prepare to repel boarders.

A good programmer must be able to work out what each object needs to do and how the objects communicate to create a solution. Note that there is never just one way to structure a program. If you look at my design, you find that the cheese ball does most of the work (you might want to call it the “Big Cheese,” I suppose—but I won’t) but it is perfectly possible to organize everything around another game object if you wish. The Great Programmer says that there are only two kinds of solutions—those that work and those that don’t—and that everything else is just detail. In this, I’m inclined to agree with her.

Sample Code: Bread and Cheese Sprite Structures The sample project in the 02 Bat and Ball Sprite Structures directory in the resources for this chapter contains a `BatSpriteStruct` structure that implements a self-contained bread bat and `BallSpriteStruct` that implements the cheese. This does not implement all the game play (there are some tomatoes missing) but it does have all the behaviors for the bat, ball, and other game objects. A full table of all the objects and how they interact is also included in the directory.

Container Objects

We now have a very well-organized game that is not complete. The ball and the bat interact properly, but there are presently no tomato targets to aim at. Actually, it turns out that “No Tomatoes” is the punch line of one of my favorite jokes (“What is red and not there?”), but this is not going to help in terms of getting a game that is worth playing. We now need to investigate how we can create tomato target objects and add them.

When adding tomatoes to the game, we have to ask ourselves whether the game should work with individual tomato targets or whether it should work in terms of a collection of them. From the point of view of the game, it makes very good sense to regard the whole row of targets as a single item. The row has to manage things like deciding when the last target has been destroyed, and it makes sense for all this behavior to be hidden from the game itself. The game just calls the Update and Draw behaviors for the row, as it would any other object in the game.

The fact that there are lots of targets inside this object does not affect the game at all. You can use this technique to good effect whenever a game of yours needs to manage lots of related items. Many games have “waves” of attacking aliens, and putting them all in a single collection like this makes them much easier to manage. Table 14-3 lists methods for a target collection.

TABLE 14-3 Methods in *TargetRowStruct*

| Method | Description | Users |
|----------------|---|--------------------|
| LoadTexture | Loads the texture for use on the targets | BreadAndCheeseGame |
| StartGame | Calculates the texture size and positions all the targets for the start of the game | BreadAndCheeseGame |
| Draw | Draws all the visible targets | BreadAndCheeseGame |
| Update | Updates the targets and redraws the row if no targets are left | BreadAndCheeseGame |
| CheckCollision | Checks for collision with the cheese and hides the target that was hit | Ball |

These methods look very similar to the ones supplied by the bat sprite, although the way that they are used is slightly different.

The next block of code shows the data that `TargetRowStruct` stores for a row of tomato targets. The texture is stored once for the entire row, and there is an array of rectangles that holds the position on the screen of each of the targets. This illustrates another common game technique: the same texture is used for a large number of game objects. There is also an array called `TargetVisibility`, which is used to keep track of which targets in the row are visible. This controls the draw process and is also used to decide when a row needs to be restored and redrawn at the end of a level:

```
public struct TargetRowStruct
{
    private Texture2D targetTexture;
    private Rectangle[] targets;
    private bool[] targetVisibility;

    private int numberOfTargets;
    private float targetWidth;
    private float targetHeight;
    private float targetStepFactor;
    private float targetHeightLimit;
}
```

Sample Code: Bat, Ball, and Targets The sample project in the 03 Bat, Ball and Targets directory in the resources for this chapter contains a version of the game that is nearly playable. You can direct the bread bat around the screen and use it to send the ball toward the targets, which vanish when they are hit. When the last target is destroyed, the whole row is redrawn correctly.

Perhaps the most interesting thing about this sample program is the Draw method:

```
protected override void Draw(GameTime gameTime)
{
    GraphicsDevice.Clear(Color.CornflowerBlue);

    spriteBatch.Begin();

    BreadBat.Draw(spriteBatch);
    CheeseBall.Draw(spriteBatch);
    TomatoTargets.Draw(spriteBatch);

    spriteBatch.End();

    base.Draw(gameTime);
}
```

This Draw method is now tiny. All the responsibility for the draw behaviors has been delegated to the objects in our game. If we add more game objects, we can use the same mechanism.

Background and Title Screen Objects

The final two objects that are needed for the game are the background and title screen. These are actually very similar, in that they are both just textures that must be drawn over the entire screen. However, the title screen is slightly different in that it has an Update behavior that checks for the player pressing the A button. When the player presses the A button, the game needs to start, which means that the BreadAndCheeseGame object must provide a method that can be called to get the game going. Here's the title screen's Update method:

```
public void Update(BreadAndCheeseGame game)
{
    if (game.GamePad1.Buttons.A == ButtonState.Pressed)
    {
        game.StartGame();
    }
}
```

This is the Update method for TitleSpriteStruct. It is provided with a reference to the game from which it reads the gamepad settings. If the gamepad has the A button pressed, the StartGame method is called to get the game going.

Sample Code: 04 Bread and Cheese The sample project in the 04 Bread and Cheese directory in the resources for this chapter contains a version of the game that is fully playable. It works in exactly the same way as the one you developed in the previous chapter, but the Great Programmer prefers to play this version because it is structured better.

At first glance, it looks very similar to the original code, but there are some important changes. All the components could be taken out and used in other games. If you think another game you're developing would be improved by a row of targets or some bouncing balls, you can add the objects and connect them into the Draw and Update behaviors of the game easily.

You have started to build a library of items that can be reused for different games. It now looks a lot easier to make an XNA version of tennis because you have the ball and bat components ready-made. However, reusing components isn't quite as easy as you might like, and we do seem to have a lot of code duplication, in that every structure we have made contains the same `LoadTexture` method. You might be wondering if there is an easier way to arrange the game objects, and it turns out there is. At this point, we have to leave behind structures and start to work with classes. But first we have to consider how classes and structures differ.

Classes and Structures

In C#, classes and structures are two different kinds of object. They can both hold data fields and contain methods. However, there are some crucial differences between the two. One is that structures are managed in terms of *value*, whereas classes are managed in terms of *reference*. We first discovered these terms in the section entitled "Working with Arrays, Objects, and References," in Chapter 9, "Reading Text Input." Now it is time to understand how they really work and how to use them.

Creating and Using a Structure

We have already seen how to make a structure in C#. The `BackgroundSpriteStruct` structure was created to hold information about the background display in our game. This is the simplest display element in the game; it just displays the tablecloth texture behind our game sprites:

```
public struct BackgroundSpriteStruct
{
    private Texture2D spriteTexture;
    private Rectangle spriteRectangle;

    public void LoadTexture(Texture2D inSpriteTexture)
    {
        spriteTexture = inSpriteTexture;
    }
}
```

```

public void SetRectangle(Rectangle inSpriteRectangle)
{
    spriteRectangle = inSpriteRectangle;
}

public void Draw(SpriteBatch spriteBatch)
{
    spriteBatch.Draw(spriteTexture, spriteRectangle, Color.White);
}
}

```

Once the structure has been set up, the program can declare variables of this type:

```
public BackgroundSpriteStruct Background;
```

This sprite contains the texture for the background. Later in the program, the sprite is set with the size of the rectangle it is going to use to draw:

```

// fill the visible area with the background texture
Background.SetRectangle(
    new Rectangle(
        (int)minDisplayX, (int)minDisplayY,
        (int)(maxDisplayX - minDisplayX),
        (int)(maxDisplayY - minDisplayY)
    ));

```

This statement creates a `Rectangle` that fills the playable area of the screen and sets this as the one that is used by the background texture when it draws itself.

Creating and Using an Instance of a Class

We can make a tiny change to the C# code shown previously by converting the background sprite to a class:

```

class BackgroundSpriteClass
{
    // rest of object just as before
}

```

The game element information is now being held in a class rather than a structure. You might think that we can now use a `BackgroundSpriteClass` value in exactly the same way as the structure version, but this does not work. The program compiles correctly, but when we try to run it, the following exception is thrown:

```
System.NullReferenceException was unhandled
```

What is going on? To understand what is happening, you need to know what is performed by this statement:

```
BackgroundSpriteClass Background;
```

It looks like the declaration of a variable called `Background`. But in the case of a class, it is not what it seems. What you actually get when the program obeys the statement is a new reference variable called `Background`. This reference variable is allowed to refer to instances of the `BackgroundSpriteClass`. You can think of a reference a bit like a luggage tag, in that it can be tied to something with a piece of rope. Figure 14-1 illustrates this concept.



FIGURE 14-1 The `Background` reference variable as a luggage tag

A program uses a reference by following the rope to the object it is tied to. When we used arrays in Chapter 9, we had the idea of arrows that “point” at the object. A tag tied with a piece of rope is a slightly more accurate way of describing what is happening. The thing to remember is that when you create a reference, you don’t actually get one of the things that it refers to, you just get a tag. When the program runs and tries to follow the reference to get to an object, it fails, because the reference does not actually go anywhere. A reference is initially set to the value `null` which we first saw in Chapter 9 in the section entitled “References and *null*.” As we saw then, following a `null` reference results in a program failing.

You can solve this problem by creating an instance of the class and then connecting our tag variable to it. The best place to do this is in the `Initialize` method of the game:

```
protected override void Initialize()
{
    setScreenSizes();

    Background = new BackgroundSpriteClass();

    // Other initialization stuff here

    base.Initialize();
}
```

This part of the method creates an instance of the `BackgroundSpriteClass` class and makes the reference variable `Background` refer to it. We have seen this new key word before. We use it to create arrays. This is because an array is actually implemented by a class, and so we use `new` to create it. When we create the instance, we actually connect the tag to an object in memory, as shown in Figure 14-2.

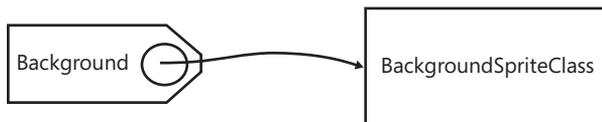


FIGURE 14-2 The `Background` reference variable connected to a `BackgroundSpriteClass` instance

References

We now have to get used to the idea that if we want to use classes, we have to use references. The two come hand in hand and are inseparable. Structures are useful, but for real object-oriented satisfaction, you have to have a class, and that means that we must manage our access to a particular instance by using references to it. Actually, this is not that painful in reality, in that just about all the time you can treat a reference as if it really was the object, but you must remember that when you hold a reference, you do not hold an instance—you hold a tag that is tied onto an instance.

Multiple References to an Instance

Perhaps another example of references would help at this point. Consider the following code:

```
BackgroundSpriteClass Background = new BackgroundSpriteClass ();
BackgroundSpriteClass temp = Background;
temp.SetRectangle(
    new Rectangle(
        0, 0,    // position of rectangle
        800, 600 // size of rectangle
    ));
```

The question is What is the resulting value of the rectangle in Background? If we draw a diagram like the one in Figure 14-3, the answer becomes clearer.

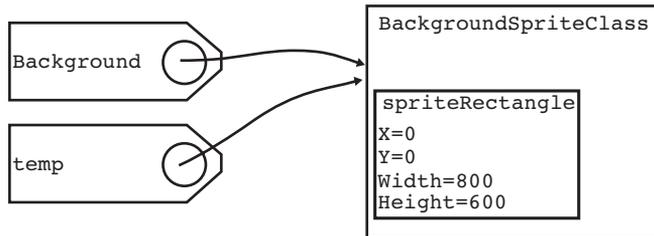


FIGURE 14-3 Multiple references to a single *BackgroundSpriteClass* instance

Both of the tags refer to the same instance of *BackgroundGameSprite*. This means that any changes that are made to the object that *temp* refers to also are reflected in the one that *Background* refers to because they are the same object. This indicates a trickiness with objects and references. There is no limit to the number of references that can be attached to a single instance, so you need to remember that changing the object that a reference refers to will change that instance from the point of view of other references to the same object.

No References to an Instance

Just to complete the description, we need to consider what happens if an object has no references to it, as in the following:

```
BackgroundSpriteClass Background = new BackgroundSpriteClass ();
Background.SetRectangle(
    new Rectangle(
        0, 0,    // position of rectangle
        100, 200 // size of rectangle
    ));
Background = new BackgroundSpriteClass ();
Background.SetRectangle(
    new Rectangle(
        0, 0,    // position of rectangle
        800, 600 // size of rectangle
    ));
```

This code makes a `BackgroundSpriteClass` instance, sets the rectangle to a particular value, and then makes another `BackgroundSpriteClass` instance and sets the rectangle of that one to a different value. The question is: What happens to the first instance? Again, this can be made clear with a diagram such as Figure 14-4.

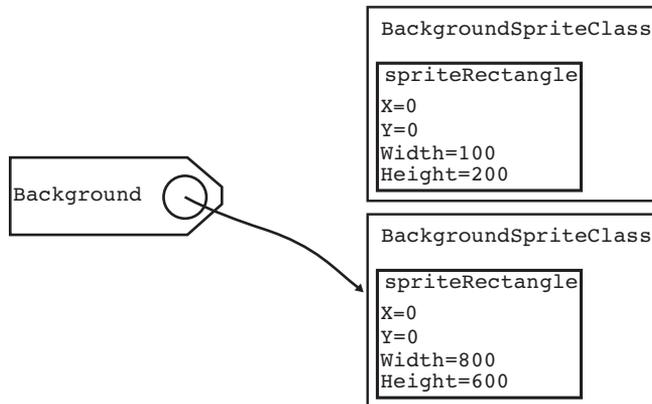


FIGURE 14-4 No references to a `BackgroundSpriteClass` instance

The first instance is shown “hanging” in space, with nothing referring to it. As far as using data in the instance is concerned, it might as well not be there. When your program is running, a special process called the *garbage collector* has the job of finding such useless items and disposing of them. You first saw the garbage collector in Chapter 9 in the aptly named section “Say Hello to the Garbage Collector”; now you know the full reference-powered truth about how the process works.

Why Bother with References?

References don’t sound much fun at the moment. They seem to make it harder to create and use objects and can be the source of much confusion. So why do we bother with them?

To answer this, we can consider the Pacific island of Yap. The currency in use on this island is based around 12-foot-tall stones that weigh several hundred pounds each. The value of a “coin” in the Yap currency is directly related to the number of men who died in the process of bringing the rock to the island. When the residents pay someone with one of these coins, they don’t actually pick it up and give it to the person. Instead, they just say, “The coin in the road at the top of the hill is now yours.” In other words, they use references to manage objects that they don’t want to have to move around.

That is why we use references in our programs. A program can load textures, sounds, and other large objects and they can be left sitting in memory. If a method needs to be given a particular object to work with (for example, if a large sound effect needs to be played), the method can be supplied with a reference to the sound to be used. A downside with using references is that whenever a program wants to use an actual value, it needs to follow the reference to get to the item. This can slow a program down slightly.

Value and Reference Types

We know that everything in C# is an object and that objects can contain methods and data fields. We also know there are two kinds of objects: those managed by value and those managed by reference. Objects managed by value include all the low-level data types such as `int`, `float`, and `double`, along with slightly more complex XNA data types such as `Color`. Any object created as a C# `struct` is also managed by value. By default, whenever a program does something with an object that is managed by value, the *value* of that object is used. The assignment operation copies the value of a variable from one to another. Value types are used in situations where you are working with small amounts of data (for example, numeric values), and the effort of following references would slow things down.

Objects managed by reference include large and complex types such as the `SoundEffect` and `Texture2D` items in an XNA game. The reference assignment makes the variable being assigned to refer to the same object as the source. Whenever a program does something with an object that is managed by reference, a *reference* to that object is used. This means that large objects can be used within a program without the effort of actually copying their contents around in memory.

Should Our Game Objects Be Classes or Structures?

Classes are objects that are managed by reference. Structures are objects that are managed by value. Up to now, we have used structures because we like the way that they can combine data and behaviors and we don’t need to use `new` to make them; but now, classes are starting to look interesting. We have come to an important question. What should we do with our game objects? Should they be value types (structures) or reference types (classes)? We have reached that high spot of many films and TV shows, the courtroom scene. This is where the prosecutor and the defendant do battle to decide the outcome—should the hero walk free or go to jail? So, without further ado, let’s present the case for both sides, with you as the judge.

Game Objects Should Be Structures Managed by Value

First, we have the case for game objects as structures. The case here looks pretty clear-cut. Value types are a good idea when the objects don't hold much data, your program makes heavy use of them, and you want to have lots of them in memory. The objects in our game are actually quite small, only a few tens of bytes in size, and a game could have hundreds, perhaps thousands of them on the screen at once. All the game objects are updated and drawn 60 times a second, and so they are used a lot. This would be much quicker if the program didn't have to waste time following references to find each one.

At this point, the case for the structure looks pretty watertight, and the Great Programmer (who is presenting the case that we should be using classes) should be looking nervous. But she doesn't. Perhaps this is because she knows something we don't.

Game Objects Should Be Classes Managed by Reference

The Great Programmer doesn't say a great deal at the start of her presentation. Instead, she just opens up a diagram that she has brought with her and shows it to you. Look at Figure 14-5.

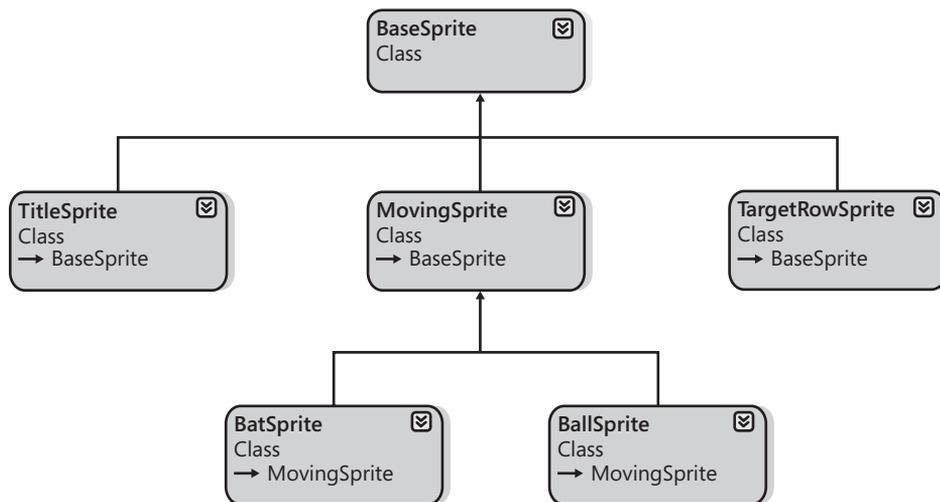


FIGURE 14-5 The *GameSprite* hierarchy

It looks a bit like a family tree, with a `BaseSprite` at the top and others descended from this parent. At the bottom, you can see `BatSprite` and `BallSprite`, and there are some other sprite types in the middle of the tree. The Great Programmer explains that if you use classes, you can build a class hierarchy where you can create a child class that inherits the behaviors of a parent. The great thing about this, she says, is that you only have to write a behavior in the parent and then the child class can pick this up and just has to add any new behaviors that it needs. In other words, it is much easier to reuse code.

You find this interesting; you have not heard of object hierarchies before (this is not the first time that a case has been swayed by the sudden arrival of new evidence), and so you

ask for more information. As an example, she produces Exhibit A, which is a version of the `BreadAndCheeseGame` that she has created using classes. She tells you that it is over 150 lines shorter and much simpler because she used the class hierarchy that she has shown you.

This is all very well, you reply, but it does not really answer the question as to why classes are managed by reference and not value. The reason, says the Great Programmer, is that using references actually makes a class hierarchy possible. For example, a `BallSprite` object must contain a bit of ball behavior (to check for collisions with the bread bat) and a bit of `BaseSprite` behavior (to draw itself on the screen). This means that the elements that make up a `BallSprite` are not necessarily held in one place in memory. Therefore, it is not possible to think of a single block of memory that holds the “value” of a `BallSprite`; bits of it might be stored in different parts. Fortunately, this is not a problem for the programmer because the environment in which your code runs takes care of this automatically.

When your program follows a reference to a `BallSprite` instance, the underlying system can work out the whereabouts of each part of the object. However, this makes it impossible to manage a `BallSprite` as a single value, and so classes must be managed by reference. But, she continues, the fact that you can reuse code means programs can be simpler and smaller. The previous version of the `BreadAndCheeseGame` contained five copies of the `LoadTexture` method. Her new version contains just one. Furthermore, she concludes, using classes makes adding new game elements really easy.

That sounds like a convincing argument, and so you decide that game objects should be classes and resolve to find out more about class hierarchies. So let’s do that now.

Creating a Sprite Class Hierarchy

A class hierarchy is a great way that similar types of object can all share the same code. The Great Programmer has created one for our Bread and Cheese game to show how they work.

The *BaseSprite* Class

The starting point for the hierarchy is the class at the very base. (This is drawn at the top of the diagram.) The class that the Great Programmer has put at the base of the hierarchy is called `BaseSprite`. It does not seem to do very much:

```
public class BaseSprite
{
    protected Texture2D spriteTexture;
    protected Rectangle spriteRectangle;

    public void LoadTexture(Texture2D inSpriteTexture)
    {
        spriteTexture = inSpriteTexture;
    }
}
```

```

    public void SetRectangle(Rectangle inSpriteRectangle)
    {
        spriteRectangle = inSpriteRectangle;
    }
    public virtual void Draw(SpriteBatch spriteBatch)
    {
        spriteBatch.Draw(spriteTexture, spriteRectangle, Color.White);
    }

    public virtual void Update(BreadAndCheeseGame game)
    {
    }
}

```

The `BaseSprite` is the simplest type of sprite. It contains the bare minimum of sprite behaviors. It can be given a texture and a destination rectangle and be asked to draw itself. It also declares an update behavior, although in this version of the sprite, it doesn't do anything. We shall see how you can add an actual Update behavior later in this chapter. This `BaseSprite` class serves as the starting point for all the sprite classes. It brings together some fundamental data items (the texture and the drawing rectangle) that all sprites need, along with the essential methods (`LoadTexture`, `SetRectangle`, `Draw`, and `Update`). Every sprite class that we are going to create needs these facilities, and so it is put in the parent class, which every child class extends.

Using the *BaseSprite* to Store the Background

The `BaseSprite` class is perfect for the game's background. This is created, set to the size of the display, and then drawn at the start of each call of the game's `Draw` method. It is used in exactly the same way as the `BackgroundSpriteStruct` you saw earlier, so the game contains an instance of a `BaseSprite` to manage the background display.

Extending the *BaseSprite* to Produce a *TitleSprite*

The next most complicated sprite is the `TitleSprite`. This is exactly the same as the `BaseSprite`, except that it has an Update behavior that checks to see if the player has pressed the A button on the gamepad. If this button is pressed, the sprite must then start the game. Here's the code for that:

```

public class TitleSprite : BaseSprite
{
    public override void Update(BreadAndCheeseGame game)
    {
        if (game.GamePad1.Buttons.A == ButtonState.Pressed)
        {
            game.StartGame();
        }
    }
}

```

The interesting part about this sprite is the size of the code. There is only one method present, which gives the new Update behavior. The rest of the methods are inherited from the parent sprite. This means that a `TitleSprite` has `LoadTexture`, `SetRectangle`, and `Draw` behaviors, but it gets them from the `BaseSprite` class it extends. The compiler is told that the `TitleSprite` is extending the `BaseSprite` by the way that `TitleSprite` is declared, as shown in bold here:

```
public class TitleSprite : BaseSprite
```

The name of the class being created is followed by a colon and the name of the class being extended. The compiler now knows that the class is being based on another, and so inherits all the methods and data properties in the parent.

Overriding Methods from a Parent Class

The `BaseSprite` has an empty Update method. This is fine for our background, which does not need to do anything when it updates itself. However, the `TitleSprite` has to test the A button on the gamepad to see if the player wants to start a new game. What you want to do is provide a replacement Update method that works for the `TitleSprite`. It turns out that this is very easy to do. The empty method in the `BaseSprite` class has been marked as *virtual*, as shown here in bold:

```
/// Empty Update method in BaseSprite  
public virtual void Update(BreadAndCheeseGame game)  
{  
}  
}
```

A method that is virtual can be *overridden* by a method with the same name in a child class. When a program calls the Update method on a reference to a `TitleSprite` instance, this Update method is used instead of the one in `BaseSprite`. In other words, the `TitleSprite` class can contain a new version of the Update method that behaves in the way it needs:

```
public override void Update(BreadAndCheeseGame game)  
{  
    if (game.GamePad1.Buttons.A == ButtonState.Pressed)  
    {  
        game.StartGame();  
    }  
}
```

Note that the compiler is told that some overriding is taking place by the `override` key word.

Building a Class Hierarchy

The Great Programmer has grouped together the sprites in a very sensible way (as you might expect). She has created another child class called `MovingSprite`. These are sprites that need to move around the screen. They have extra properties and methods that allow them to be set

up and their movement managed. There are two moving sprites in our game at the moment: the `BatSprite` and the `BallSprite`, both of which inherit all their movement information from the `MovingSprite` parent. The only method that differs between these classes is `Update`. In the `BatSprite` class, the `Update` method reads the gamepad and uses it to control the position of the bread bat. In the `BallSprite` class, the `Update` method bounces the cheese ball around the screen and checks for collisions between the ball and other game objects.

Using Protected Members from a Parent Class

One thing worthy of note here is the way that data is protected in class hierarchies. You know that members of an object can be marked `public` (everyone can use them) or `private` (nobody outside the object can use them). This protection also works between classes in hierarchies, in that if the parent class contains `private` members, they are not visible to code in the child classes. However, it is sometimes useful for the children of a class to be able to use things in the parent. In the case of the bread bat and cheese ball, these classes need access to the texture and the rectangle in the `BaseSprite`. The Great Programmer has solved this problem by using another feature of C#. Members of a class can be marked as *protected*, which means that they are visible to code in children of the class, but not to any code in classes outside the hierarchy. Note the following code:

```
public class BaseSprite
{
    protected Texture2D spriteTexture;
    protected Rectangle spriteRectangle;
    // Other BaseSprite content here
}
```

You can regard `protected` as a halfway house between `private` and `public`.

Sample Code: 05 Bread and Cheese Classes The sample project in the 05 Bread and Cheese Classes directory in the resources for this chapter contains a version of the game that is implemented using classes. Because it has been designed and written by the Great Programmer, you can regard it as pretty much the last word on our simple game.

Adding a Deadly Pepper

The Bread and Cheese game is now reasonably playable, but it needs a few extra features. You ask your younger brother for advice, and he suggests a “deadly pepper” that constantly moves about the screen. Sometimes the pepper is green, at which point it is harmless, but at other times it is red. If the bread bat collides with the pepper when it is red, the player loses a life. Shooting the pepper with the cheese when it is red gains 50 points and turns the pepper green again. We already have an image of a pepper in our arsenal, and so this should be easy to add.

Creating a *DeadlySprite* Class

The first thing you need to decide is where in our class hierarchy the deadly pepper sprite should be located. The Great Programmer has arranged things so that there is a class called `MovingSprite` that provides all the elements required to make a sprite that moves across the screen. This includes working out the size of the sprite and how fast it should move. This seems to be a good place to start, and so you start by extending the `MovingSprite` class to make a new class called `DeadlySprite`. This needs to contain an extra data field that records whether or not the pepper is deadly, as follows:

```
private bool isDeadly;
```

If the value of `isDeadly` is `true`, the sprite is deadly; if it is `false`, the sprite is harmless.

Drawing the Deadly Pepper Sprite

Your younger brother wants the pepper to be red when it is deadly, and green when not. You need to provide an updated `Draw` behavior to do this. It turns out that this is really easy to do, and you can achieve it using only one pepper texture. The first thing you do is convert your image of the pepper to black and white. You can use any image-processing program to do this, including `Paint.Net`, which you can download from <http://www.getpaint.net/>.

Then you just have to provide a new version of the `Draw` method for the `DeadlySprite` class that uses a different color to draw the pepper, depending on whether it is deadly or not:

```
public override void Draw(SpriteBatch spriteBatch)
{
    if (isDeadly)
    {
        spriteBatch.Draw(spriteTexture, spriteRectangle, Color.Red);
    }
    else
    {
        spriteBatch.Draw(spriteTexture, spriteRectangle, Color.Green);
    }
}
```

This method overrides the `Draw` method in the `MovingSprite` class. This means that when `Draw` is called on a `DeadlySprite` instance, this code runs instead of the method in the parent class. It tests the value of `isDeadly`. If the sprite is deadly, it draws the texture using a red light. If the sprite is safe, it draws the texture using green. This works quite well, and you can use it if you want to display the same texture in a game using different colors. You can also use it to show things “heating up” by changing the draw color from white to pink.

Setting Up the Deadly Pepper Sprite

The next thing you need to do is provide the method that sets up the pepper at the beginning of the game. The `MovingSprite` class provides a method called `StartGame` to set up a moving sprite. It works out the size of the texture to use, and also calculates the speed of movement.

However, the version of `StartGame` in `DeadlySprite` must also set the `isDeadly` property to `false`, so that the pepper is green when the game starts. What you want to do is override the `StartGame` method in `MovingSprite` and replace it with one that does everything the parent one does, plus the action of setting `isDeadly` to `false`. This turns out to be really easy, the power of XNA Game Studio and the C# language being extremely helpful at this point. If you start to override a method, XNA Game Studio provides Intellisense to help you choose the method to override. When you type “`public override`” into the code inside the `DeadlySprite` class, XNA Game Studio shows you a menu of methods that can be overridden. Figure 14-6 shows how this works.



FIGURE 14-6 Intellisense helping override a method

XNA Game Studio uses the comments that the Great Programmer put in the code to display information about the method as you step through them in the Intellisense list. You want to override the `StartGame` method, so you select that from the list and press Enter. At this point, XNA Game Studio makes an empty version of the method to get you started, as shown in Figure 14-7.

```
private bool isDeadly;

public override void StartGame(float widthFactor, float ticksToCrossScreen
{
    base.StartGame(widthFactor, ticksToCrossScreen, inMinDisplayX, inMaxDi:
}

public override void Draw(SpriteBatch spriteBatch)
{
```

FIGURE 14-7 An empty `StartGame` method in the `DeadlyPepper` class

This empty version contains a key word we haven’t yet discussed. The `base` key word is used to call the method that has been overridden. If you think about it, this is exactly what you want. You don’t want to have to replace the entire `StartGame` method; you just want to add something to set the `isDeadly` value. This is very easy to write:

```
public override void StartGame(float widthFactor, float ticksToCrossScreen,
    float inMinDisplayX, float inMaxDisplayX, float inMinDisplayY,
    float inMaxDisplayY, float initialX, float initialY)
```

```
{
    isDeadly = false;
    base.StartGame(widthFactor, ticksToCrossScreen,
        inMinDisplayX, inMaxDisplayX, inMinDisplayY,
        inMaxDisplayY, initialX, initialY);
}
```

The `base` key word is very useful when creating class hierarchies. It means that you can use the behavior of the parent method and then add something extra. You have actually seen `base` lots of times in the XNA programs that we have written already. The `Draw` and `Update` methods in the games that you have written so far are overrides of methods that exist in the parent class of the game you are creating. They always call the base behavior of their parent, and you have seen this call of `base` at the bottom of every `Draw` and `Update` method in the game class.

Updating the Deadly Pepper Sprite

The final thing you need to do is write the `Update` behavior for the `DeadlySprite` class. This is the largest method you need to make. It must move the sprite around the screen and also check for collisions with bat or ball. Finally, it needs to control when the sprite becomes deadly.

The movement code is easy to write—it is the same as that used for the ball:

```
x = x + xSpeed;
y = y + ySpeed;

spriteRectangle.X = (int)(x + 0.5f);
spriteRectangle.Y = (int)(y + 0.5f);

if (x + spriteRectangle.Width >= maxDisplayX)
{
    // sprite has hit the right side
    xSpeed = Math.Abs(xSpeed) * -1;
}

if (x <= minDisplayX)
{
    // sprite has hit the left side
    xSpeed = Math.Abs(xSpeed);
}

if (y + spriteRectangle.Height >= maxDisplayY)
{
    // sprite has hit the bottom
    ySpeed = Math.Abs(ySpeed) * -1;
}

if (y <= minDisplayY)
{
    // sprite has hit the top
    ySpeed = Math.Abs(ySpeed);
}
```

The only difference is that the player does not lose a life when the deadly sprite hits the bottom of the screen.

The collision code is also easy because you have seen this kind of code in the ball before. The only new bit is that the program must test for collisions only when the sprite is deadly. Here's the code:

```
if (isDeadly)
{
    if (game.BreadBat.CheckCollision(spriteRectangle))
    {
        // bat has hit the sprite.
        isDeadly = false;
        // lose a life
        game.LoseLife();
    }

    if (game.CheeseBall.CheckCollision(spriteRectangle))
    {
        // ball has hit the sprite
        isDeadly = false;
        // update the score
        game.UpdateScore(50);
    }
}
```

When the deadly pepper sprite collides with the cheese ball, the player is awarded 50 points, as this is a skill shot. When the pepper collides with the bread bat, the player loses a life, because this is not very skillful.

The final part of the Update method deals with the appearance of the deadly sprite. You talk it through with your younger brother and agree that the pepper should become deadly after the player has scored 200 points, and every 100 points after that. This means that the deadly pepper sprite needs to be able to obtain the score of the game. You look to see if the Great Programmer has thought of this and, sure enough, there is now a method in the BreadAndCheese class that returns the current score of the game:

```
public int GetScore()
{
    return score;
}
```

The deadly sprite needs to keep track of the next score to trigger its deadly behavior. To do this, it uses two variables:

```
int deadlyScoreStep= 100;

int deadlyTriggerScore = 200;
```

The code in Update gets the score and compares it with the trigger value:

```
if (game.GetScore() > deadlyTriggerScore)
{
    // Score has passed a threshold.
    // Turn deadly mode on and move the threshold.
    isDeadly = true;
    deadlyTriggerScore = deadlyTriggerScore + deadlyScoreStep;
}
```

When the score passes the trigger value, the sprite turned deadly and the trigger level is moved to the next step. It is up to the player whether to shoot the deadly pepper sprite or just avoid it when it is deadly. At the start of a game the `deadlyTriggerScore` value must be set back to 200. You can do this in the `StartGame` method.

Sample Code: 06 Bread and Cheese with Deadly Pepper The sample project in the 06 Bread and Cheese with Deadly Pepper directory in the resources for this chapter contains a version of the game that adds a deadly pepper to the game. The game has now become quite challenging.

Conclusion

This has been another packed chapter. You have learned how to organize a solution properly using object-based design. You now know the meaning of coupling and cohesion in software engineering. You have finally solved the mystery of the difference between values and references and learned about classes for the first time. You have also discovered how a class can build on the behaviors of an existing class to create working systems from objects that cooperate together. And to cap it all, you have seen some code written by the Great Programmer.

Chapter Review Questions

What better way to follow a chapter than with a review? You know what to do.

1. High cohesion is bad for programs.
2. High coupling is bad for a system.
3. Data in an object should be made public to protect it.
4. Structures are managed by reference.
5. Using references makes a program run more slowly.
6. References make class hierarchies possible.

7. A class can only have one child class.
8. Methods must be marked `virtual` if they are to be overridden.
9. It is impossible for an overriding method in a child class to use the method that it has overridden.
10. Protected members of a class are also visible to code in child classes that extend that class.
11. The key word `this` refers to the class that a child class is overriding.
12. A child class must override all the methods in the parent class.
13. You can have only one reference to an object.
14. Objects without references referring to them are destroyed automatically by the garbage collector process.

Chapter 15

Creating Game Components

In this chapter, you will

- Find out what turns an object into a component.
- See how Microsoft XNA really uses components to make game creation easy.
- Experiment with artificial intelligence (AI) in a game.
- Turn "Bread and Cheese" into an arcade-quality game.

Introduction

You now know a lot about how programs are made. You have traveled all the way from performing simple calculations with your programs to creating complex game objects that show high cohesion (that is, they can look after themselves) and low coupling (that is, they interact in the simplest manner possible). In this chapter, you are going to find out how to take a high-level view of your programs and use this perspective to create software components that can be used in many different games. You also write your first code which displays AI and find out how to store large numbers of game objects in a program.

Objects and Abstraction

I take the view that as you develop as a software writer, you go through a process of "stepping back" from problems and thinking at higher and higher levels. The Great Programmer calls this *abstraction*. This is the progress that you have made so far:

- Representing values by named locations (variables)
- Creating actions that work on variables (statements and blocks)
- Putting actions into lumps of code to which we can give names. We can reuse these actions and also use them in the design process (methods)
- Creating things that contain member variables as properties and member methods as actions (objects)
- Making constructions that contain objects that are related in some way and want to share resources (class hierarchies)

As you think about a design in a more abstract way you will initially describe the actions that are needed in general terms. Rather than looking at specific behavior and low-level detail with statements like "A sprite will draw itself using the `spriteRect` rectangle and the

spriteTexture texture,” you are thinking about things in more general terms and saying things like “A sprite will have to draw itself.” This is because at the early stages of the design process, you are trying to focus on what things need to do rather than on the specific details of how they do them. Later on, you can come back and fill in precisely how the draw behavior works.

It is frequently the case that different components in your system that share a need for a draw behavior (for example, different kinds of game object) actually implement that draw behavior differently (some might draw a texture, whereas others might just draw a dot or a line), but from the point of view of the top-level design, it is best to think of them as just having the Draw behavior.

Creating an Abstract Class in C#

From a C# point of view, you can create abstract classes, which contain placeholders for methods that need to be present when actual instances of the class need to be created. Look at the following code:

```
public abstract class AbstractSprite
{
    public abstract void Draw (SpriteBatch spriteBatch);
}
```

This is a very simple abstract class called `AbstractSprite` that contains a single `Draw` method. You would not be able to create an instance of the `AbstractSprite` class. If you tried as follows, the compiler would reward you with an error:

```
AbstractSprite s;
s = new AbstractSprite(); // would cause a compilation error
```

The `Draw` method is not actually present in the class—it is an abstract placeholder. It is saying to the compiler, “A class that extends `AbstractSprite` must have a `Draw` method if you want to make an instance of it.”

You could think of an abstract class as a really strict family business. To join the business, you have to be related to someone already in it and be able to do all the things that the business needs. Members of the `AbstractSprite` business must have a `Draw` method and be a child of a class in the hierarchy that has `AbstractSprite` at the base.

Extending an Abstract Class

The idea of an abstract class is that it provides a template of behaviors that are required in all the children of the class. We can create a child class called `MySprite` that satisfies these requirements. In fact, XNA Game Studio makes it very easy to do this. All you have to do is start typing the class declaration, then right-click the parent class name. This action brings up a menu from which you can select the `Implement Abstract Class` option, as shown in Figure 15-1.

```
public abstract class AbstractSprite
{
    public abstract void Draw(SpriteBatch spriteBatch);
}

public class MySprite : AbstractSprite
```

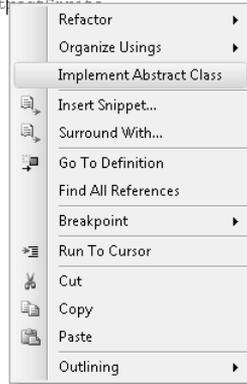


FIGURE 15-1 Implementing an abstract class in XNA Game Studio

When you select the option, an empty child class that contains a placeholder Draw method is created automatically. If the parent class contained many abstract methods, the new class would have a placeholder for each. This is a lovely example of just how an intelligent editor that is aware of the design of the language you are using can make life much easier for the programmer. Figure 15-2 shows how XNA Game Studio fills in the child class started in Figure 15-1.

```
public abstract class AbstractSprite
{
    public abstract void Draw(SpriteBatch spriteBatch);
}

public class MySprite : AbstractSprite
{
    public override void Draw(SpriteBatch spriteBatch)
    {
        throw new NotImplementedException();
    }
}
```

FIGURE 15-2 XNA Game Studio filling in an abstract class

The code for MySprite that XNA Game Studio has created allows a program to create an instance of the MySprite class. This is because the MySprite class contains an implementation of the abstract Draw method and therefore fulfills the entry requirements to join the AbstractSprite “club.” Here’s the code for this:

```
public class MySprite : AbstractSprite
{
    public override void Draw(SpriteBatch spriteBatch)
    {
        throw new NotImplementedException();
    }
}
```

The next thing that you would do is fill in the `Draw` method with the code that performs the draw behavior for this particular type of sprite. If you forget to do this, you can still create instances of the `AbstractSprite` class and call the `Draw` method, but the version of `Draw` shown here throws an exception and stops the program.

An exception is a way that a program can signal it is unhappy and bring this to the attention of an exception handler that might be able to sort things out. You have seen exceptions before in this book: in Chapter 4, “Displaying Images,” in the section entitled “Loading XNA Textures,” and in Chapter 8, “Creating a Timer,” in the section entitled “Using Data in an Array.” However, in these situations, things that you are using have thrown exceptions when something bad happens (such as trying to load a texture that isn’t there, or trying to read elements beyond the bounds of an array). This time it is the other way around, in that the code you are writing is signaling that something has gone wrong—in this case, that the programmer has not filled in a placeholder produced by XNA Game Studio.

Designing with Abstract Classes

Abstract classes let you design a system by working out what a particular kind of object needs to do and then setting a specification or template to ensure that all the objects of that kind can do these things. You have already been working along these lines in this book. In Table 14-1 in Chapter 14, “Classes, Objects, and Games,” you saw how we set out the requirements for a bat sprite. If you were using abstraction, you would find those behaviors that are common to all sprites (`Draw`, `Update`, `BeginGame`, and `EndGame`) and put them in an abstract parent class, so you could be sure that all classes in the sprite hierarchy had those minimum behaviors. The class could even have some data members and non-abstract methods that could be used by all the child classes.



Note Of course, the fact that a class contains a `Draw` method does not actually mean that it can draw itself properly. A properly built system also has some tests that can be applied to objects to ensure that they really can do what is needed, just like you should have to pass some kind of interview to join the family business even if your dad owns the company. You have seen this test-driven approach in the section entitled “Playing with Images,” in Chapter 10, “Using C# Methods to Solve Problems.”

References to Abstract Parent Classes

You have seen that it is not possible to create an instance of an abstract class like `AbstractSprite`. This is because if the program ever needed to perform the `Draw` operation on such an object, it would not know what to do. However, you might find it surprising that you can create references of type `AbstractSprite`, and in fact, this is a very sensible thing to do. Here’s code that does this:

```
AbstractSprite anySprite;  
  
anySprite = new MySprite();  
  
anySprite.Draw(spriteBatch);
```

This code creates a reference called `anySprite` of type `AbstractSprite`. It then sets this to a new `MySprite` instance and calls `Draw` on it. You might think that the compiler would take issue with this, but in fact, it is completely happy. A reference to a parent class can always refer to any of the child types. This is because a child is always able to do everything that a parent can. (Note that this is in direct contradiction to real life, in that none of my children seem to have inherited my dancing ability—and they are very relieved about this.)

The compiler knows that an instance of `MySprite` has a `Draw` method that can be called when required. This would be true for any child of the `AbstractSprite` class, although which actual code runs depends on precisely what class is on the end of the reference.

This turns out to be very useful. You might change the design of your game so that all the sprites on the display are managed using an array. You would want to hold a large number of sprites in such an array and not have to worry about precisely what kind of sprites they are. This can be achieved by making the array of type `AbstractSprite`:

```
AbstractSprite[] screenSprites = new AbstractSprite[100];
```

This would create an array that could hold references to 100 sprites, which could be any of the classes that are in the hierarchy that has `AbstractSprite` as its root. Actually, references like this also work with parent classes that are not abstract, so you could manage the game objects in `BreadAndCheese` using an array of `BaseSprite` objects as well.

The Great Programmer Speaks: Abstraction Is a Good Idea The Great Programmer is a big fan of abstraction. She says that “stepping back” from a problem and just concentrating on what the system needs to do is a great way to start. She reckons that too many software projects fail because the developers focused on the programming aspects of the problem rather than on what the customer wants. In fact, her first question to a customer is even more abstract than asking what he or she wants. She tends to ask, “What is the budget for your project?” so that she can decide in advance whether she even wants to do the job.

We will see an even better abstraction tool, the `C#` interface, a little later in this chapter.

Constructing Class Instances

The Great Programmer takes code writing very seriously. She is always concerned that objects in her programs contain valid data at all times. To her, this means that if an object has been created, it must contain values that mean it will not do something stupid if someone

tries to use it. She had a look at the `BreadAndCheeseGame` code when she created her class hierarchy for Chapter 14 and she reckons that it has a serious flaw: it is possible to create sprites that would cause the game to crash if it ever tried to draw them.

The Great Programmer Speaks: Code Review Really Is a Good Idea Letting other programmers see your programs (or “code review” as the professionals call it) is actually a really good idea. It might not be that good for your self-esteem as other people find problems with your solution that you hadn’t thought of, but it does result in a better program. The Great Programmer has taken part in a lot of reviews (both as a reviewer and someone being reviewed) and she reckons that so long as you check your ego at the door, they work pretty well.

You take a look at the code and it turns out that she is right. The following statements create a `BaseSprite` reference called `b` and then try to draw it:

```
BaseSprite b = new BaseSprite();  
b.Draw(spriteBatch);
```

These statements cause an exception to be thrown because the `Draw` method would try to use values of `spriteRectangle` and `spriteTexture` in the class that haven’t been set up yet. What you want is a way of making sure that whenever a `BaseSprite` is created, it must be given a texture and rectangle. It turns out that this is very easy to do—you just need to add a *constructor* to the `BaseSprite` class. This is code that gets control when your object is being created, and can be used to set it up. Your constructor method, shown in bold in here, has the same name as the class and accepts two parameters:

```
public class BaseSprite  
{  
    protected Texture2D spriteTexture;  
    protected Rectangle spriteRectangle;  
  
    public void LoadTexture(Texture2D inSpriteTexture)  
    {  
        spriteTexture = inSpriteTexture;  
    }  
  
    public void SetRectangle(Rectangle inSpriteRectangle)  
    {  
        spriteRectangle = inSpriteRectangle;  
    }  
  
    public virtual void Draw(SpriteBatch spriteBatch)  
    {  
        spriteBatch.Draw(spriteTexture, spriteRectangle, Color.White);  
    }  
  
    public virtual void Update(BreadAndCheeseGame game)  
    {  
    }  
}
```

```
public BaseSprite(Texture2D inSpriteTexture, Rectangle inRectangle)
{
    LoadTexture(inSpriteTexture);
    SetRectangle(inRectangle);
}
}
```

This constructor for `BaseSprite` is given the texture to draw and the rectangle to be used to draw it. The constructor then calls the methods in the class to set these values. This means that now the only way that you can create a `BaseSprite` is by supplying a texture and a rectangle when you use the `new` keyword to create a `BaseSprite` instance:

```
Texture2D background = Content.Load<Texture2D>("Images/Background");
Rectangle position = new Rectangle ( 0,0, 500,500 );
BaseSprite b = new BaseSprite(background, position);
```

Any `BaseSprite` instance referred to now always has a texture and a rectangle, which means that it can be drawn without problems. You have been using `new` in this way ever since your first program. Even this code uses `new` in the constructor call to set up the `Rectangle` being used to make the `BaseSprite`.

You can provide as many constructors as you like for a class, so that if there are different ways of providing the initial values, you can provide a constructor for each. You have already seen this in action, too: the `Color` type provides lots of different constructors so that you can make a new color value in many different ways.

Constructors in Structures

There is a subtle difference in the way that constructors are applied to value types. If you create a constructor for a value type, it must set a value for every data member of the structure:

```
struct demo
{
    int i;
    int j;
    int k;

    public demo(int newi, int newj, int newk)
    {
        i = newi;
        j = newj;
        k = newk;
    }
}
```

The structure called `demo` (which is a value type) contains three data members. If you create a constructor for it, the compiler insists that the constructor must accept some parameters and must explicitly set all three members of the structure. This is not the same as for types managed by reference, where the compiler is much more relaxed about what has been initialized and automatically sets member data to default values (0 for numbers and `null` for references).

Constructors in Class Hierarchies

You haven't had to create constructors before because the compiler has provided an "empty" constructor (that is, one that accepts no parameters) automatically for each object you have created. However, once you add your own constructor, the compiler stops doing this. The designers of C# worked on the basis that if you provide a constructor you are indicating that you want complete control over how classes are created. This can lead to problems, as you now discover.

Armed with your knowledge of how constructors work, you now decide to sort out all the classes in the *BreadAndSprite* game. This does not go well. As soon as you add a proper constructor to the *BaseSprite* class to improve the program, it actually breaks everything. Figure 15-3 shows the errors that are produced by XNA Game Studio from this "improvement."

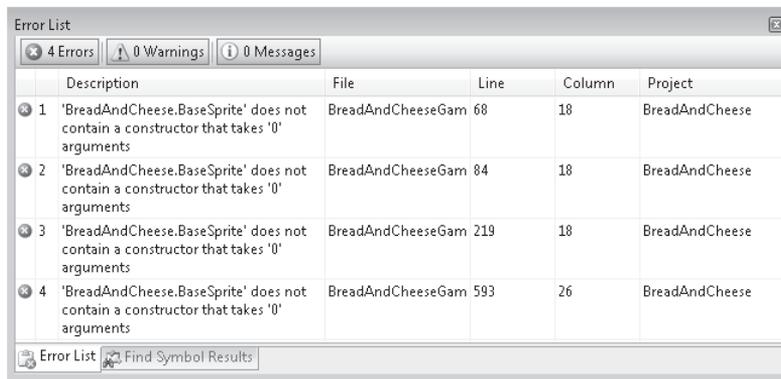


FIGURE 15-3 Compilation errors after adding a *BaseSprite* constructor

The compiler is not very happy with the *BaseSprite* class. It seems to want back the empty constructor, the "constructor that takes 0 arguments." The compiler is trying to tell you that some parts of your program are trying to use the empty constructor to create a *BaseSprite* class. This no longer exists because you have provided your own constructor. You could start by fixing the *Background* sprite, which is a *BaseSprite* instance that draws the background. When it is created, the game must provide the texture and rectangle for this sprite:

```
Background = new BaseSprite(
    Content.Load<Texture2D>("Images/Background"),
    new Rectangle(0, 0, displayWidth, displayHeight));
```

The *Background* is now created in the *LoadContent* method because this is the point at which the texture is loaded. This gets rid of one of the errors, but there are still quite a few left.

Constructors in Child Classes

The next class that you could fix is the *TitleSprite* class, which is a child of the *BaseSprite* class. From what we know of class hierarchies, this means that when a *TitleSprite* instance is created, the system must create a *BaseSprite* first. If a parent class contains a constructor

(as ours now does), this means that the child constructor must call the parent constructor to ensure that the parent class is set up properly before the child is constructed. The C# language provides a means of doing this very easily, as shown here in bold:

```
public class TitleSprite : BaseSprite
{
    // TitleSprite contents

    // TitleSprite constructor:
    public TitleSprite(Texture2D inSpriteTexture, Rectangle inRectangle)
        : base (inSpriteTexture, inRectangle)
    {
        // The constructor doesn't actually have to do anything
    }
}
```

The constructor for `TitleSprite` actually just needs to call the constructor for the base class. The preceding code shows how this is done. The parameters to the `TitleSprite` call are passed into a call of a method called `base`. We have seen this before when we called parent methods from overridden ones. In this context, it is doing something very similar, calling the constructor of the parent class (sometimes called the *base class*). The rather strange syntax, with the call actually appearing outside the body of the constructor method, is designed to make it clear that the constructor for the parent must run before the code in the child constructor runs.

To make the program compile all the children of the `BaseSprite` class must include a call of the base constructor like this. This calls for some changes to the code, but it is worth the effort as we shall see in a moment.

Sample Code: 01 Bread and Cheese with Constructors All the sample projects can be obtained from the course instructor. The sample project in the 01 Bread and Cheese with Constructors directory in the resources for this chapter contains a version of the game that has proper constructors for all the classes. The `MovingSprite` constructor is more complicated than the others, as it has to use the scaling information to make the rectangle that bounds the texture.

The construction of objects in your system is something that you should plan carefully when you design your program.

Adding 100 Killer Tangerines

Your younger brother (who seems to have taken on the role of lead game designer) has come to you with an idea for 100 “killer tangerines” that appear on the screen once the player has scored 500 points. He is not sure what they would do, or how they would work, but he reckons that they would “scare the player to death,” as he puts it. Because you are making up the game as you go along, you reckon that this might be a fun thing to do, and you can work out what to do with them once you have created them. The first thing

you need is a picture of a tangerine to use for a sprite. Fortunately, the Great Programmer likes oranges, and so you are able to take a picture of one and convert it for use as a game texture. You decide to call this new type of sprite a `KillerSprite` for now; you can always change its name later if you need to.

Creating a *KillerSprite* Class

You use the `MovingSprite` as the basis of your `KillerSprite` sprite:

```
public class KillerSprite : MovingSprite
{
    public KillerSprite(
        Texture2D inSpriteTexture,
        float widthFactor, float ticksToCrossScreen,
        float inMinDisplayX, float inMaxDisplayX,
        float inMinDisplayY, float inMaxDisplayY)
        : base(inSpriteTexture, widthFactor, ticksToCrossScreen,
            inMinDisplayX, inMaxDisplayX,
            inMinDisplayY, inMaxDisplayY,
            0, 0) // set the initial position to 0,0 for now
    {
        // TODO: Calculate a random initial position for the Killer Sprite
    }
}
```

The big scary lump of code in the class is the call of the constructor of the `MovingSprite` class. This needs to be given all the information it needs to create the sprite rectangle and set up the movement of the sprite. At the moment, the constructor for `KillerSprite` doesn't actually do anything—it just passes all the values to the base constructor of its parent class.

The base constructor for the parent `MovingSprite` class must be given an initial position for the sprite. At the moment we don't know where to put the sprite, so all `KillerSprite` objects are initially placed at 0,0. The constructor code for the `KillerSprite` will calculate a random position of this sprite, so there is a TODO comment in the constructor to remind us to add this code later.

Your game could construct a `KillerSprite` instance like this:

```
KillerTangerine = new KillerSprite(
    Content.Load<Texture2D>("Images/Tangerine"),
    0.03f, // a tangerine takes 0.03 of the screen width
    1000, // tangerine takes 200 ticks to cross the screen
    minDisplayX, maxDisplayX, minDisplayY, maxDisplayY);
```

Positioning the *KillerSprites* Using Random Numbers

Your younger brother wants the tangerine killer sprites to appear at random all over the screen. This means that you need a source of random numbers to position them. Computers are carefully designed to do exactly the same thing when given the same

sequence of instructions. A computer that did not do this would be called a “broken” one. From a programming perspective, getting truly random behavior is difficult. Fortunately, the Microsoft .NET Framework provides a way of getting “pseudorandom” numbers very easily.

Pseudorandom Numbers

A source of pseudorandom numbers is not completely random, but it is random enough to be useful. It uses the previous random number to generate the next one and so produces a sequence of numbers that appear random.

The sequence starts with a particular “seed” value. The process always produces the same sequence from the same seed. This is why it’s called “pseudorandom” rather than “completely random.” Pseudorandom numbers are actually quite useful, in that they can produce complex but repeatable behavior. You are going to use this feature so that the killer sprites always appear in the same places on the screen. This would make it possible for a keen player to learn these locations and use this to improve their game play.

The .NET *Random* Class

The .NET Framework provides a class called `Random` which exposes a number of methods that can be used to obtain random numbers in a variety of ways. The first thing the program must do is create an instance of the `Random` class:

```
Random rand = new Random(1); // create a random number generator seeded at 1
```

This statement creates a new `Random` instance and sets the variable `rand` to refer to it. The instance has been seeded with the value 1, so that it will always produce exactly the same sequence of values. The program can now call methods on this reference to get a hold of random numbers from it:

```
int diceSpots;  
int winner;  
  
diceSpots = rand.Next(1, 7); // get a value between 1 and 6  
winner = rand.Next(100); // get a value between 0 and 99
```

The constructor for the `KillerSprite` must generate random numbers that will place the sprite somewhere within the boundary of the playfield. To do this it can use the maximum and minimum values for the screen size along with the width and height of the sprites that will be drawn:

```
initialX = rand.Next((int)minDisplayX, // min value  
                    (int)(maxDisplayX - spriteRectangle.Width)); // max value  
initialY = rand.Next((int)minDisplayY, // min value  
                    (int)(maxDisplayY - spriteRectangle.Height)); // max value
```

The previous code sets the initial position for a `KillerSprite` so that it is random but within the screen boundary. Note that the `Next` method requires integer parameters, and so the values must be cast to `int` before being passed into it.

Creating a Static Random Generator for the *KillerSprite*

The `KillerSprite` class must have one random number generator which is shared among all instances of the class. If the program made a new random number generator each time it made a new `KillerSprite` instance this would not work. All the sprites would be placed in the same location because they would each contain a brand-new random number generator seeded with the value 1. They would then set their positions by using the same first two numbers produced by the identically seeded generator.

You can get around this problem by making the random number generator a *static* member of the class. When a class member is made static it is not held inside an instance, but is actually part of the class, and shared by all the instances.

```
static Random rand = new Random(1);
```

Whenever an instance of `KillerSprite` uses the `rand` member variable, it will use the single, static variable which is part of the class.

You first saw static class members in Chapter 11 in the section “Static Classes and Methods,” where you saw how useful it can be to make methods static so that they can be called without needing to create an instance of a class. This is a situation where you want a particular data item to be shared among class members. The `KillerSprite` constructor uses the random number generator to position a sprite at a random position, as shown here in bold:

```
public class KillerSprite : MovingSprite
{
    static Random rand = new Random(1);

    public KillerSprite(
        Texture2D inSpriteTexture,
        float widthFactor, float ticksToCrossScreen,
        float inMinDisplayX, float inMaxDisplayX,
        float inMinDisplayY, float inMaxDisplayY)
        : base(inSpriteTexture, widthFactor, ticksToCrossScreen,
            inMinDisplayX, inMaxDisplayX,
            inMinDisplayY, inMaxDisplayY,
            0, 0) // set the initial position to 0,0 for now
    {
        initialX = rand.Next((int)minDisplayX,
            (int)(maxDisplayX - spriteRectangle.Width));
        initialY = rand.Next((int)minDisplayY,
            (int)(maxDisplayY - spriteRectangle.Height));
    }
}
```

Getting a Random Sequence of Numbers

Your younger brother has been reading this section with interest. He is obviously planning some kind of card game program where he can know exactly what cards the other players are holding, because of the way that he can get a predictable sequence of values from the `Random` class. If you need to get truly random behavior you can create a `Random` instance without giving it an initial seed value:

```
Random rand = new Random(); // create a truly random number generator
```

If you do not provide a seed value the .NET Framework uses a seed that's obtained from the precise time that the program runs, so that the game program gets a different random sequence each time the game is played.

Using Lists of References

The next problem to solve is how to store all the `KillerTangerine` variables that you are going to create. Arrays are, at the moment, the only way we know to hold large numbers of things. We used them when we were decoding the scores in the section entitled "Finding Winners Using Arrays," in Chapter 8, "Creating a Timer." They let you create a storage area of a particular size and fill the elements in the store with data.

You could use arrays to hold all the game objects, but the C# libraries provide a much better mechanism for doing this. It is called a `List`. The `List` is a "collection" class, which is designed to hold lists of things. It is so useful that you feel like taking it home to meet your parents.

The `List` collection uses a C# feature called *generics*, where a program construction can be designed and made to work on items independent of their type. The great thing about a `List` is that you can create it and add items to it without worrying about it filling up. Some clever software behind the scenes (that you don't have to know about) reserves extra space when required. The `List` collection seems to have arrived just in time. For now, you need to create something that can manage a very large number of sprites.

Creating a *List* Collection

You declare a `List` collection as you would any other variable, as shown in bold here:

```
// The Game World
public BreadSprite Bread;
public CheeseSprite Cheese;
public DeadlyPepper Pepper;
public TomatoRowSprite Tomato;
public TitleSprite Title;
public BaseSprite Background;

public List<BaseSprite> GameSprites = new List<BaseSprite>();
```

This is the game world for our game. It includes all the original sprites, plus the list variable called `GameSprites`, which is going to hold all the sprites that are on the screen when the game is active. The type of the items you want to put in the list is given between the left-angle bracket (<) and the right-angle bracket (>) characters. In this case, you are creating a list of `BaseSprite` references, but you can create lists to hold any type. Note that because a reference to a parent class is able to refer to any of the child classes of that parent, we can add any of our sprite types to the list.

Adding Items to a List

The `List` class provides a method called `Add`, which can be used to add things to the `List`, as shown here in bold:

```
for (int i = 0; i < 100; i++)
{
    KillerSprite Tangerine;
    Tangerine = new KillerSprite(
        Content.Load<Texture2D>("Images/Tangerine"),
        0.03f, // a tangerine takes 0.03 of the screen width
        1000, // tangerine takes 200 ticks to cross the screen
        minDisplayX, maxDisplayX, minDisplayY, maxDisplayY);
    GameSprites.Add(Tangerine);
}
```

This code creates 100 tangerines and adds them to the `GameSprites` list. Note that if we wanted 1,000 of them (which would really scare the player), we just have to change the upper limit of the for loop and hope that the Xbox can keep up.

Accessing List Elements

Getting a hold of elements from a list turns out to be very easy. You can use subscripts just like an array, as follows:

```
for (int i = 0; i < 100; i++)
{
    GameSprites[i].Draw(spriteBatch);
}
```

This code would call the `Draw` method on all the tangerines in the list. If the program tries to access an element that is not present (perhaps the one with a subscript of 100), then the program fails with an exception, just as an array would. The `List` class provides a `Count` method, which can be used to find out how many items the list contains:

```
for (int i = 0; i < GameSprites.Count(); i++)
{
    GameSprites[i].Draw(spriteBatch);
}
```

This version of the loop would work correctly for any size of list. In this respect, the `Count` method is directly analogous to the `Length` property of an array.

Working Through List Elements Using *foreach*

Lists (and indeed arrays) can also be used with another form of C# loop construction called `foreach`. This provides a really neat way of performing an operation on a large number of items in a collection. It removes the need for you to create a control variable and worry about the size of the collection:

```
foreach (BaseSprite sprite in GameSprites)
{
    sprite.Draw(spriteBatch);
}
```

The `foreach` construction takes each item out of a collection and feeds it into the statements to be repeated. This code asks all the sprites in the game to perform their `Draw` operation. The elements of the `List` collection are fetched by the `foreach` loop in the same order that they were added. You can also use `foreach` to work through the elements of an array in the same way. Note however that other collection classes might not return the elements in the same order that you stored them; only lists and arrays are guaranteed to do this.

Setting Up the Game Sprites

It makes sense to add all the sprites into the game into the `GameSprites` list. This means that the `Draw` and `Update` methods can be made much simpler because they just have to use a `foreach` construction. The sprites would be added to `GameSprites` when they are created:

```
CheeseBall = new BallSprite(
    Content.Load<Texture2D>("Images/Cheese"),
    0.07f, // a cheese takes 0.07 of the screen width
    200, // cheese takes 200 ticks to cross the screen
    minDisplayX, maxDisplayX, minDisplayY, maxDisplayY,
    displayWidth / 4, // a quarter across the screen
    displayHeight / 4); // a quarter down the screen

GameSprites.Add(CheeseBall);
```

Note that you now have two ways that to get to the `BallSprite` instance that represents the cheese in the game. The program can either follow the `CheeseBall` reference, or use the reference stored in the `GameSprites` list. You can now remove the use of the individual

references in the Draw and Update methods so that they are now even simpler, as shown in the complete Draw method below:

```
protected override void Draw(GameTime gameTime)
{
    GraphicsDevice.Clear(Color.CornflowerBlue);

    spriteBatch.Begin();

    switch (state)
    {
        case GameState.titleScreen:
            Title.Draw(spriteBatch);
            drawHighScore();
            break;
        case GameState.playingGame:
            foreach (BaseSprite sprite in GameSprites)
            {
                sprite.Draw(spriteBatch);
            }
            drawScore();
            break;
    }

    spriteBatch.End();

    base.Draw(gameTime);
}
```

The only sprite that is not added to the list of `GameSprites` is the `Title` sprite, which is drawn when the title screen must be displayed.

Extra *List* Features

The `List` collection also provides `Remove` methods that let you remove elements from a list. When an element is removed, the list is “shuffled down” so that there is no empty slot. This would be a very useful way of removing items from game that have been destroyed. If they are removed from the list, they are not drawn.

Sample Code: 02 Bread and Cheese with Tangerines The sample project in the 02 Bread and Cheese with Tangerines directory in the resources for this chapter contains a version of the game that draws 100 tangerines when it starts.

Figure 15-4 shows how the tangerines are drawn. Note that because the code uses a random number generator seeded with the same number each time, the tangerines are placed in exactly the same position each time the program runs.

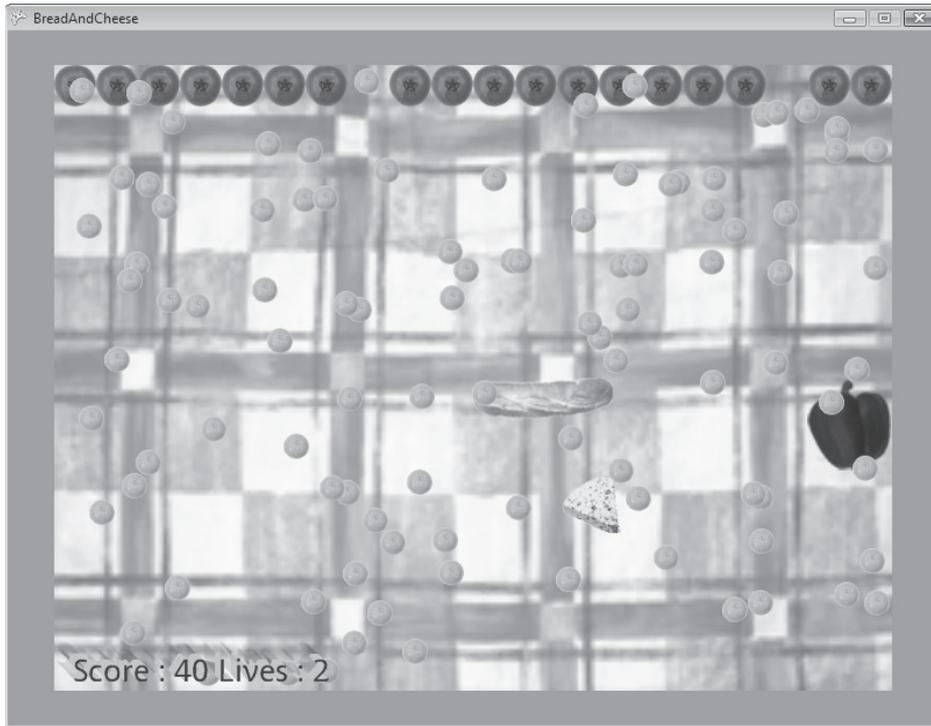


FIGURE 15-4 100 tangerines (count them if you like) in the Bread and Cheese game

Adding Artificial Intelligence

At the moment, the tangerines just stay at their initial positions on the screen looking dangerous, which is rather boring. Perhaps they could chase the bread bat instead (your younger brother really likes this idea). The posh name for what you are doing now is artificial intelligence (AI). You want to make it look as though the tangerines are being controlled by an intelligent opponent who knows where you are and is heading that way.

Chasing the Bread Bat

To change the way the tangerines behave, you just have to override the `Update` method in the `KillerSprite` class. To chase the bread bat, a killer sprite first has to know where the bat is. At the moment, this information is hidden inside the `Bat` class, so we need to add some code to make this information visible. The best place to put this code is the `MovingSprite` class; then we can get the position of any of the moving sprites on the screen, including the `Cheese` and the `DeadlyPepper`.

Using Properties to Read the *Bread Bat* Position

We could provide a method called `GetX` to read the X position of the a `MovingSprite`, but C# provides something called a *property*, which makes this much easier. Look at this code:

```
public float XPos
{
    get
    {
        return x;
    }
}
```

When placed inside the `MovingSprite` class, the code provides a property that lets objects read the value of `x` (which is the member of the sprite that holds the position). The new `XPos` property can be used very easily:

```
float breadX = Bread.XPos;
```

This assigns the `x` location of the bread to the value of `breadX`. This looks a lot like direct access to a member of a class, but what is actually happening is that the code inside `get` portion of the property is running and the value following the `return` is being sent back as the result of the property. At the moment, there is no way that the position of the bread can be changed (which is what we want in this case). However, this would not stop programmers like your younger brother from trying, as in the following code:

```
Bread.XPos = 99;
```

Because there is no `set` behavior, this fails to compile. However, you can provide such a behavior if you like by adding a `set` part to the property declaration, as shown here in bold:

```
public float XPos
{
    get
    {
        return x;
    }

    set
    {
        x = value;
    }
}
```

The set behavior of a property uses the key word `value` as a placeholder for the value specified on the right side of the assignment operator. So if your younger brother's code to write to the property was performed, the value of `x` would be set to 99.

Properties are quite neat, and they can make code look simpler. I don't use them much myself (and neither does the Great Programmer) because we like it to be very clear to a user of a class just when code is running within it (as opposed to just accessing a property within it). If you provide a set behavior in a property you should of course make sure that this validates the incoming data before changing a value held inside the object.

Creating the *KillerSprite-Chasing AI*

The code to make a killer sprite chase the bread bat is actually quite simple:

```
if (game.BreadBat.XPos > x)
{
    x += xSpeed;
}
else
{
    x -= xSpeed;
}
if (game.BreadBat.YPos > y)
{
    y += ySpeed;
}
else
{
    y -= ySpeed;
}
```

This is pure AI. These statements are doing exactly what you would do if you were steering a tangerine towards the bread. They work on the principle that if the bread was to the left of you, you'd move left. If the bread was below you, you'd move down, and so on. If this code is placed in the Update method, the tangerines try to head towards the bread. The speed of the tangerine has been set so that the tangerines move quite slowly, but it definitely feels like they are chasing you. If you really want to scare the player, you can speed the tangerines up. Figure 15-5 shows the situation in the game a few seconds after the tangerines have been made to appear. This is actually quite a scary point in the game, as the pepper is also deadly.

If you want to make tangerines that ran away from the bread bat (to make a kind of chasing game), you just have to reverse this behavior.

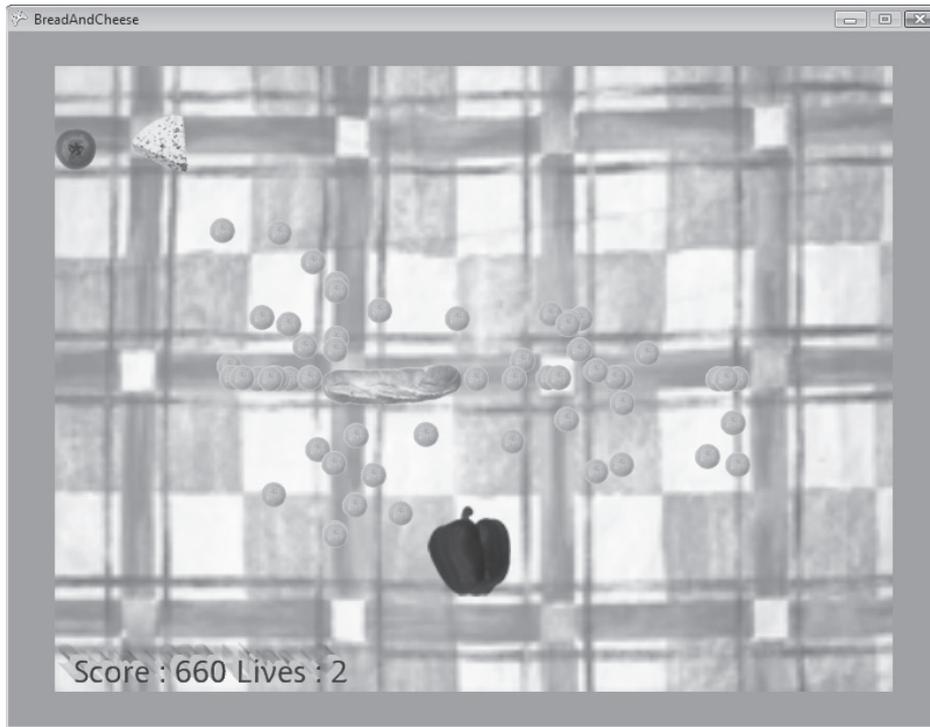


FIGURE 15-5 Starting the chase

Hitting the Killer Sprite Tangerines

The only problem with the tangerines is that we can't really have them make the player lose a life when they touch the bread bat. This would be very unfair because the player would almost certainly die quickly. We get your younger brother to test this form of the game play and see how long he can survive and the answer is what we expected—not very long.

However, we can arrange things so that the player suffers in other ways. Every killer sprite that hits the player's bat could cost them 10 points, whereas every one they manage to get rid of by hitting it with the cheese could earn them 10 points. This makes the killer sprite a bit like the pepper in some respects. The final `Update` behavior for the `KillerTangerine` looks like this:

```
public override void Update(BreadAndCheeseGame game)
{
    if (game.GetScore() > killerTriggerScore)
    {
        // Score has passed a threshold.
        // Turn the killer sprite on and move the threshold.
        isDeadly = true;
        killerTriggerScore = killerTriggerScore + killerScoreStep;
    }
}
```

```

if (isDeadly)
{
    if (game.BreadBat.CheckCollision(spriteRectangle))
    {
        // bat has hit the Killer Sprite.
        isDeadly = false;
        // lose some score
        game.UpdateScore(-10);
    }

    if (game.CheeseBall.CheckCollision(spriteRectangle))
    {
        // ball has hit the Killer Sprite.
        isDeadly = false;
        // update the score
        game.UpdateScore(10);
    }

    if (game.BreadBat.XPos > x)
    {
        x += xSpeed;
    }
    else
    {
        x -= xSpeed;
    }
    if (game.BreadBat.YPos > y)
    {
        y += ySpeed;
    }
    else
    {
        y -= ySpeed;
    }
}

spriteRectangle.X = (int)(x + 0.5f);
spriteRectangle.Y = (int)(y + 0.5f);

base.Update(game);
}

```

Note that, unlike the pepper, the tangerines are drawn and moved only when they are deadly.

Sample Code: 03 Bread and Cheese with Killer Tangerines The sample project in the 03 Bread and Cheese with Killer Tangerines directory in the resources for this chapter contains a version of the game that creates 100 killer tangerines when the score reaches 500. It also creates them every 400 points after that.

The interesting thing about this is that we have added only a few lines to the game to get the new character, and many of the lines we have added were copied from other methods. We could easily add other kinds of sprites and make them appear and disappear when we want them. It would also be quite easy to add things like “Extra Life” sprites if we wanted the game sprites that increase the number of lives available.

Adding Game Sounds

The BreadAndCheese game is now quite playable. It has a bit of variety and it can get quite hectic, with the player having to keep an eye on lots of things at the same time to stay alive and rack up a big score. However, there is one thing missing from it, and that is sounds. At the moment, playing the game is very much like watching the TV with the sound turned off.

Such is the value of sound to a game that even the very first computer games had sound output, even if it took the form of primitive beeps. You now need to think about how sounds can be added to the game. You have seen how easy it is to load and play sound effects; now you have to bind them into the game sprites so that when something happens to each sprite, it plays an appropriate sound effect. But before we can add sounds, we have to decide how to do it and decide who makes the sounds in the game.

This is actually a profound question. Does the BreadAndCheeseGame class make the sound, or do the sprites do it themselves? After some thought, you probably come to the same conclusion that I did, which is that the sound of a sprite is a bit like the texture that is used to draw it; it is a property of the sprite. Furthermore, on the principle of high cohesion being good (that is, it is best if an object can look after itself and not rely on any other objects), it makes sense for the sprite to make the sound. Sprites that need to make sounds can be given the sound effects when they are constructed and play the appropriate ones as required. You can make the sounds any way you like. I created mine using a little electronic sound generator. Figure 15-6 shows the sounds after I had imported them. Note that the name of each sound file directly reflects its purpose.

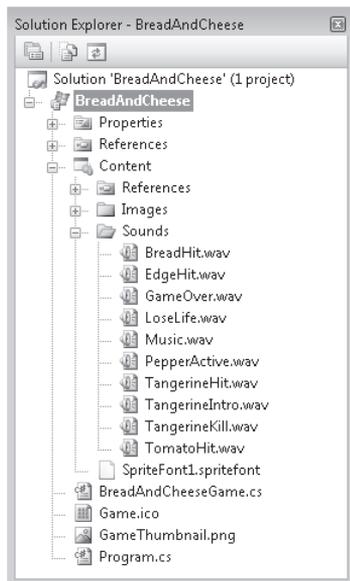


FIGURE 15-6 All the sound effects in the Bread and Cheese game

Each of them is loaded into the game as content, and the constructor of each sprite class is modified to accept the sound effect resources when the sprite is created:

```
CheeseBall = new BallSprite(  
    Content.Load<Texture2D>("Images/Cheese"),  
    0.07f, // a cheese takes 0.07 of the screen width  
    200, // cheese takes 200 ticks to cross the screen  
    minDisplayX, maxDisplayX, minDisplayY, maxDisplayY,  
    displayWidth / 4, // a quarter across the screen  
    displayHeight / 4, // a quarter down the screen  
    Content.Load<SoundEffect>("Sounds/BreadHit"),  
    Content.Load<SoundEffect>("Sounds/TomatoHit"),  
    Content.Load<SoundEffect>("Sounds/EdgeHit"),  
    Content.Load<SoundEffect>("Sounds/LoseLife"));  
GameSprites.Add(Cheese);
```

This code creates a new `CheeseBall` and passes it all the information it needs, including the sound effects. The constructor of the class stores the sound effects so that they can be used to produce the sounds as required:

```
public BallSprite(Texture2D inSpriteTexture,  
    float widthFactor, float ticksToCrossScreen,  
    float inMinDisplayX, float inMaxDisplayX,  
    float inMinDisplayY, float inMaxDisplayY,  
    float inInitialX, float inInitialY,  
    SoundEffect inBatHitSound,  
    SoundEffect inTargetHitSound,  
    SoundEffect inEdgeHitSound,  
    SoundEffect inLoseLifeSound)  
: base(inSpriteTexture, widthFactor, ticksToCrossScreen,  
    inMinDisplayX, inMaxDisplayX,  
    inMinDisplayY, inMaxDisplayY,  
    inInitialX, inInitialY)  
{  
    batHitSound = inBatHitSound;  
    targetHitSound = inTargetHitSound;  
    edgeHitSound = inEdgeHitSound;  
    loseLifeSound = inLoseLifeSound;  
}
```

This code actually looks rather horrible, and for that I apologize. The constructor for the cheese actually does very little work because most of the heavy lifting is done by its base constructor, which sets up the moving sprite. All the constructor does is copy the incoming sound effects into members inside the `BallSprite` class, so that they can be used in the `Update` method to make the appropriate sounds. I think it is fair to say that when you understand this lump of code, you properly understand constructors and class hierarchies.

Here is part of the Update method in the BallSprite class that plays a sound when the cheese ball hits the top of the screen:

```
if (y <= minDisplayY)
{
    // ball has hit the top of the screen.
    edgeHitSound.Play();
    ySpeed = Math.Abs(ySpeed);
}
```

Sample Code: 04 Bread and Cheese with Sound The sample project in the 04 Bread and Cheese with Sound directory in the resources for this chapter contains a version of the game that has all the existing game play with sounds added. I have used the code from the music player that we created in Chapter 7, “Playing Sounds,” to play background music and to make the sound for the deadly pepper repeats when it is on the screen. And you should make sure that you have the volume turned down a bit before the tangerines turn up.



Note The game will run on a Zune but because the Zune has fewer sound channels than the Xbox or Windows PC it may fail when the bat or the ball collides with a large number of killer tangerines. This is because the game will try to play a sound for each collision, and these are all played on separate sound channels. To fix this problem you could make a Zune version that does not play a new collision sound if the existing one is already active. I will leave this for you to sort out.

From Objects to Components

We now have a whole set of sprite components that are used in the BreadAndCheeseGame. These components use some methods in the game itself, so that they can tell the game when something important happens. As an example, the Update method in the Ball is given a reference to the BreadAndCheeseGame that it is part of so that it can tell the game when a life has been lost, as shown here in bold:

```
public override void Update(BreadAndCheeseGame game)
{
    ...

    if (y + spriteRectangle.Height >= maxDisplayY)
    {
        // cheese has hit the bottom. Lose a life.
        LoseLifeSound.Play();
        ySpeed = Math.Abs(ySpeed) * -1;
        game.LoseLife();
    }
    ...
}
```

The `LoseLife` method is part of the `BreadAndCheeseGame` class and is how game sprites tell the game that a life has been lost. You use a similar method when you score points. Sprites need to have this form of coupling so that the sprites can affect the game where required. However, this means that they are tightly linked with the `BreadAndCheeseGame` class and can be used only with it. This is actually a serious restriction. We would like to use the same set of sprites in an “Alien Wars” game that we are also working on, but because this is held in a class called `AlienWarsGame`, our sprites can’t talk to it. We can’t use abstract classes to solve this problem, because the game classes are children of the `XNA Game` class, whereas our sprites are all children of the `BaseSprite` class.

C# Interfaces

However, it turns out that we can use another C# feature to solve this problem and turn our sprites into genuine components. This feature is called an *interface*.



Note One point I should make here is that we are *not* talking about the user interface to our game. The user interface is the way a person using a program would make it work for them. These are usually either text-based (that is, the user types in commands and gets responses) or graphical (that is, the user clicks “buttons” on a screen using the mouse). In programming terms, an interface just specifies how a software component could be used by another software component.

You can think of interfaces in terms of plugs and sockets. When you plug your computer into the wall socket, you are actually using an interface. The power company has created a standard that describes the shape of the outlet on the wall and the voltage and frequency of the power that comes out of it. This interface lets you plug in anything built to use that connection, whether it is a computer, a toaster, or an Xbox 360. You can create a software interface to specify the connection between your game and the sprite you would like to plug into it. You can design this interface by deciding what a sprite needs to be able to do with the game that it is part of:

- Update the lives
- Update the score
- Get the current score in the game
- Get the gamepad state
- Start the game
- End the game

Anything which provides these behaviors can act as a “host” for our sprites, in that it can do anything that they need.

Creating an Interface

I worked out the contents of the interface by looking at the existing classes and deciding which methods the sprites actually needed. These methods can be put into a C# interface as follows:

```
public interface ISpriteBasedGame
{
    void UpdateLives(int update);
    void UpdateScore(int update);
    int GetScore();
    GamePadState GetGamePad();
    void StartGame();
    void EndGame();
}
```

A C# interface looks a lot like an abstract class. It is a collection of method specifications. The idea is that rather than using a reference to a particular class, you can instead use a reference to a class that can implement that interface. In other words, rather than thinking of the host of a sprite as a `BreadAndCheeseGame`, we think of it as a class that implements the `ISpriteBasedGame` interface. The `BreadAndCheeseGame` class can indicate that it implements the interface, as shown in bold here:

```
/// <summary>
/// This is the main type for your game
/// </summary>
public class BreadAndCheeseGame : Microsoft.Xna.Framework.Game,
    ISpriteBasedGame
{
    // All of the game class code goes here.
    // This must include implementations of UpdateLives,
    // UpdateScore, GetScore, GetGamePad, StartGame;
    // and EndGame
}
```

When you declare a class, you can state that it extends a parent (in this case, the `Microsoft.XNA.Framework.Game` class) and also give a list of any interfaces that it implements (in this case, the `ISpriteBasedGame` interface). A class can implement many interfaces, depending on the number of things you want to be able to ask it to do.



Note The name of the interfaces I have created is `ISpriteBasedGame`. There is a convention in C# that interfaces have names that start with `I`. This is so that a programmer can tell whether a given item is an interface or an object. You do not have to use this convention, but the Great Programmer has told me that she will hunt you down if you don't.

Implementing an Interface

When a class implements an interface, it is saying, “I can do these things.” In other words, it contains public versions of all the methods described in the interface. You can regard an interface as a kind of resume if you like. My resume says that I can teach computer science. This means that you can stand me in front of a class and call my “StartTeaching” method, and I do something in response. You could replace me with any other teacher, or perhaps even a robot, or anything that also has “teach computer science” on its resume because you know that means it contains the required method.



Note The interface doesn’t say anything about what the methods actually do (any more than me having “computer science teacher” on my resume says how I will teach my class); it says only that the object contains them. If we want to prove that a component can provide the expected behaviors appropriately, we have to create tests for these methods.

References to Interfaces

From the programming point of view, this means that we can now refer to objects in terms of what they can do, as opposed to what they are. We can refer to an object of type `BreadAndCheeseGame` by using a reference of type `BreadAndCheeseGame`. But we can also refer to such an object by using a reference of type `ISpriteBasedGame`. A reference of type `ISpriteBasedGame` can refer to any object that implements the interface. The compiler is quite happy with this. It knows that if it needs to use any of the methods in the interface, they are there, and it doesn’t need to care precisely what type of object the instance actually is. The `Update` method in the sprites is now passed a reference to the `ISpriteBasedGame` so that it can use the methods it provides. For example, here is the `Update` method in the `TitleSprite` class:

```
public override void Update(ISpriteBasedGame game)
{
    if (game.GetGamePad().Buttons.Start == ButtonState.Pressed)
    {
        game.StartGame();
    }
}
```

This `Update` method reads the gamepad of the game using the `GetGamepad` method and calls the `StartGame` method if it is time to start the game. It doesn’t know exactly what it is being given to work with, but it does know that the object that the game parameter refers to contains the `GetGamePad` and `StartGame` methods because the game reference is only allowed to refer to objects that implement the interface.

Linking Bread, Cheese, and Tomatoes

Earlier versions of the Bread and Cheese game used the game class itself to link the `Bat`, `Ball`, and `Target` classes. In other words, when the ball wanted to find out if it had collided with the bat, it would access the `BreadAndCheeseGame` class to get a hold of the reference to the `breadBat` that is stored within the game.

You are trying to make the behavior of the bat, ball, and targets independent of the game they are part of, and to do this you need to couple the bat, ball, and targets together, and not have them use the game to find each other.

This means that the constructor of the ball must now be passed a reference to the bat and the targets it must interact with so that it can store these for use later. This is actually quite sensible design, in that it makes the coupling more direct; rather than coupling via a third party, the bat, ball, and targets are directly connected.

Designing with Interfaces

Interfaces provide a very neat solution to the problem of wanting to reuse our sprites in the `AlienWarsGame` game. If the `AlienWarsGame` class implements the `ISpriteBasedGame` interface, the sprites can be used with that game.

Our sprites can work with any class that implements the `ISpriteBasedGame` interface. You could also create an interface that works the other way. An `ISprite` interface would have all the methods required to control a sprite. This would make it possible to plug any kind of sprite into a game, not just ones that are children of the `BaseSprite` class.

The Great Programmer Speaks: Interfaces Are Very Useful The Great Programmer uses interfaces a lot when she designs her programs. When she has decided what objects are needed to implement a solution, she next works out how they need to communicate with each other and creates interfaces based on these interactions. The result is that she can plug in new versions, or even plug in test versions, of objects very easily.

Sample Code: 05 Bread and Cheese with Interfaces The sample project in the 05 Bread and Cheese with Interfaces directory in the resources for this chapter contains a version of the game that uses interfaces to connect the game sprites with the game of which they are a part.

Conclusion

This has been another very busy chapter. We have seen how abstract classes can be used as templates, to make sure that a child class provides implementations of the methods it needs to perform its work. We have also discovered how a class can take control during its construction and how this can be used to set the initial values of the class. We have used the `List` collection to store a large number of sprites in our game and we have written our first piece of AI code to control a tangerine. Finally, we have explored interfaces as a way of creating true component-based software.

Chapter Review Questions

More chapter review questions. Never mind—we have just one more chapter to get through.

1. An abstract class cannot contain any working code.
2. An abstract class is not allowed to contain a constructor.
3. You can make only one instance of an abstract class.
4. You can mark data in an abstract class as `abstract`.
5. A `C#` class can extend more than one parent class.
6. An abstract class can be used as the base of a class hierarchy.
7. A reference to an abstract class can refer to any instance of children of that class.
8. The constructor of a class is called when a new instance of the class is created.
9. If a class contains one constructor, this must be called to create an instance of that class.
10. In a class hierarchy, the data members of an instance of a child class must be initialized before the data members of the parent class are initialized.
11. The `.NET` system can be used to provide random numbers.
12. The `List` collection class must have its length set when it is created.
13. The `foreach` construction can be used to work through all the elements in a `List`.
14. Artificial Intelligence involves adding brain cells to a program.
15. An interface contains a list of methods.
16. A reference to an interface can refer to any object that implements the interface.

Chapter 16

Creating Multi-Player Networked Games

- See how Microsoft XNA games can be made to connect together.
- Look at the C# constructions that let network games exchange data.
- Create a multi-player game for Microsoft Windows PC, Xbox, and Zune.

Introduction

You are well on the way to becoming a full-fledged programmer. You don't know everything yet, but you have enough programming and XNA knowledge to produce very playable (and marketable) games. One XNA feature that is worth exploring, though, is the way that XNA makes networked games possible.

In this chapter, we are going to find out a bit about how networks function and create a simple networked game for PC, Xbox, or Zune.

Networks and Computers

It should come as no surprise to you that networks are used to link computers. Before we look at how XNA provides network connections, we need to learn a little bit about how networks work. This is not a detailed examination of the field, but it should give you enough background to understand what the XNA networking support does.

Starting with the Signal

The first computer networks used wires to send their data signals, although more modern networks can use radio or fiberoptic cables. Whatever the medium is, the fundamental principle is that you have hardware that can put data onto the medium in the form of bits and get it off again. A bit is either 0 or 1 (or you can think of a bit as either true or false) and can be signaled by the presence or absence of a voltage, a light from a light-emitting diode (LED), or a radio signal.

If you imagine signaling your friend in the house across the road by flashing your bedroom light on and off, you have an idea of the starting point of network communications. Figure 16-1 shows how such a bedroom-to-bedroom signaling system might work.

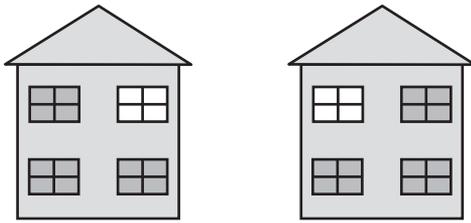


FIGURE 16-1 Sending messages from one bedroom to another using a light

Once we have this raw ability to send a signal from one place to another, we can start to transfer useful data.

Building Up to Packets

Just flashing your light to your friend willy-nilly does not allow you to send much information. To communicate useful signals, you have to agree on a system. You could say, “If my light is off and I flash it twice, it means it is safe to come round because my sister is out. If I flash it once, it means don’t come, and if I flash it three times, it means come and bring pizza with you.” This is the basis of a thing called a protocol, which is an arrangement by parties on the construction and meaning of messages.

Addressing Messages

Your bedroom light communication system would be more complicated if you had two friends on your street with whom you needed to communicate. You would have to agree with them that you would send two sets of flashes. The first one would indicate who the message was for, and the second would be the message itself. Computer networks function in exactly the same way. Every station on a network must have a unique address. Messages sent to that address are picked up by the network hardware in that station.

Networks also have what is called a *broadcast* address. This allows a system to send a message which will be picked up by every system. This is the network equivalent of “Calling all cars...” In our communication network, this could be used to warn everyone that your sister has come home and brought her boyfriend, so your house is to be avoided at all costs.

Everyone can receive and act on a broadcast. In fact, if it wanted to, a station could listen to all the messages traveling down its part of the wire or WiFi channel. This illustrates a problem with networks. Just as both of your friends can see all the messages from your bedroom light, including ones not meant for them, there is nothing to stop someone from eavesdropping on your network traffic. When you connect to a secure Web site, your computer is encoding all the messages that it sends out so that someone listening other than the intended recipient would not be able to learn anything.

Routing

If you had a friend on the next block, she might not be able to see your bedroom light. But she might be able to see the light of your friend across the road. This means that you could ask your friend across the road to receive messages and then transmit them on for you. Your friend across the road would read the address of the message coming in, and if it was for your friend on the next block, she would transmit it again. Figure 16-2 shows how this works. Your friend uses the window on the left to talk to you and the window on the right to relay messages to your more distant friend.

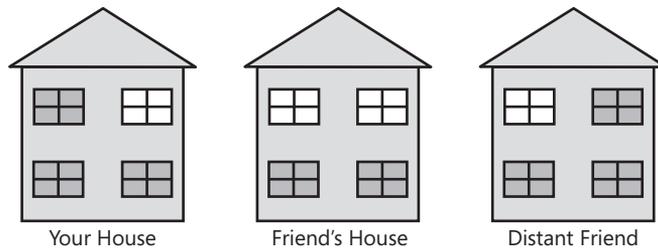


FIGURE 16-2 Using your friend to route messages to a friend farther away

This is the basis of routing, and it is how the Internet works. Messages that you send from your home PC to distant machines are passed to the network hardware at your Internet service provider (ISP), which then passes them along to the next system in the path to the destination. Messages might have to be sent over several machines to reach their destination. The Internet constantly changes the routes that messages take. This makes the Internet very reliable and able to manage sudden surges in traffic and failures of systems in the network, but it can lead to situations where a message arrives before another which was sent first. Sometimes messages can get lost (although this is fairly rare), so you can't be sure that one has arrived until you receive an acknowledgement. One thing you should remember is that you do not really "connect" your system to the Internet. Whenever your system is connected, it actually becomes part of the Internet.

Anything that you send via the Internet will be transferred using one or more individual messages. Each message contains the address of the destination and each message is numbered, so that missing messages can be detected and messages can be put into the right order when they are received (if you want that). If you need to transfer a large file, this will be broken down into a number of messages.

Calls and Datagrams

The Internet provides two forms of connection: calls and datagrams. A datagram is a single message that is sent from one system to another. You don't know if a datagram has been received. This is like flashing your bedroom light to ask for pizza (message 3) and then just waiting for someone to turn up.

You could agree with your friend that she would flash her light once to indicate that she has received your message. Then perhaps you could send another message. When she was leaving to fetch the pizza, she could flash her light twice to indicate that she was “going off the air.” This would be the basis of a call between the two of you.

When two systems are in a call, they have to perform extra work to manage the call itself. When one system sends a message that is part of a call, the network either tells that system that the message was successfully transferred (once the network have received an acknowledgement) or give an error saying that it could not be delivered. Some Internet services use datagrams, and some use calls.

Datagrams are used for things like broadcasting video. In this situation, if a message is lost by the network, there is no point in asking for it again because by the time the replacement arrives, it will be too late to display it. So the display program must make up for the missing data and just keep going, hoping the viewer does not notice. Datagrams are used when you want to send data as fast as you can and it doesn’t matter if some gets lost on the way. Game data is often sent like this because you want the objects in the game to update as smoothly as possible and there is no time to resend missing information. Datagrams are also used for streaming media, where moving video is being sent and the priority is to get the signal to you as fast as possible.

Calls are used when it is important that the entire message gets through. When your browser is loading a Web page, your computer and the Web server are connected by a call across the network. This makes sure that all parts of the Web page get through and that any pieces that don’t arrive are retransmitted. The effort of setting up and managing the call and requesting retransmission when things fail to arrive means that data in calls is transferred more slowly and places heavier demands on the systems communicating by means of a call.

Networks and Protocols

A protocol is a set of rules that tells you how to behave in a certain situation. There is a protocol that tells you which knife and fork to use in a posh banquet, and another that tells you to kiss a maiden on her hand having just rescued her from a dragon. You already have one with your friend, where you have agreed on the meaning of the various messages that you send with your bedroom lights.

In networking terms, a protocol sets out the design of all the messages and how stations in a network should cooperate to move data around. There are essentially two levels at which this must take place. There must be a “local-level” protocol that lets local stations (ones on the same piece of physical media) exchange data, and there must be an “internetwork” protocol that allows messages to be sent from one local network to another.

You can regard a local-level network as the same as the internal mail that is used in many organizations, including my university at Hull. If I want to send a message to our chemistry department, I just put the address “Chemistry Department” on the envelope and drop it

in the internal mail. There is a local protocol (called the internal mail system) that makes sure that the message gets there. However, if I want to send a message to the chemistry department at York University, I must put a longer address on the envelope. When the letter gets to the mailroom, the staff notice that the destination is not local, and they route it out to the postal system, which sends it to York. This is the “Internet Protocol” for letters.

The Internet is powered by a local protocol (Transport Control Protocol, or TCP) and an internetwork protocol (Internet Protocol, or IP). Put these together, and you have the familiar TCP/IP name that refers to the combination. You can also use the TCP/IP protocol to connect machines without linking them to the Internet. In effect, you can create an “Internet in your bedroom” from just a few machines. Windows PCs and Xbox consoles connected in this way can be used to play games using a connection called “System Link,” which we’ll discuss in the next section.

Xbox Live

Xbox Live uses the TCP/IP protocol to connect Xbox consoles and Windows PCs for networked game play. All Xbox games provide support for some form of network connection using Xbox Live. This can be as simple as the uploading of high scores and achievements to your gamertag. However, many games provide very advanced network play facilities, with Xbox Live connectivity allowing gamers to set up and play multi-player sessions.

Gamertags and Xbox Live

If you have used Xbox Live, you know about “gamertags.” A gamertag is a name by which a player is known on the Xbox Live network. You have created an account on the Xbox Live network associated with a unique gamertag that other gamers can use to find you. Your gamertag is also linked to your game achievement records and other game-related information that is stored for you by the Xbox Live system. You can also create an avatar which lets other gamers see what you look like.

It is possible to create XNA programs that make use of the Xbox Live gamertags and worldwide servers and provide a multi-player experience just like that from any full-fledged game. However, to develop and test such a game requires multiple XNA Creators Club memberships and some fairly complex coding that is beyond the scope of this introductory text. However, you can still create multi-player games using the somewhat simpler System Link technology, which XNA also supports.

System Link and XNA

System Link is a game networking technology that allows Xbox 360 consoles and Windows PCs on the same physical network to engage in network game play. When I say “same physical network,” I mean the network is connected to the same piece of wire or WiFi access point.

The bad news is that this means for multi-player action, your friend has to bring her computer or console round to your house and plug it into your network. The good news is that PC and console owners can play against each other. The better news is that System Link is also the way that Zune devices communicate using XNA, so you can use your System Link skills to write games that allow handheld multi-player gaming.



Note It is not possible to use XNA to play network games between PC and Zune at the moment. Although the Zune can use its WiFi connection to link to a Windows PC to synchronize media, it is not possible for it to perform XNA game play with a PC or Xbox 360.

System Link provides a set of methods that can be used to allow a program running on one system to send a message to another. What the message contains and how it is formatted are completely up to the game developer. You also get a means by which a network game can be set up between two or more players. A System Link game is “local,” which means that it does not need to use the Xbox Live gamertag system to find players; instead, you can create local Gamer Profiles on machines.



Note By “local network,” I really do mean local. I have encountered problems creating System Link games using machines connected via WiFi adapters. It seems that XNA works best when communicating across real wire. Bearing in mind that during network play it is important that the systems have a reliable and speedy network connection, it is probably best to use wire anyway.

Bread and Cheese Pong

To find out how to create a network game, you are going to make a new game called “Bread and Cheese Pong.” Your younger brother really likes the name. It will be a simple pong game, with each player controlling a bat and hitting the cheese towards the opponent. You can use a lot of the bread and cheese sprite code that you have already written in previous chapters. A good starting point would be a simple, two-player pong game, as shown in Figure 16-3.

This game finally answers the question, “Which is better, white bread or brown bread?” with bread bats being used to hit the cheese ball. The players are defending their back wall—if cheese hits the back wall, the player on the opposing side gains a point.

Sample Code: 01 Bread and Cheese Pong Game All the sample projects can be obtained from the course instructor. The sample project in the 01 Bread and Cheese Pong Game directory in the resources for this chapter contains a two-player pong game that uses two gamepads to control the bread bats. This is the starting point for our game.

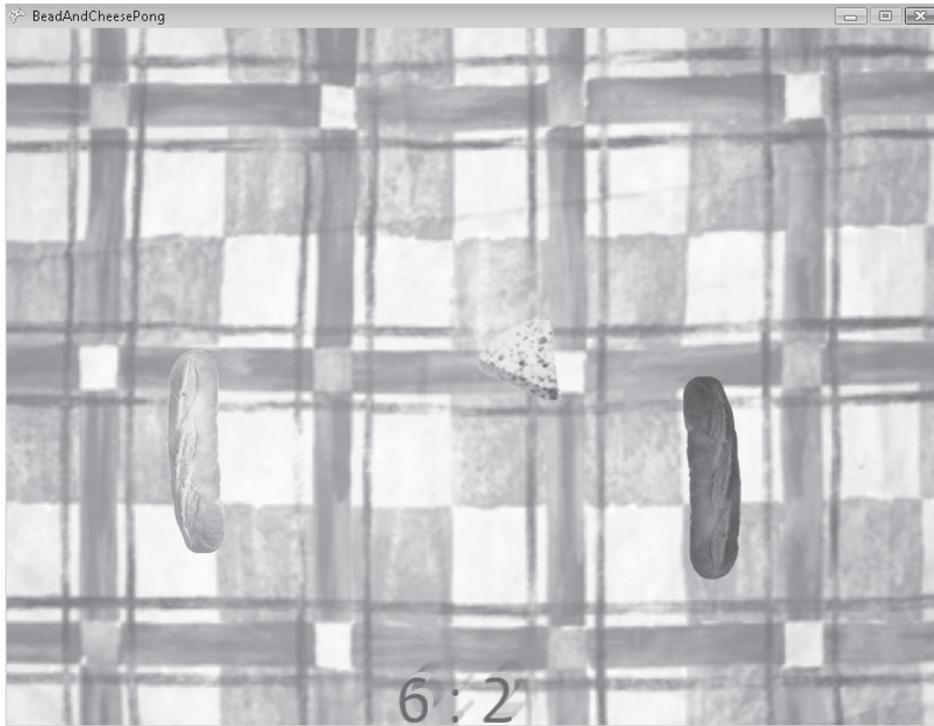


FIGURE 16-3 Two-player Bread and Cheese Pong game

Managing Gamer Profiles in XNA

Before a game can start network play, the players must be signed in. On an Xbox 360, you perform this kind of task using the Guide part of the user interface, which you access by pressing the big silver X button in the middle of the gamepad. This facility is part of the Xbox and is always available. When running XNA programs on a Windows PC, you can access a similar facility by pressing the Home key on the PC keyboard. However, if you start one of the games we have already written and press the Home key, you find that nothing happens. This is because the Guide behavior is managed by the `GamerServicesComponent`, which is part of XNA and must be loaded into a game if the game wishes to use it. This is simple to do—you just have to add an extra line to the constructor of your game class:

```
public PongGame()
{
    graphics = new GraphicsDeviceManager(this);
    Content.RootDirectory = "Content";

    this.Components.Add(new GamerServicesComponent(this));
}
```

This creates a new `GamerServicesComponent` instance and connects it to your game. Now, when you run your game, you can press the Home key to call up the display. Figure 16-4 shows the initial sign-in screen.



FIGURE 16-4 Initial sign-in screen

Creating a Profile

The very first time you use the `GameServicesComponent` on your Windows PC, you do not have any gamer profiles on it. This means that it displays the screen shown in Figure 16-4, from which you can create a new profile. You can control the screen from an Xbox gamepad or from the keyboard. You should move the highlighted menu option to select `Create New Profile`, and then press the A button on the gamepad, the A key on the keyboard, or the Enter key to select this option. You can also use the Windows PC mouse to select options on any of these screens. Once you have selected `Create New Profile`, the screen changes to the one shown in Figure 16-5, where you can enter your profile name.

Once you enter your profile name and select `Submit`, you are taken to the `New Profile Save` screen, as shown in Figure 16-6.

**FIGURE 16-5** Creating a user profile**FIGURE 16-6** Saving a profile

You are allocated a random icon, but you can change this by selecting Customize Profile. The profile that you are about to create is local to the Windows PC you are using. If you want to create a Windows Live–based profile, you can select that option and you are directed to a browser-driven interface where you can set up your account. You can do this later if you wish. Once you have created your profile, you are taken to your profile page, as shown in Figure 16-7. At this point, the system has signed you in.



FIGURE 16-7 A signed-in user profile

You can close the guide by pressing the Home key again or the B button on the gamepad, or by clicking the X in the top right corner of the display.

Automatic Sign-In

The next time you start an XNA game that has `GameServicesComponent` active, it automatically signs in for you using the last active profile. It shows you that this has happened by momentarily displaying a message at the base of the screen, as shown in Figure 16-8.

The message also reminds you that you can sign out and change to a different profile, or even create a new profile, by pressing the Home key.



FIGURE 16-8 Notice of automatic sign-in

Sample Code: 02 UserDisplay The sample project in the 02 UserDisplay directory in the resources for this chapter is a brand-new, empty project that has the `GameServicesComponent` loaded. You can use it to create a new profile for yourself.

Ensuring a Gamer Is Signed In for Network Play

It is impossible to start a network game until a gamer has signed in. This is because the gamertag is used to identify this player on the network, and if the player is not signed in, there is no tag. The `Gamer` class provides a property called `SignedInGamers`, which contains a collection of the gamers currently signed in at your game. On the Xbox 360, it is possible for more than one gamer to sign in to a single console (this is so they can use split-screen multi-player mode in networked games). On the Windows PC, there can never be more than one signed-in gamer at a machine.

The game must make sure that a gamer has signed in for network play. It can test to see if a gamer is signed in by checking the number of items in the `SignedInGamers` collection. If this

is zero, no players are signed in. This means that the game must display the menu that lets a player sign in with his or her profile. The XNA menus are created using the `Guide` class, which can display a number of different menus. The one that you want is activated using the `SignIn` method on the `Guide`. The `Guide` also provides a property called `IsVisible`, which is set to `true` when the guide is active. You can use this to stop the guide being displayed on top of itself. Your program should only try to display a new guide menu if the `IsVisible` property is `false`:

```
protected override void Update(GameTime gameTime)
{
    // Allows the game to exit
    if (GamePad.GetState(PlayerIndex.One).Buttons.Back ==
        ButtonState.Pressed)
        this.Exit();

    if (Gamer.SignedInGamers.Count == 0)
    {
        if (Guide.IsVisible == false)
        {
            Guide.ShowSignIn(1, false);
        }
    }

    base.Update(gameTime);
}
```

This version of `Update` displays the sign-in screen if there are no signed-in gamers. If a user closes the guide without signing in, this code displays the sign-in screen again. Note that the `ShowSignIn` method for the `Guide` has two parameters. The first is the number of sign-in screens to display. For a Windows PC game, this must always be `1`. The second is whether or not to restrict the sign-in to permit only online gamers to sign in. Online gamers have profiles linked to Xbox Live. For our game, we want to allow local gamer profiles as well, and so this parameter should be `false`.

Zunes and Gamer Profiles

The Zune does not support multiple gamer profiles. As far as XNA is concerned, it is always signed in, and the gamertag that it uses is the name of the Zune itself. The Zune also lacks the `Guide` behavior because it doesn't need to perform user management. If you try to use the `Guide` object in a Zune XNA program, it fails to compile, but this doesn't keep us from making a single game that works on all platforms, as you will see later.

Creating a Game Lobby

Playing a network game is just like any other. If you wake up one morning with a strong desire for some “Snakes and Ladders” action, you have to find your copy of the game and then get a hold of enough people to join you and start playing. This might involve standing somewhere shouting, “Who wants to play Snakes and Ladders?” until you have enough people who want to take part.

In computer gaming terms, this is sometimes called a “game lobby,” where one system on the network proposes a game session and other players enter the game lobby and wait together until there are enough of them there to play the game. To create a network game, you are going to have to add code to set up a lobby and invite people to join your game. In the case of Bread and Cheese Pong, you need only one additional player, but the system we are going to build will handle more than two players.

Network Games and State

We have looked at game states before. The original Bread and Cheese game had a “Title Screen” state and a “Playing” state and would switch between them. In the case of a networked game, state is even more important. There are a number of possible states that the networked game might occupy. The best way to represent these is to use an enumerated type as follows:

```
public enum GameState
{
    titleScreen,
    NotSignedIn,
    SelectingRole,
    WaitingAsHost,
    WaitingAsPlayer,
    PlayingAsPlayer,
    PlayingAsHost
}

GameState state = GameState.titleScreen;
```

These are all the possible states that the game can occupy. For each state, there will be events that cause the game to move from that state into another. Figure 16-9 shows the states, the screens that they display, and the events that cause the states to change. The variable `state` holds the current state of the game.

The `Update` and `Draw` methods contain `switch` statements that control what the game does when in each state, something we used before when creating the original Bread and Cheese game. We can now look at how the states are used to start the game and play it.

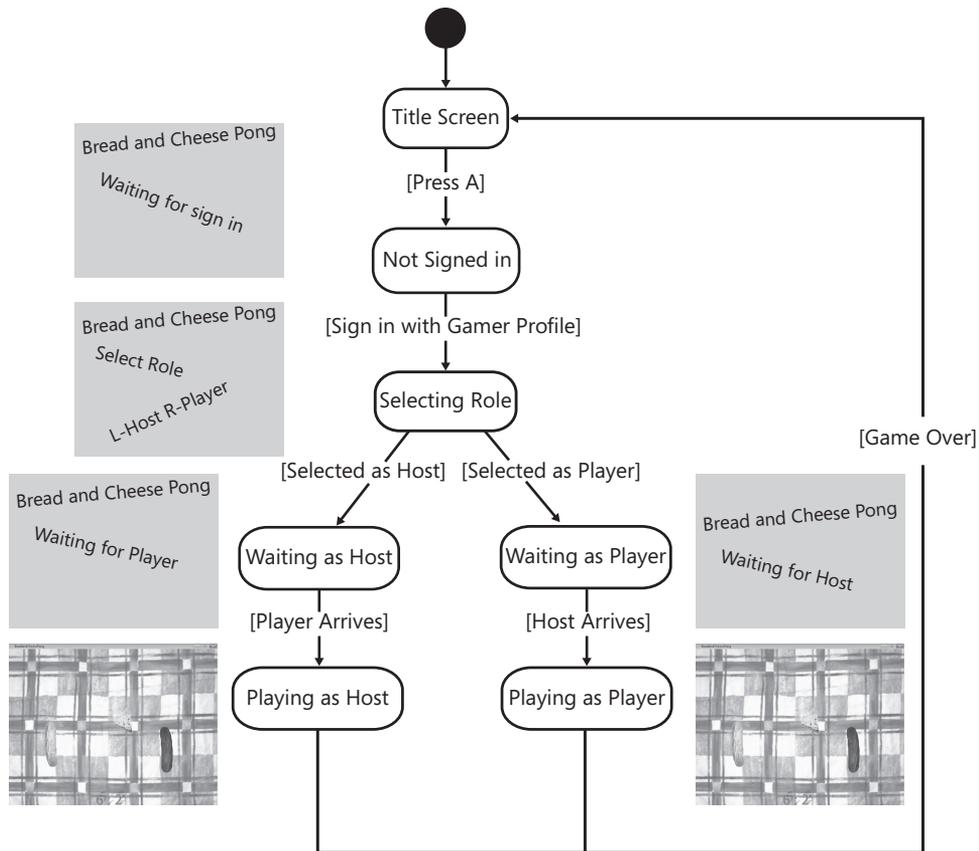


FIGURE 16-9 States in the Bread and Cheese Pong game

Starting at the Title Screen

The `titleScreen` state is the state the game occupies at the start. A title screen is displayed and the player is invited to press A on the gamepad to continue. The game returns to this state when a game finishes. You have seen the code for this state before—it simply reads the gamepad of the player and checks whether the A button has been pressed. This is the part of the `switch` statement in `Update` that deals with the behavior of the game when in the `titleScreen` state:

```

case GameState.titleScreen:
    if (gamePad1.Buttons.A == ButtonState.Pressed)
    {
        state = GameState.NotSignedIn;
    }
    break;
  
```

When the player presses A, the game state is changed to the `NotSignedIn` state.

Signing In Players

The first thing the game must do is make sure that the player is signed in with a gamer profile. The code for the `NotSignedIn` state in the `Update` method must check whether a gamer is signed in and display the `ShowSignIn` page from the `Guide` if not. This code is made slightly complicated by the fact that if the game is running on a Zune device; it is not possible to use the `Guide` at all, and if the program refers to a `Guide`, it does not compile.

The code here uses *conditional compilation*, a C# feature we have seen before in Chapter 6, "Creating a Multi-Player Game," in the section entitled "Adding Test Code." This lets you turn on and off lines of C# source code, depending on symbols which can be defined in the program. The designers of XNA have provided the symbol `ZUNE`, which is defined if the program is being compiled for a Zune device. This means that when we compile for a Zune target, we can make sure that the offending lines are "switched off":

```
case GameState.NotSignedIn:
#if ZUNE
    // Special handling for the Zune device

    // This state will never be reached
    // because the zune is always signed
    // in with the device profile.
    // So we move on to the selecting role state
    // if we ever do end up here for
    // any reason

    state = GameState.SelectingRole;

#else

    if (Gamer.SignedInGamers.Count == 0)
    {
        if (!Guide.IsVisible)
        {
            Guide.ShowSignIn(1, false);
        }
    }
    else
    {
        state = GameState.SelectingRole;
    }

#endif
break;
```

As XNA automatically signs in a player, the game normally moves straight through this state into the `SelectingRole`, where the player selects the role he or she is going to play.

Selecting the Role of Host

One player must be the host of the game, and the other will be the player. The host sets up the game lobby and waits for the player to join. The role to be taken is selected using the D-pad on the gamepad, which is tested when the game is in the `SelectingRole` state.



Note The lobby system works fine whether the player waits for the host or vice versa. However, you might have to wait a second or two after both systems have selected their roles as the systems find each other on the network.

Pressing the left button on the pad selects the Host role. The host must create a network session and wait for other players to join. The session is created using the `Create` method, which is told the type of the game, the maximum number of local gamers on a machine and the maximum number of players the game can support:

```
if (gamePad1.DPad.Left == ButtonState.Pressed)
{
    // Selected Host role
    // Create the session
    session = NetworkSession.Create(
        NetworkSessionType.SystemLink,
        1, // only 1 local gamer
        2 // no more than 2 players
    );

    session.GamerJoined +=
        new EventHandler<GamerJoinedEventArgs>(hostSession_GamerJoined);
    session.GamerLeft +=
        new EventHandler<GamerLeftEventArgs>(hostSession_GamerLeft);

    state = GameState.WaitingAsHost;
```

Once the session has been created, the game program must bind to events that tell it when more players arrive. At this point, we need to digress into events.

The Great Programmer Speaks: You Need to Know About Events The Great Programmer reckons that events are, quite literally, what make programs tick. They underpin the way that software responds to user actions on your Windows PC, including mouse movement, key presses, and even the system clock. A good understanding of how events are managed in a program is a very good thing to have, and the game sessions of XNA provide a good place to start exploring this subject.

Events let programs deal with things when they happen instead of the program having to hang around waiting. In the case of the Pong game, it might take several seconds for a player to join the host in a game. However, the XNA system wants to keep calling the `Draw` and `Update` methods until a player arrives. So instead of waiting for a response, the program tells the session what to do when a gamer arrives by connecting, or binding, a method to the events the program wants to know about.

To do this, the program needs a way of creating a reference to a method. You have seen references to objects before, but references to methods are different. They are called *delegates*. A delegate is an object that refers to a particular method in a class. You declare a delegate by telling the compiler the type returned by the delegate, and the type of the parameters to the delegate:

```
delegate int DoSimpleSum(int v1, int v2);
```

This creates a delegate type called `DoSimpleSum`. This particular delegate accepts two integer values and returns an integer result. It can be made to refer to any method that accepts two integers and returns an integer result, such as the two methods below:

```
int DoAdd(int v1, int v2)
{
    return v1 + v2;
}

int DoMultiply(int v1, int v2)
{
    return v1 * v2;
}
```

To create an instance of the delegate that refers to one of these methods we must declare a variable and create an instance of the delegate, as shown below.

```
DoSimpleSum mySum = new DoSimpleSum(DoAdd);
```

This code creates a delegate variable of type `DoSimpleSum`, which has the identifier `mySum`. This is then set to a new delegate instance that refers to the `DoAdd` method. This means that if I use the `mySum` delegate it will call the `DoAdd` method:

```
int result = mySum(3, 3);
```

The code above would put the value 6 into the `result` variable, because the delegate points to the `DoAdd` method.

A program can use the `mySum` delegate to tell another part of the program which method to call when a sum needs to be performed. Because `mySum` is an object like any other, I can pass it into a method as a parameter.

Delegates are *type-safe*, in that they are allowed to refer only to methods that match their declaration. For example, it would not be possible to create a delegate of type `DoSimpleSum` that referred to a method that only accepted a single parameter.

If I give a program a delegate value, it can use that to call the method that the delegate points to. The first event the game is interested in is when a gamer joins. You will create a method called `hostSessionGamerJoined` that will deal with this situation and then connect it to the event. The C# that connects to this event is shown here:

```
session.GamerJoined +=
    new EventHandler<GamerJoinedEventArgs>(hostSession_GamerJoined);
```

The event that we are interested in is the `GamerJoined` property of the session object. The event manages a list of people to contact when a gamer joins the session. The `+=` operator is one we have seen before. It lets you add a value easily. For example, `x += 3` adds 3 to the value `x`. In this case, the `+=` is adding a new delegate value to the `GamerJoined` event in our session.

The delegate is set up to refer to an `EventHandler` method that accepts `GamerJoinedEventArgs`. The method being connected to the event is called `hostSession_GamerJoined`. This method must check to see if there are enough remote gamers connected, and if there are, it must start the game and change the state of the game to `PlayingAsHost`. It is actually quite a simple method. It checks to see if we have enough gamers available and then, if we have, it calls `StartGame` to set up all the game elements and changes the state to indicate that the game is now playing with this machine as the host, as shown here:

```
void hostSession_GamerJoined(object sender, GamerJoinedEventArgs e)
{
    if (session.RemoteGamers.Count == 1)
    {
        StartGame();
        state = GameState.PlayingAsHost;
    }
}
```

This version of `hostSession_GamerJoined` lets anyone join the game. It is, however, possible for the event handler method to get the gamertag of the player wishing to join and start playing only with certain people.

Events and delegates are used extensively throughout the Windows operating system to allow programs to bind to events such as button presses in the Windows graphical user interface. If the code looks a bit confusing, do not worry. The nice thing is that XNA Game Studio creates most of the code for you automatically.

Just remember that delegates provide a way that you can connect an event generator (something that wants to tell our program something) with a method (that needs to do something to respond to that event). The game also binds a method to the event for when a gamer leaves. If a gamer leaves, we want the game session to end and return to the title screen. The following method handles this event:

```
void hostSession_GamerLeft(object sender, GamerLeftEventArgs e)
{
    session.Dispose();
    EndGame();
}
```

Calling the `Dispose` method on a session causes it to shut down. This means that the player should be able to initiate a new game at this point. The `EndGame` method tells all the sprites in the game that it has ended and resets the game state to `titleScreen` so it is ready for the next game.

Displaying the Contents of the Lobby

While the game is acting as a host, waiting for players to join, it shows a list of players already in the game waiting to take part:

```
case GameState.WaitingAsHost:
    displayMessage = "";
    foreach (Gamer g in session.AllGamers)
    {
        displayMessage += g.Gamertag + "\n";
    }
    session.Update();
    break;
```

This part of a game is sometimes called the “lobby display.” The `foreach` loop assembles a string called `displayMessage` containing the gamertags of all the gamers who are presently in the lobby waiting to play the game. For your game, this just shows the gamertag of the host of the game (because a host is always part of the session she is hosting), but if a game was waiting for several players, it would let the host see how many people had joined so far. The string `displayMessage` is drawn on the screen by the `Draw` method.

Note that there is also a call of an `Update` method on the `session` that is being managed. When a system is using the network, it must do this to keep the network active.

Selecting the Role of Player

The role of player is selected by pressing the right button on the D-Pad when the game is in the `SelectingRole` state. When in this state, the game looks for game sessions being presented by hosts and joins one if it finds it. This is much simpler than the host behavior. As shown here, the game just moves into the `WaitingAsPlayer` state, where all the work is actually performed.

```
if (gamePad1.DPad.Right == ButtonState.Pressed)
{
    // Selected Player role
    state = GameState.WaitingAsPlayer;
}
```

Waiting for a Host

If the game is in the `WaitingAsPlayer` state, it is waiting for a host. The game must repeatedly look for hosts who are presenting sessions that it might want to join. In a full-fledged lobby system, players would be able to choose which games they might like to join. Your game is much simpler, in that it simply finds the first available hosted game and joins it:

```
case GameState.WaitingAsPlayer:
    AvailableNetworkSessionCollection sessions =
        NetworkSession.Find(NetworkSessionType.SystemLink, 1, null);
```

```
if (sessions.Count > 0)
{
    AvailableNetworkSession mySession = sessions[0];
    session = NetworkSession.Join(mySession);
    session.GamerLeft +=
        new EventHandler<GamerLeftEventArgs>(playerSession_GamerLeft);
    StartGame();
    state = GameState.PlayingAsPlayer;
}
break;
```

The `Find` method is called on the `NetworkSession` class, which looks for games and returns a collection of the ones that it finds. It can be supplied with the properties of the game you want it to look for, in terms of the type of game, the number of local players, and other filtering options. The call shown previously looks for `SystemLink` games with no more than one local player. If it finds some games, it joins the one at the start of the collection (`sessions[0]`) and then adds the method `playerSession_GamerLeft` to the `GamerLeft` event so that the game is informed if the host leaves the game. It then starts the game and sets the game state to `PlayingAsPlayer`, so that the players can start their networked battle.

At this point, you now know how the lobby system works, and what happens to get the players this far in the network game. This would be a good time to go for a cup of coffee.

Playing the Game

The lobby mechanism has brought the two players to the point where one game is in the `PlayingAsHost` state and the other is in the `PlayingAsPlayer` state. Both games also have an active `session` instance that is providing the link between the two XNA programs. Now they can start playing the game.

Game Topology

You can arrange a network game in a number of ways. Some games are based on a configuration called “peer to peer,” where no one player is in overall control and each player must exchange game status information with all the other players in the game. This works for small numbers of players, but for games with many systems, it can result in a lot of network traffic.

A better way to arrange network play is to have one system operate as a server and have all the others send their information to it. The server can then send out a message to everyone that contains the position of all the elements in the game. This results in much less network traffic. In terms of game arrangement, it is often the case that there must be one system in overall control of the game. The server for a game is usually, but not always, the system that proposed it in the first place.

In the case of our game, the system that is in the `PlayingAsHost` state works as a server and manages the game state, with the `PlayingAsPlayer` system working as a client. This means that if you wanted to add players (whole-grain bread, anyone?), then this would be easy to do.

Creating the Server Behavior

The host system performs all the game mechanics for player 1. These are very recognizable from previous games. The first part of the update is very familiar:

```
CheeseBall.Update(this);  
Player1Bat.Update(this);
```

These two calls move the cheese ball and update the position of the bread bat for player 1. The ball update method also checks for collisions between the bats and the ball and performs the scoring.

Once the ball and the player 1 bat have been updated, the host must then send this information to the client system so that the game running on the other player's machine can use it to drive the display. You can think of the connection between the server and the client as two pipes which are plugged into your program. A system can push information into the "send" pipe and also check to see if anything has arrived from the "receive" pipe. The connection itself is not aware of the meaning of the data that is being transferred, and so we must make sure that it is clear to the receiver what they are getting.

XNA provides classes that take our data and convert it into a format suitable for transfer over the network connection. These classes are called `PacketWriter` and `PacketReader`. They do the same kind of thing for a network connection that `SpriteBatch` does for the graphics. They let a program assemble a bunch of items and then transfer them in one lump. We declare the reader and writer as part of the game world along with the network session that we are going to use:

```
// Game World  
  
NetworkSession session = null;  
  
PacketWriter writer = new PacketWriter();  
PacketReader reader = new PacketReader();
```

The host system needs to tell the clients three things:

- The position of the cheese
- The position of the player 1 bat
- The message containing the score

The client can use this information to update the display. Note that the client is not handling any of the collisions between ball and bats or keeping track of the score. The code to use a packet writer to assemble this information is as follows:

```
writer.Write('H');  
  
writer.Write(Cheese.XPos);  
writer.Write(Cheese.YPos);
```

```
writer.Write(Player1.XPos);  
writer.Write(Player1.YPos);  
  
writer.Write(displayMessage);
```

The `Write` method provided by a `writer` can be given any number of simple values (number or string), and it assembles this into a message. The first thing that is sent is the character `H`, to indicate the message is from the host. A character is a single letter. The `C#` type `char` is provided for holding such single characters, and a `string` of text is made up of individual `char` values. You need to put this on the front of the message so the receiver can tell which message it is. The character is followed by the `X` and `Y` positions of the cheese, and then the positions of the `Player1` bat, and finally the message presently being displayed.

Having assembled the message in the `writer`, it can now be sent to the game session for delivery for all the players in the game:

```
LocalNetworkGamer localHost = session.LocalGamers[0];  
localHost.SendData(writer, SendDataOptions.ReliableInOrder);
```

The first statement gets a reference to `LocalNetworkGamer` from the session. The next statement uses the `SendData` method on this gamer to send the contents of the `writer`. The second parameter to the `SendData` method selects how the message is to be sent. There are a number of possible settings for this:

- **Chat** The message is part of a chat between systems. This option lets your game send chat messages in a properly formatted manner.
- **InOrder** Data is not guaranteed to be delivered, but messages are received in the same order they were sent.
- **None** There is no guarantee that the messages get to their destination or that they arrive in the order they were sent.
- **Reliable** Messages are guaranteed to arrive, but they are not guaranteed to arrive in the same order they were sent.
- **ReliableInOrder** Messages are guaranteed to arrive, and they will be in the same order they were sent.

The option that you select depends on the importance of data integrity and synchronization. You should remember that if you ask for a `Reliable` or `ReliableInOrder` transfer, this means that the transfer is slower and involves more effort to manage. In effect, the system must manage a virtual call to implement `ReliableInOrder`. It must wait for late packets so that they can be given to your program in order, and it must also request retransmission of lost ones. On the other hand, selecting `None` means that data arrives more quickly, but some pieces of the data might be missing or out of order.

In our game, it does not really matter if messages are missing or out of order; all that happens in that case is that the ball or bats might seem to jump slightly. However, because the data is small and the systems are on the same network, I've selected the `ReliableInOrder` setting. You might like to experiment with other ones.

The next thing the host must do is read the position of the player 2 bat. This is managed by the client game, which uses a call of `SendData` to transfer the data to the host. To read data is actually very easy; it is done as follows:

```
while (localhost.IsDataAvailable)
{
    NetworkGamer sender;
    localhost.ReceiveData(reader, out sender);
    char messageType = reader.ReadChar();
    if (messageType == 'P')
    {
        Player2Bat.XPos = reader.ReadSingle();
        Player2Bat.YPos = reader.ReadSingle();
    }
}
```

The `localhost` provides a property called `IsDataAvailable`, which is true when data is available. This is used to control a loop construction that we haven't seen before. The `while` loop repeats a block of code while the condition controlling it is true. In this case, we want the game to read packets repeatedly until there are none left. The code inside the loop reads messages and processes them. The first statement in the loop uses the `ReceiveData` method. This is provided with a reference to a `PacketReader`, which it fills up with data, and also sets a reference to the `NetworkGamer` description of the system that sent the message. It does this by using an out parameter:

```
NetworkGamer sender;
localhost.ReceiveData(reader, out sender);
```

We have seen that normally parameters are passed into methods by value. In other words, the value of the parameter is copied and sent into the method. In this case, however, we want the `ReceiveData` method to actually change the value of `sender` to make it refer to the `NetworkGamer` object that describes the system from which the message came. The method has been declared as wanting to write to the value of the *parameter*, so when you use the method, we have put the `out` keyword in front of the variable name.

If a method wants full control of a parameter (that is, it wants to read and write), it can use the `ref` key word to modify the way the parameter behaves. Your game doesn't actually use this information, but you could use this in a multi-player game with lots of players to find out who sent the message. The host wants to see a message that starts with the character *P* because it knows that it comes from the player and contains the position of the player's bat. The following code reads the first character of the message, and if it is a *P*, it knows that it can read two single-precision, floating-point values to set the X and Y positions of the player 2 bat.

```
char messageType = reader.ReadChar();
if (messageType == 'P')
{
    Player2Bat.XPos = reader.ReadSingle();
    Player2Bat.YPos = reader.ReadSingle();
}
```

To make the game work, we have created a little protocol of our own. If a message starts with the character *H*, it contains four numbers (for the positions of the ball and the player 1 bat) and a string (the message for the display). If a message starts with the character *P*, it contains two numbers (for the position of player 2 bat). For a more complicated game, you could invent more messages, each with a different format.

Creating the Client Behavior

The client behavior looks very similar to the server:

```

Player2.Update(this);
writer.Write('P');
writer.Write(Player2.XPos);
writer.Write(Player2.YPos);

LocalNetworkGamer localPlayer = session.LocalGamers[0];
localPlayer.SendData(writer, SendDataOptions.ReliableInOrder);

while (localPlayer.IsDataAvailable)
{
    NetworkGamer sender;
    localPlayer.ReceiveData(reader, out sender);
    char messageType = reader.ReadChar();
    if (messageType == 'H')
    {
        Cheese.XPos = reader.ReadSingle();
        Cheese.YPos = reader.ReadSingle();
        Player1.XPos = reader.ReadSingle();
        Player1.YPos = reader.ReadSingle();
        displayMessage = reader.ReadString();
    }
}
session.Update();

```

First, the player 2 bat is updated, and then its position is sent to the host in a packet starting with the character *P*. Then the code looks for a message that starts with *H*, which it can use to set the position of the cheese, player 1 bat, and the message to be displayed. Note that the Update method on the network session is also called to keep the network active.

The Completed Game

The completed game works well, although it is not without its faults. The screen dimensions of the two systems being used must be the same because the present version passes the position of the items in terms of absolute screen coordinates. However, it would be comparatively easy to perform some scaling of these values.

Another slight problem is that because the host system performs all collision detection, it is the only system that makes sounds. However, it would be quite easy to extend the design of the messages sent from the host to include information to tell the client to play particular sound effects.

Sample Code: 03 Networked Pong Game The sample project in the 03 Networked Pong Game directory in the resources for this chapter contains a fully working version of the game that provides networked gameplay for PC, Xbox 360, or Zune. It is not possible to play the game between a Zune and a device on another platform, but the game can be played between two Zune devices.

Zune Network Games

The games work well on the Zune device, although you might want to improve the sensitivity of the gamepad inputs and also add some code to stop the player bats from going off the screen. You might also want to stop the player bats from being able to overlap on the playfield, perhaps you could make one bat bounce off another, and add a new, fighting, dimension to the game.

If you want to install the program on more than one Zune from a single PC you will have to use the XNA Device Center to select each Zune in turn for deployment of the game program.

When you have installed the pong game on a Zune device you can select and run this game from the Games menu on the Zune itself. Make sure that the Zune wireless adapter is turned on at the Settings menu before running the game. Once a game is waiting for a network connection you can only abandon the game by holding down the Back button to stop the game and reset the Zune.

Conclusion

You have learned a lot in this chapter, starting with a quick introduction to the way that networks operate and then moving on to consider how Xbox Live uses the network to provide to multi-player games the profile of the gamers that use it.

You have seen how the Guide can be used on Windows PCs to allow XNA gamers to create their own gamer profiles and store them on their systems. You have also seen how a system can use a state machine to set up a lobby and wait for players to turn up and take part in a game. Finally, you have seen how to format data so that it can be passed from one system to another during game play and how to set up a server and client arrangement that can serve as the basis of any kind of networked game. All in all, not a bad place to end up.

Making Games for Fun

Even the simplest of ideas can be explored in a fun way. So take what I've provided, play around with it, and use it as the basis for creating silly games of your own. You have a very powerful platform, a lot of flexibility, and gamepads that can lead to some really interesting developments, even without considering the high-powered graphics and processing power

that XNA provides. Many of the games that people play for fun, particularly in groups, are extremely simple to play and very amenable to a computer-based interpretation. So think of silly things that you like to do and make some games based around them. The way I see it, you'll have fun both ways—enjoying the challenge of writing the code and enjoying your creations.

The Great Programmer says that programming is “The Science of the Happy Ending” in that, at the end of a development, users should have something that does what they want and maybe even that they like working with. She says that there's nothing quite like seeing a group of people enjoying using a system that your code is making work, and I'm inclined to agree with her on that.

This slim volume does not teach you everything there is to know about C# and XNA, but I hope it will get you started on the road to enjoying programming and producing games that you and others can enjoy playing.

verysillygames.com

As you can see, I think there's definitely a place in the world for very silly game play, so all the game ideas used as examples in this book have been packaged up as fully playable games that can be downloaded from the Web site <http://www.verysillygames.com>. If you have silly games of your own that you would like to post on this site, please contact newgames@verysillygames.com and let me know.

Chapter Review Questions

And now (fanfare), the final set of review questions. As usual, say whether these statements are true or false.

1. Networks are made using wet string.
2. Every station on a particular network must have a unique address.
3. Messages sent over a network to your system cannot be received by other systems.
4. You can use XNA network gaming without a gamer profile.
5. A router is connected to only one network.
6. You can create the Internet in your front room.
7. XNA cannot be used to create games that provide full Xbox Live network game play to gamers all round the world.
8. It is not possible to play network games using the Zune.

9. The XNA `NetworkSession` class drives the network gameplay in a multi-player XNA game.
10. Only two players can take part in a network game.
11. A state machine can be used to store the score gained in a network game.
12. One XNA system must create a session that others can join to play a networked game.
13. An event is a way of attracting the attention of a program.
14. A delegate is a type-safe reference to a method in an object.
15. XNA games can only transfer floating-point values between each other when playing network games.
16. In a server-client network game configuration, the clients send information to each other about the state of the game.

Answers to the Chapter Review Questions

Chapter 1

1. False. If you enjoy solving problems and working with people, that will make you a great programmer.
2. False. You can write Microsoft XNA game programs and run them on your PC if you don't have an Xbox.
3. False. XNA is a framework for writing games. It is written in a programming language and is used by programs, but it is not a programming language.
4. True. Indeed it is.
5. False. The C# compiler produces a file containing a sequence of machine instructions that the computer can follow when the program runs. Once you have the instructions, you don't need the compiler anymore.
6. False. C# is a programming language; XNA is the framework.
7. True. Indeed you do. But you don't need to be a club member to write games for the PC.
8. False. You can plug a Zune into your PC and put programs on it from XNA Game Studio without joining anything.
9. False. This program is used to manage the connections between your PC and XNA devices that you want to use.
10. False. The compiler converts your source code into lower-level instructions for the computer to follow. But once the compiler has done this, you can just run the program that the compiler has produced.
11. False. The screen is initially blue.
12. False. Actually, you can do this, and it works very well (especially for games on a PC that require a joystick).
13. False. You don't. The version of XNA you use to write Zune games is just the same; it is just that some of the more advanced features aren't available on the Zune platform.

Chapter 2

1. False. A program is a sequence of statements. A variable is the way that we represent values that we want our program to work on.
2. False. We can call the file what we like; when coding in C#, it must have the language extension (the bit after the dot) of .cs. XNA Game Studio puts our game program into a file called Game1.cs by default, which is a good start.
3. True. We need to think of a name that represents the value that the identifier is going to hold or the action the method is going to do for us.
4. True. A method contains a sequence of statements. It also has an identifier as a name. Our program can “call” the method by name, and when the method is called, it performs the statements in the method. We don’t have to write every method ourselves; instead, we can call methods provided by other programmers.
5. False. The Draw method is not in charge of updating the game. Instead, it is supposed to perform the drawing. The method that performs the update is called, not surprisingly, Update.
6. False. A block of statements is a number of statements that have been enclosed in curly brackets. C# can treat an entire block as a whole.
7. False. A comment is put into the program by the programmer as a kind of “note to self.” The compiler completely ignores any comments.
8. False. A byte can hold only a number in the range 0 to 255. When creating a color, each of the primary colors (red, green, and blue) has a byte value that represents the intensity of that primary color. So a Color must be held as at least 3 bytes.
9. True. The C# compiler always ensures that we don’t combine variables in an incorrect way. Trying to place a Color into a byte would not work because it would not fit. Therefore, the compiler refuses to compile a program that does this.
10. False. A local variable is held inside a block. It is not visible to statements outside the block; each time the block is entered, a new version of the variable is made.
11. False. We create the identifiers. If we need to keep track of the highest score in the game, we might want to create the identifier HighScore, which can be used to identify the variable where we store the high score.
12. True. This is exactly what a variable does. We create a variable every time we need to store something in our program. Each variable has a different identifier and has a particular type.
13. False. The Boolean type has just two possible values, but they are true and false, not 0 and 1.
14. False. The word that starts a conditional statement is if.
15. False. You don’t need to add an else part to an if condition unless your program needs it.
16. True. A recipe tells you how to combine and process ingredients to cook something. An algorithm gives a sequence of actions that you can perform to achieve something.

17. False. A single equals character (=) is used to assign a value to a variable.
18. True. The methods provide the class with things it can do (behaviors) and a place to hold information (data).
19. False. `PlayGame` sounds like a good identifier for a method (an action of some kind), but it is not a good name for a class. Classes have names like `Sprite`, `Session`, `Game`, `Invoice`, and `Car`. A class represents a whole thing that you want to create and interact with, not just a single action.
20. True. `Explode` is a word that implies that an action is being performed; perhaps we are going to make one of our game objects perform an explosion behavior. Method names should be “doing” words, like verbs.
21. False. A byte holds 8 bits organized in one lump. Each of the bits can be either true or false, which means that a byte can actually occupy 256 different states.
22. False. `++` works on a single numeric operand and makes the value in the thing it works on one bigger. We use it to increase the intensity of the color values in our program. It has a complementary `--` operator.
23. False, for two reasons. One is that the compiler does not have control when your program runs. It just prepares the program for execution, so there is no way that it can react to things that happen when the program runs. The second reason is that when some numbers overflow (for example, if we try to overfill the byte type), the processor typically doesn't notice. We have to make sure that the values in our programs always stay within the range of the variables that we create to hold them.
24. True. In programs, we often need to represent things that can be either true or false. These allow us to decide whether we do something (true) or not (false).

Chapter 3

1. False. A method does something. A desk is just a holder for values. It is more sensible to regard a method as a person in the office who can do something when the method is called.
2. False. The compiler converts your C# source code into machine language instructions for the computer, Zune, or Xbox, but it is not around when your program is running. The class instances are created when the program runs.
3. False. You need to add the `else` part only if you want to perform some other statement or block of statements if the condition is not true.
4. False. The parameter feeds information into a method.
5. False. It is performed only if the condition controlling the `if` statement is false when the program runs.
6. False (aren't we having a lot of false answers this time?). The gamepad is represented by a special Microsoft XNA structure that holds all the gamepad settings. The structure is called `GamePadState`.

7. False. This method gives your program a `GamePadState` structure. You can use the `GamePadState` structure to find out what the button state is.
8. True (at last). This is exactly what a block is.
9. True. The logical expression `(true || false)` works out to `true`, as do `(true || true)` and `(false || true)`. In fact, the only condition involving explicit values and a single logical *OR* operator that works out `false` is `(false || false)`.
10. False. I feel terrible about this one. The condition is fine, but it does not test the value of `greenIntensity`.
11. False. We may have to do this ourselves when the game is stopped.

Chapter 4

1. False. The compiler is the program that converts *C#* source code into machine instructions for the computer. Images are held by the XNA Content Manager, which ensures that they are incorporated into your program once it has been compiled successfully.
2. True. A texture is a special type of data that can hold images. The examples in Chapter 4 use the `Texture2D` data type to hold an image because the examples are for textures that are to be displayed as flat.
3. False. This method brings the images into the program. It gets the item of content and loads it into the target texture, but it does not display the image.
4. This might be true, but it is not relevant to Microsoft XNA graphics. A sprite is a texture and a position. It represents something in the game you want to draw at a particular position. In your programs, you've used a `Texture2D` variable to hold the image to be drawn and a `Rectangle` to express where the image is to be put on the screen.
5. True. The clue is in the name. You can use `SpriteBatch` to perform a number of drawing operations, and then, when the `Draw` method is called the `SpriteBatch` actually does the drawing, it can organize all the draw operations in the most resource-efficient way.
6. True—but with reservations. The `Initialize` method is simply a placeholder where you can put *C#* code that runs when the game is being initialized. If you need to get control at this point in the game process, you can add code to this method. Otherwise, you can leave it empty.
7. True. It also has a `Height` field for the height and `X` and `Y` fields that describe where on the screen it is to be positioned.
8. False. An XNA game can store many image resources. Each of them is given a name and can be loaded by the Content Manager when required.
9. False. I'd say that an inch is a better measure of screen size. A 20-inch monitor could have different numbers of pixels depending on the quality of the images it can show. A monitor with 1,024 pixels across displays a more detailed picture than one with only 800. The number of pixels really gives you an idea of the resolution of the images, not the actual size as displayed.

10. True. Unlike graph paper, which has the origin on the bottom left, the XNA display area has the origin at the top left corner.
11. False. Although you could use a Portable Network Graphics (PNG) picture in this way, you might find that a large image (such as you would use for a background) stored in this file format would be quite a large file. If you do not need transparency (and background images do not) then I would suggest that you use a Joint Photographic Experts Group (JPEG) image for that. A JPEG image can be much smaller than an equivalent PNG picture.
12. False. The XNA system provides an easy way to find out this information. The `GraphicsDevice.Viewport.Width` and `GraphicsDevice.Viewport.Height` values will do this a treat.

Chapter 5

1. False. The font information is concerned with the shape of the characters. You decide the color of the text only when you use the font to draw the text on your output device.
2. False. You can incorporate as many fonts as you like in a Microsoft XNA game. You just need to remember that each additional font uses up space in the memory and make the game program larger.
3. False. The Content Manager is told which fonts are required. It then reads the font information and makes each requested font part of your game in a way that makes it possible for you to use the font.
4. True. This is exactly what a resource is. The resource itself is fetched only when the program is being created.
5. False. Nice thought, though. XML stands for Extensible Markup Language. XML is widely used in computing to allow two different programs to share information. An XML file contains the names of settings (for example, `<size>`) and the values that these should have (for example, `100`).
6. True. A vector is given as coordinates that identify a point, such as (200, 300). You get the direction and distance of movement by considering how you would travel from the origin (0, 0) to that point. In the case of (200, 300), you would be moving across and down the screen if you were drawing in 2-D.
7. False. The first program you write should display "Hello World."
8. False. Although the Xbox can be programmed to update the clock by using a network connection, the hardware itself holds a clock, backed up by a battery, that keeps track of time for the Xbox device.
9. False. Both the PC and the Xbox have special software to "localize" them to a particular area. One aspect of localization is how the date and the time are displayed, so the same program code might display the date and time differently on machines in different countries.
10. True. That is exactly what it does. Inside the structure itself are fields that hold the day, month, year, hour, minute, and second that the particular value of `DateTIme` represents.

11. False. For example, the `DateTime` structure provides a property called `Now`. This delivers a `DateTime` instance that is set to the current time. Properties are used by objects as a way for the outside world to interact with the data that they hold.
12. True. That is what `ToString` is for. Exactly what you get when you call `ToString` depends on what the object holds and what the programmer who created the type of object has decided that `ToString` should return. In the case of a `DateTime` object, the `ToString` method returns the date in a text format.
13. False. A programmer can make it run forever, either intentionally or by mistake. However, how long the `for` loop runs depends on your requirements. In Chapter 5, you've used it to draw items a particular number of times.
14. False. The first time around the loop, the value of `layer` is 0; the second time, it is 1; the third time, it is 2; and the fourth time, it is 3. At the end of the fourth time around the loop, the value of `layer` is increased to 4, and then the condition is checked before the next time around the loop. Because the value of `layer` is no longer less than 4, the condition is not true, and the loop ends after four times around.
15. False (nasty ones, these). The value left in `layer` when the loop has stopped is the value that caused the condition to fail. The value 10 would not cause the condition to fail, as `layer` would be equal to 10. The value of `layer` that causes the loop to end would be 11 because that is not less than or equal to 10.
16. True. The test is always performed before the code controlled by the `for` loop is obeyed. The first time the test is performed, the value of `layer` is 4. Because 4 is not less than 0, the test fails, and the loop never runs.
17. True—sort of. Because you're making the value of `layer` 1 bigger each time and it starts at 4, the condition (`layer > 0`) is always true, so you would expect the loop to repeat forever. But this is not quite the case, given what you know about variable types. If `layer` were a byte, you know that the range of a byte is from 0 to 255. This means that once the value of `layer` reached 255, it would wrap around to 0, and the loop would stop. Note that this kind of mistake would result in the program acting strangely and would be hard to uncover.
18. True. They can. This is where the idea of a color as a paint can or colored light breaks down. You'd be happy drawing red text on the screen by using the red color. However, you can also use red text through which the background can be seen by using a red color value with a transparency value. Furthermore, because you know that you can draw images in a particular color, this means that you can draw transparent images by drawing them with a transparent color.

Chapter 6

1. False. Any of the buttons on a gamepad can be used to detect edges.
2. True. The program can notice that a signal has changed only if it has before and after values that it can compare. If these two values are the same, there has been no change, but if they are different, it means that the signal has changed.

3. False. The whole point of an edge-triggered input is that you detect when the button changes state. They are used for flicking switches, changing gears in a car, or for your button-press-counting game. The only way that you can detect an edge is to compare the state now with the state it had last time you looked.
4. False. The clue is in the name. The compilation process, where your program is converted into executable statements, is where conditional compilation takes place. By the time the program runs, the statements have either been included in the program or ignored.
5. False. The preprocessor, as the name implies, looks at the C# code going into the compiler. If it's given commands to ignore sections of the program, these are not passed into the compiler for conversion into machine instructions in the finished program.

Chapter 7

1. True. The Content Manager provides a version of the Load method that loads and converts audio files for use in a game.
2. True. You can also use .wma and .wav files.
3. False. The files are copied automatically for you by the Content Manager.
4. False. Each hardware platform supports a different number of simultaneous sound samples, but it is always more than one.
5. False. The Play method is used to play an existing effect. The effect should have been loaded when the game started running.
6. False. The Play method actually returns a reference to a SoundEffectInstance that describes the particular instance of the sound being played. You can call methods on this to control the sound playback.
7. False. There is no such thing as a null object. A null reference is defined as explicitly referring nowhere. It is used to denote the fact that the reference does not refer to anything at all.

Chapter 8

1. False. The code creates a variable called scores that can refer to arrays of integers, but it does not create the array itself. The program must actually construct the array to use it: `int[] scores = new int [4];` would do this. To make the array bigger, change the 4 to a different value. You can even use a variable to set the size of an array, so that a program can allocate the correct amount of storage for its needs automatically.
2. This is both true and false. You can create an array of any type, so you can have arrays of integers, arrays of strings, and pretty much arrays of anything you like. However, once an array has been created, it has a particular type and keeps that type forever; for example, an array of integers can hold only integer values.

3. True. When you create an array, you make an instance of an array object. You can tell this because making the array (that is, the step where you set up how many elements the array has in it) uses the key word `new`. The identifier you give the array is a reference that refers to the array object.
4. False. In some languages (Microsoft Visual Basic, for example), this is true. However, in C# the convention is that the first element in the array is zero. If you think of a subscript as giving the distance down the array you need to travel to get to the element, then it is reasonable to have a subscript value of zero. It is unfortunate that different languages handle this differently, but there's nothing you can do about it.
5. False—to the extreme. The system running your programs cares a great deal about this. If you try to get a hold of an array element that is not there, your program stops.

Chapter 9

1. False. Exactly how many keys can be pressed at once depends on the keyboard hardware, but multiple keys can be registered.
2. False. The `Keys` type holds information that describes a particular key on the keyboard. For every key on the keyboard (including the Shift, Ctrl, and Alt keys), there is a corresponding `Keys` value that matches that key.
3. False. The `Keys` type has values just for physical keys on the keyboard. The only way that you can determine whether an uppercase letter has been typed is by checking the state of the Shift keys when the key press is detected.
4. True. Each value of a variable of type `Keys` describes one physical key on the keyboard. There are as many `Keys` values as there are keys on the keyboard. An enumerated type allows programmers to create their own types that have just the values that are required by their application.
5. False. A reference provides a way that a program can find and use an object. However, you should not regard a reference as letting your programs find out where in memory something is stored. The way that C# works, you're not allowed to know where the objects in your program are actually located. In this respect, a "telephone number" analogy works best, in that a telephone number provides a way you can contact someone but does not tell you where he or she physically is. You can think of a variable that refers to an object in memory as holding the "telephone number" of that object.
6. False. It's very common in C# programs for a particular object to have multiple references referring to it. This is the best way that a large resource (for example, a particular texture or sound) can be shared in a program.
7. False. In C#, garbage collection takes place while a program is active. The garbage collection process runs alongside your program to make sure that the maximum amount of memory is available at all times.
8. False. You've used the `break` key word in two situations: when you wanted to exit from a `for` loop and when you wanted to exit from a case in a `switch` statement. It does not stop the program; instead, it says, "I've done all I want here, and I want to escape from this construct."

9. False. The idea of a program turning the computer off is interesting but is not what the `switch` statement is used for. It's used to select an option from a number of different possible ones, depending on the value of a control.
10. True. Note that this does not cause the contents of the string itself to change; instead, you should regard methods like `ToUpper` and `ToLower` as different views of the string, much as you can get a `DateTime` instance to give you a string that contains only the time information.
11. False. You can add strings together, but the effect is to put one string on the end of the other, which is called *string concatenation*. `C#` uses the same operator, `+`, for adding numbers and for concatenating strings but the meaning of the action changes depending on what it is applied to. A `+` between two integers would add them together. A `+` between two strings causes them to be strung together to make a longer string.

Chapter 10

1. False. The `Rectangle` tells the draw process the position and size of the drawing area, but it does not do the drawing itself.
2. False. Although the Microsoft XNA programmers have made methods for you to use, there's nothing to stop you from creating methods of your own.
3. True. A method is a member of a class. It's how you can ask an instance of a class to do something for you.
4. True. The statements are performed when the method is called. Used like this, a method lets you use a given sequence of statements from any part of your program simply by calling the method.
5. False. A method that specifies a return type of `void` does not return a result to the caller.
6. False. A method can contain many return statements. If the method returns a result, each return statement must be followed by a result that's an expression of the correct type.
7. False. You've seen methods that don't accept any parameters.
8. False. The `C#` compiler is very picky about method calls. If the call doesn't exactly match the header definition (the signature) of the method, the compiler produces an error.
9. False. When you work with test-driven development, you do the testing as you write the program. Often you write the tests before you write the code.
10. False. One of the many wonderful things about XNA Game Studio is the way that you can set a breakpoint in your code even if it's running on an Xbox. When you run the program in debugging mode, the next time the program reaches the breakpoint, it stops.
11. False. The `int` type holds a value that doesn't have a fractional part. This means that when you move a floating-point value (which does have a fractional part) into an integer variable, the fractional part of the data is lost. This is called *narrowing*. The `C#` compiler

won't let a programmer unintentionally lose or damage data in this way, so it refuses to allow such a transfer unless the programmer explicitly takes responsibility for the effect of the action by adding a cast.

12. True. The double precision type can hold all integer values, so data is not lost when the move takes place. This is called *widening*.
13. True. It tells the compiler that although the actual data is in one type, for the purposes of the program, it needs to be converted into an alternative type. This is the programmer's way of "taking responsibility" for the consequences of the action. When you move a floating-point value into an integer location, you're destroying data because the fractional part of the floating-point value is lost. The cast is the way that you tell the compiler that you know what you're doing, and the compiler then allows the conversion to take place.
14. False. Although casting does perform conversion between similar types (programmers can cast between integers, bytes, doubles, floating points, and the like), it cannot convert any type to any other type automatically. Only conversions that have been predefined are allowed.

Chapter 11

1. False. You can use any image that you like in your games (subject to copyright laws, of course). The images must be in file formats that can be imported into the games, but you can create the images yourself.
2. False. The solution contains the project. A solution brings together a number of projects that are used to create a single application. When you create a new project, XNA Game Studio creates a solution that contains it.
3. False. The Program.cs file is created for you when the project is created by XNA Game Studio.
4. True. The Program.cs source code starts the game running in that it creates an instance of your game class, but it doesn't contain the game program itself.
5. True. The compiler is told to search namespaces by using directives at the start of the program source file. When the compiler comes across the name of a resource it hasn't seen before, it looks in the namespaces to find the resource.
6. False. But this is really unfair. The method that starts the program is called Main (with an uppercase "M"). In C# this is important because the case of letters in identifiers is significant.
7. False. The term *static* means that the static item is always there. It doesn't need to be created by your programs because static items are created automatically when the program is loaded.
8. True. When program execution exits the block of code after the using statement, it means that the item created at the top of the using statement can now be removed and that any resources it uses can be reclaimed.
9. False. When a floating-point value is converted into an integer, the fractional part is simply removed.

Chapter 12

1. False. Cows are held in fields, but structures are not. A field is a member of a structure that holds data.
2. True. Whenever you have a number of related items, you should think about creating a structure to hold them.
3. False. Structures are managed by value. You can tell this because you don't have to use the new key word to make a new structure variable. By default, the value in the structure is copied when passed into a method call.
4. False. Public is used to explicitly make members visible to code outside a class or structure. To restrict access to a member you would use the private modifier.
5. False. An absolute value is always positive or zero.
6. True. When a value type is passed as a parameter a copy is made of the contents of the variable. This is the value passed into the method. When a reference is passed as a parameter a copy of the reference is passed into the method. If you want the method to change the content of a value or change a reference to refer to a different object you must use the ref modifier to ask the compiler to generate a reference.
7. False. Oh, yes you can. XNA Game Studio lets you add breakpoints or pause a running program even when it's running in an Xbox or Zune.
8. True. If you make a method static, it means that it's always around and not part of any object. This means that you can use Abs without needing to make an instance of the Math class.
9. False. Nothing in C# forces you to keep the name of a method once you've written some code. It was once difficult to change the name of a method because you needed to make sure that you changed all the places in which it was used. Fortunately, XNA Game Studio makes it much easier to do this, so you should consider doing this (it is called *refactoring*) whenever you notice that the things a method does no longer fit its name.

Chapter 13

1. False. A programmer can add a return key word anywhere in a method. In fact, a method can have as many return statements as you like, although the Great Programmer won't approve of this because it can make programs harder to understand if you have too many ways that a method can return.
2. False. The type of the variables is not usually changed, although the name used to identify a variable might be changed if you decide on a better name to use.
3. False. The Refactor menu in Microsoft Visual Studio can be used to change the name of a method in your program. The only proviso is that you can't change the name of methods that are part of the system; for example, it's not possible to change the name of the Update method, as this is based on a method that's part of Microsoft XNA.
4. False. A code region is a way of grouping together a number of items in your program source file. A single source code file can hold a large number of regions.

5. False. A code region just lumps together parts of your program. Certain Intellisense information is retrieved from specially formatted comments that programmers can place inside the code as they write it.
6. False. A state machine can have as many states as the application requires. The Great Programmer uses an enumerated (enum) type to keep track of the states that a state machine can occupy. The state machine that we created for the game had two states: when the game was being played and when the title screen was being displayed. It would be easy to add a third state in which the high-score table is displayed.

Chapter 14

1. False. If an object has high cohesion, it means that it can go about its business with no need to use resources from other objects. This is good because it means that changes to the rest of the system do not affect the object.
2. True. The amount of coupling in a system reflects on how much objects rely on each other. Coupling is a form of dependency in that if A is coupled to B, you have to test A if you make any changes to B. Large amounts of coupling make it difficult to modify or repair systems because of the number of internal components that need to be checked if one is changed.
3. False. Public data can be read and written by code running outside the object, making it possible for unmanaged changes to be made to the data. The data in an object should be made private. The object should contain methods that provide managed access to the data so that objects can be created which always hold data that is in a valid state.
4. False. Structures are managed by value. When you work with a structure variable, you are actually using the value it contains. This means that during assignment, the data from the structure is copied from one variable to another.
5. True. When using the data pointed to by a reference, the program must follow the reference to get to the data itself. This introduces an extra stage into the use of a variable which adds a delay. However, modern processors run so quickly that this is virtually never a problem within a program. Furthermore, the delay can be compensated for by time saved moving data around memory.
6. True. A class hierarchy is a means of code reuse. A child class is created based on an existing one (the parent). This means that the new class contains its own data elements as well as those of the parent. The data from the parent and child portions of the variable may not necessarily be held in a single place in memory and so cannot be regarded as a single value. When you use references, the run-time system can find the requested data when a reference is followed.
7. False. A class can be extended by many other classes as required. There is no upper limit on the number of child classes that a parent can have.
8. True. Overriding is the process by which a child class replaces an existing method in the parent class with one that meets the needs of the child. However, it is possible to override a method in a parent only if the parent method has been marked as virtual.

9. False. The key word `base` allows the overriding method to use the method in the parent that it has replaced. This is very useful if you want to add to existing behaviors in the parent method.
10. True. The protected key word is provided so that child classes can be given access to data members in the parent.
11. False. The key word `this` means “a reference to the currently executing instance.” If an object needs to supply a reference to itself for any code outside the class to use, it uses the key word `this`. We used it so that the `BreadAndCheeseGame` class could provide a reference to the currently executing game. The cheese needs `this` so that it can get hold of the bread in that game, and check for collisions.
12. False. The child class does not have to override any of the methods in the parent. It could just add new methods and leave all the old ones untouched.
13. False. A single object can have many references to it.
14. True. The garbage collector continuously searches for such objects and reclaims the memory they occupy.

Chapter 15

1. False. Although an abstract class can be used as a template for child classes and states which methods the child classes must contain, there is nothing to keep a programmer from putting full methods and member data inside an abstract class. In fact, this can be a very sensible design if a method or data must be used in all the child classes.
2. False. If there are data members of the abstract class that always need to be set up, there is no reason why the class shouldn't contain a constructor method to set these properties.
3. False. You can't make any instances of an abstract class. This is because it is intended to serve as a template for child classes.
4. False. Only the methods can be abstract. An abstract method is a way of signaling that there is a need for a particular behavior; it has nothing to do with member data.
5. False. In C#, a class is allowed to have only one parent class. If you are used to other languages like C++, this will be surprising because C++ lets a class have multiple parents. However, the designers of C# left this ability out, perhaps because it can make classes too confusing.
6. True. That is the best way to use abstract classes. A user of an instance of any child in the class can be sure that it provides implementations of all the abstract methods in the abstract class at the base of the hierarchy.
7. True. This is a good way to allow a program to manage collections of objects that must perform a particular function but do it in their own way.
8. True. The constructor provides the way in which a programmer can get control at the moment an instance of a class is created. If the constructor accepts parameters, these can be used to set up data inside the class.

9. True. If the programmer has provided a constructor for a class, the constructor must be called to create an instance. This is how a programmer can ensure that all instances of a class start out with valid data.
10. False. The child must make sure that the constructor for the parent (if there is one) is executed before the code in the child constructor. The base key word is how the child makes use of the parent constructor.
11. True. The Random class provides a “pseudorandom” sequence of values based on a starting value called the seed. If this starting value is based on something effectively random (such as the number of milliseconds since midnight), then from a programmer’s point of view, the sequence can be sufficiently random. Note, however, that using a particular seed value allows the same sequence of random numbers to be generated repeatedly.
12. False. The great thing about the List is that you do not have to set the length of the list. It automatically expands to hold all the values that are added to it. In this respect, it is much more useful than an array.
13. True. That is exactly what foreach was created for. It removes the need to worry about managing a counter value to keep track of the particular length of the collection being used.
14. False. It just means making a piece of program that is intended to mimic the effect of intelligence in a particular situation.
15. True. If a class implements an interface, it must contain public implementations of all the methods in the interface.
16. True. This means that objects can be regarded in terms of what they can do rather than what they actually are. In this respect, interfaces are a very powerful way to let programmers create software components that behave according to a set of requirements given in the interface.

Chapter 16

1. False. A network can be made using radio, fiberoptic, or wires, but probably not wet string. The actual medium of the connection is not really the most important thing these days, though; it is the protocol that runs on top that makes it useful.
2. True. If the stations are actually wired together, all the machines on that particular wire (or radio channel) must have a unique address so that messages can be sent to them. If a particular physical network is connected via a route to another network (using an Internet Protocol, or IP) then they must also have an address that is unique in the world. The IP address of your computer must be the only one of its kind so that only you get the messages sent to you.
3. False. This depends on the precise type of network, but very often, the same physical media is used to carry traffic between lots of machines. This means that anyone with the right equipment could eavesdrop on conversations between any machine. The way this problem is solved today is to have software that scrambles (or encrypts) important information before it is sent so that eavesdroppers don’t hear anything of use to them.

4. False. The profile provides the gamertag information that allows you to be identified on the network. If you do not have a profile, you cannot perform network gaming. Profiles can be held locally on your Windows PC, however, and they are easy to create.
5. False. The idea of a router is to send information from one network to another. This means that it must be connected to at least a couple of networks. Stations on the network send their messages to the router if they determine that the destination machine is not on their physical network, and the message must be routed to a distant network.
6. True. Well, perhaps not the complete Internet, but you can create a network using the Transport Control Protocol/Internet Protocol (TCP/IP) standard, which is used by the Internet. You could use such a network for System Link games. If you connected your little network to a router, it could then become part of the worldwide Internet.
7. False. If you wish, you can create highly advanced network game play with servers, lobbies, and vast numbers of players. However, to deploy and test such games, you need to have two Premium-level memberships in the XNA Creators Club. On the other hand, System Link network game play can be achieved between Windows PCs with no need to join the XNA Creators Club. You can also create network game play between Windows PCs and Xbox consoles.
8. False. The Zune has built-in WiFi hardware, which can be used for System Link network games using XNA. However, it is not possible to play network games between a Zune and a PC or an Xbox 360. Zune networking is strictly a Zune-to-Zune affair.
9. True. This class is used to set up and manage the connection between machines taking part in a network game. It also provides lobby support so that systems can propose games that others can join.
10. False. When a game is proposed, the proposer can specify how many players the game is for. This takes the form of an upper limit.
11. False. A state machine is not really used to store scores. Instead, it is used to manage the state of the game itself, for example whether it is waiting for more players, it is being played, or it is at the title screen.
12. True. The system is notified when players join the game.
13. True—mostly. Rather than having a program waiting for something to happen, an event lets a program say, “When this happens, call this method.”
14. True—exactly. It is like writing your phone number down on a piece of paper, giving it to a garage mechanic, and saying, “Call me when my car is ready to be picked up.” A delegate is a lump of data that identifies a particular method. I give this to an event generator (perhaps the thing that fires when someone joins a game I’m proposing) so that the event can be bound to the method that needs to act on it.
15. False. The PacketWriter class can accept many different C# types and assemble them for transfer to another system. The PacketReader class can then extract these items.
16. False. This would result in a lot of unwanted network traffic. In a game that uses a server, the clients would communicate only with the server, not with each other.

Glossary

abstract Something that is abstract does not have a “proper” existence as such. When writing programs, we use the word to mean “an idealized description of something.” In the case of component design, an abstract class contains descriptions of things that need to be present, but it does not say how they are to be realized. In C# terms, a class is abstract if it is marked as such, or if it contains one or more methods that are marked as abstract.

You can’t make an instance of an abstract class, but you can use it as the basis of, or the template for, a concrete one.

For example, you might decide that you need many different kinds of sprite in the BreadAndCheese game: bat sprite, ball sprite, target sprite, and so on. We don’t know how each particular sprite will work inside, but we do know those behaviors that it must have to make it into a sprite.

We can therefore create an abstract `Sprite` class that serves as the basis of all the concrete ones. Each “real” sprite class is created by extending the parent, abstract one. This means that it is a member of the sprite family (that is, it can be treated as a sprite) but it works in its own way.

Algorithm An algorithm is a description of steps to solve a problem. You can think of it as a recipe if you like. It gives a sequence of steps to be followed and decisions to be taken. A good “getting wet avoidance” algorithm would be “If it is raining, take an umbrella.”

Analog An analog value is one which can never be held exactly. Some data items, for example the number of attacking spaceships in a space shooter, or whether or not a button has been pressed, can be

represented precisely in a program. Other values, for example the physical position of a thumbstick on the gamepad, cannot be held exactly since there are in theory an infinite number of positions available. Programs often need to manipulate analog values, and they do this by storing them within a particular range and to a particular precision. The analog thumbsticks on a gamepad are represented by a floating point number in an XNA program which has a particular number of decimal places. The `float` and `decimal` types in C# are used to represent analog values.

Arithmetic The adjective *arithmetic* is applied to operators that perform some form of calculation on their operands and generate a numeric result. The `*` (multiply) operator can be used as an arithmetic operator to multiply values together.

Array An array holds a large number of items in a single variable. A one-dimensional array holds a number of values in a single row. You use a subscript to indicate which box in the row you want to use. Consider the following, which creates an array to hold 10 integer high scores and sets all the elements to 0:

```
int[] scores = new int[10];
for (int i = 0; i < 10; i = i + 1)
{
    scores[i] = 0;
}
```

The `int[] scores` part of the code tells the compiler that you want to create an array variable. You can think of this as a reference that can be made to refer to an array of integers. The array itself is created by `new int[10]`. When the program runs, a 10-element array is created; if the value 10 is replaced by a different number, an array

of that size is made. Each item in the array is called an element. In the program, you identify which element you mean by putting its number in square brackets [] after the array name. This part is called the subscript. The size of an array can be set using an expression as well as a constant, allowing the program to create exactly the right-sized array for a given task.

Arrays can have more than one dimension; a two-dimensional array equates to a grid, with two subscripts used to specify the row and column of the desired element. A three-dimensional array equates to a pile of grids and requires three subscripts. The C# language can handle arrays with a very large number of dimensions, but it is unlikely that you'll ever need to go beyond three.

Aspect ratio This is the ratio of height to width of a display screen. The first TV sets had an aspect ratio of 3:2 (that is, their screens were 3 units wide and 2 units high). Wide-screen displays have a ratio of 16:9 (that is, the screen is 16 units wide and 9 units high). Games must be written to accommodate the possibility that they will be used with different display formats.

Assembly An assembly is used by .NET framework to bring together program code and resources that the program might need. It is created when a project is built. There are two forms of assembly: programs that can be executed (which have the file extension .exe) and libraries (which have the file extension .dll). Only program assemblies have a `Main` method, which starts the program running.

Asset An asset is any item of content that is used as part of a game. This includes sounds and images that the game requires, as well as 3-D models and any other game information. The XNA Framework provides a Content Manager, which manages the assets in a game project.

Assignment There are two parts to an assignment: the thing you want to assign and the place you want to put it. For example, consider the following:

```
int first, second, third ;
first = 1 ;
second = 2 ;
third = second + first ;
```

The program declares three variables: `first`, `second`, and `third`, each of which is of integer type. The last three statements are the ones that actually do some work. These are assignment statements. An assignment gives a value to a specified variable that must be of a compatible type. The value that is assigned is an expression. The equals sign in the middle is there mainly to confuse you; it does not mean "equals" in the numeric sense. I like to think of it as a "gozzinta." A gozzinta takes the result on the right-hand side of the assignment and drops it into the box on the left.

Bit A bit is a single "binary digit." It is the smallest unit of data that a computer can hold and has two possible states: on (1) or off (0). Bits are combined so that values larger than 1 can be represented. Each bit that you append doubles the number of possible values.

Block A block is a number of code statements that are enclosed in curly brackets. These are the characters `{` and `}` and are also known as braces. Any block can contain any number of local variables; that is, variables that are local to that block. Here's an example:

```
{
    int localToThisBlock;
    // create a variable local to
    // the block
    localToThisBlock = 99;
    // OK because the variable
    // exists here
}
localToThisBlock = 100;
// will cause compilation error
```

Blocks are used as the bodies of methods and in any situation where you want to lump a number of statements together so that they can be treated as a single entity, such as in an `if` condition or loop.

Boolean Boolean arithmetic deals only with values that can be true or false. A variable of type `bool` can hold a value that is true or false. Sometimes that is all you need. An example of a `bool` variable could be one that holds the state of a network connection, like this:

```
bool networkOK;
```

This variable can be set to indicate the state of the network. The results of conditions are Boolean values, and variables of type `bool` can be used directly in conditions:

```
if (networkOK) sendPlayerMove();
```

The preceding statement would call `sendPlayerMove` if `networkOK` was set to true.

Bounds (of an array) The bounds of an array is the range of possible subscripts that can be used to access elements in the array. This ranges from 0 (the element at the base of the array) to `(size-1)`, which is the element at the end of the array. If your program “goes outside the bounds of the array”—that is, tries to access an element with a subscript that is not in the permitted range—then it fails with an exception.

Brace The curly bracket characters (`{` and `}`) are sometimes called braces. This is perhaps a reference to the fact that they come in pairs; that is, every open bracket must be matched by a closed bracket. Braces are used to enclose statements and create blocks.

break The `break` keyword is used in looping constructions and `switch` statements to allow program execution to exit from the construct:

```
for (int i = 0; i < 10; i++)
{
    if (i == 5) break;
}
// get here when i reaches 5
```

The loop would terminate when the value of `i` reaches 5. The `break` causes execution to transfer to the statement immediately following the loop block. The `break` keyword is used in the `switch` construct to end the execution of the `switch` statement.

Breakpoint Breakpoints are used when debugging programs. They are a way of finding out what a program is doing. Within XNA Game Studio, you can mark program statements with breakpoints. In debugging mode, a program runs until it reaches (or hits) the breakpoint, at which point it pauses and returns control to you so that you can investigate the state of the program. You can then resume execution or step through statements. Note that you can set breakpoints while your program is running, even if it is running inside an Xbox, as long as you started it using debugging mode in XNA Game Studio.

Byte A byte is the smallest unit of addressable storage in a computer. It is made up of 8 bits, meaning that it can represent any one of 256 possible values, from 0 to 255.

C# “The Programming Language of Champions,” I reckon.

Call When you want to use a method, you call it. When a method is called, the sequence of execution switches to that method, starting at the first statement in its body. When the end of the method, or a `return` statement, is reached, the sequence of execution returns to the caller.

Cast A cast gives an additional instruction to the compiler to force it to convert a value in a particular way. You cast a value by putting the required type in brackets before the value. For example:

```
double d = 1.7;
int i = (int) d ;
```

Because the `double` type has greater range and precision than an integer, the programmer must tell the compiler explicitly that the assignment is sensible. In the previous code, the message to the compiler

is "I don't care that this assignment could cause information to be lost. I, as the writer of the program, take the responsibility of making sure that the program works correctly." Casting can cause data to be lost. In the code above the fractional part of `d` would be truncated when it is transferred leaving the value 1 in `i`.

char The `char` type is used to hold a single character in a program. The character can be a letter, a digit, a punctuation character, or a nonprintable character, such as the newline character. Here's an example:

```
char ch = 'A';
```

Some characters have special "control" behaviors and do not map to printable characters on the screen. They are expressed using a sequence of characters that starts with a special escape character. Escape in this context means "Escape from the normal humdrum conventions of just meaning what you are, and let's do something special." The escape character in `C#` is the backslash (`\`). Control characters and their possible escape sequences are shown in the following table.

| Character | Escape Sequence |
|-----------------|-----------------|
| <code>\'</code> | Single quote |
| <code>\"</code> | Double quote |
| <code>\\</code> | Backslash |
| <code>\0</code> | Null |
| <code>\a</code> | Alert |
| <code>\b</code> | Backspace |
| <code>\f</code> | Form feed |
| <code>\n</code> | New line |
| <code>\r</code> | Carriage return |
| <code>\t</code> | Horizontal tab |
| <code>\v</code> | Vertical tab |

The effect of these control characters depends on the device you send them to. Some systems beep when you send the alert character to them. Some clear the screen when you send the form feed character. You can use them as follows:

```
char beep = '\a' ;
```

Note that the `a` must be lowercase. Within Microsoft XNA, you can use the New Line escape sequence `\n` in a string to produce a control character that will cause the `DrawString` method to take a new line.

Class A class is a collection of behaviors (methods) and data (fields). Class instances are managed by reference. Declaring a variable of the type of the class creates a reference to an instance of that class. To make an instance of a class, you have to use the `new` keyword.

Cohesion *Cohesion* is a software engineering term that refers to how "together" an object is. Objects with high cohesion are self-contained and self-reliant. They contain all the data and behaviors they need to do their job and do not require the involvement of other objects. High cohesion is generally a good thing because it means that the objects can be interchanged with others more easily and alterations to the way they work internally do not affect other objects.

Comment A comment is an item that you put into your program for the humans to read and the compiler to ignore. Comments can be given in two forms, depending on how much you want to say:

```
// This is a simple comment that
   just runs to the end of
   this line
```

```
/* This is a comment in which I'm
   going to try to express the
   creative forces that drove
   me to write this program,
   which was forged in the
   smithy of my soul and for
   which all should be
   grateful.
```

```
*/
```

The first comment begins with the characters `//` and finishes at the end of the line. The second kind of comment begins with the `/*` characters and continues until

the `*/` characters appear. Comments are a good thing; you can use them to provide useful information to someone trying to make sense of your program (or, indeed, even to yourself).

Compiler The compiler is the part of XNA Game Studio that converts the C# program that you write into instructions to be executed on the target device. It ensures that the statements that you write have the correct C# syntax and that your code is broadly sensible. The compiler produces compilation errors if it finds problems with your source code that prevent it from being able to produce an output, such as a missing semicolon or mismatched brackets or braces. The compiler also produces warnings if it detects something in the program that indicates you might have made a mistake—for example, if a variable is created but never used, or that some part of the code would never be reached when the program runs.

Component A component is a piece of software that has a particular set of behaviors that are exposed in a particular way. It can be exchanged with another component that is configured the same way. A Microsoft XNA Game class can be regarded as a component in that it has `Initialize`, `Draw`, and `Update` behaviors that can be used by other classes. The XNA Framework uses these behaviors when it runs your game. In this way, the XNA Framework can treat a game as a component that it is using. Components often expose their behaviors by means of an interface.

Conditional compilation This allows a programmer to “switch off” statements in the program so that the statements are compiled only if a given symbol is defined:

```
#if debug
// debug code goes here
#endif
```

The debug symbol is defined at the top of the program:

```
#define debug
```

If the debug symbol is not defined, the compiled program does not contain any of the statements controlled by it.

Constructor A constructor is a method in a class or structure that gets control when a new instance of the class or structure is being created. Constructor methods often accept parameters so that an instance can be given values to set it up. The `Color` structure has a number of constructor methods that accept different numbers of parameters, depending on how the color is to be created. You used one constructor when you created the colors for the mood light, like so:

```
Color background = new Color
(redIntensity, greenIntensity,
blueIntensity);
```

When you create your own classes or structures, you can give them constructors so that they can be initialized when they are created:

```
class Player
{
    public string Name;
    public int Score;
    public Player ( string inName,
        int inScore )
    {
        Name = inName;
        Score = inScore;
    }
}

Player p = new Player("Rob", 100);
```

Once you declare a constructor for the `Player` class, the only way that an instance of the `Player` class can be created is by calling this constructor, which must initialize the `Name` and `Score` fields, typically based on values passed to the constructor.

A constructor method has the same name as the class or structure of which it is part. Once you have added one or more constructor methods, programmers must call one of the constructors to create an instance.

Content Manager The Content Manager is the component of Microsoft XNA that manages all the assets used by a particular game. It includes the tools that prepare the content when a game project is being built and is also the component that makes the content available when the game is running. The Content Manager is component-based so that it can be extended to handle new types of assets as required.

continue The `continue` keyword is used to cause the execution of a loop to return to the “top” of the loop and perform the update behavior:

```
for (int i = 0; i < 10; i++)
{
    if (i == 5) continue;
    // will never get here with
    // i holding 5
}
```

In this example, the code after the conditional statement is not executed when `i` has the value 5 because the `continue` will have been performed, causing the execution to return to the top of the loop. Note that this behavior is not the same as the `break` keyword in that it does not cause the loop to be abandoned completely.

Control characters Character variables normally represent letters, digits, or symbols that can be read from a keyboard or displayed on a screen. A control character is not visible, but it has some form of control effect; for example, it takes a new line or returns the cursor to the start of a new line. A control character is expressed in a program as an escape sequence. A list of the control characters and escape sequences that can be represented in a C# program is given in the entry for *char* in this glossary.

Control expression A control expression is used in a switch to select the case to be performed.

Coupling Two objects are said to be coupled if one of them relies on the other to perform its work. This reliance means that there is a dependency between the two objects such that if one of them (the one being relied on) changes the way it works, it is necessary to make sure that the other class is not affected. As an example, you could consider a menu screen that displays settings for the player of a game. The menu screen object must read data from the game and display it. In this respect it is “coupled” to the game. If the way the game stores its data changes, the menu screen might have to change as well. However, this dependency is only one-way. Changes to the menu screen do not affect the behavior of the game. Large amounts of coupling in a system make it hard to maintain and update because time must be spent checking dependencies and making sure that a change in one object does not break others.

Creators Club See XNA Creators Club.

Debug Faults in programs are called bugs, which perhaps is a reference to an insect that was found trapped in a piece of computer hardware by Grace Hopper, one of the world’s first programmers. The body of the insect was physically stopping the program from working, and she “debugged” the program by removing it. A bug is caused by a misunderstanding of the problem, a limitation in the algorithm that is intended to solve the problem, or a mistranslation when the algorithm is converted into program code. Programs are debugged by a mixture of skill, determination, and luck. You often have to add extra statements to find out what is going on in the program when it fails. You can also use *breakpoints* to stop a running program and investigate the state of the variables in it.

Declaration A declaration is a program statement that tells the compiler about a new variable or method in your program. The new item must be given an identifier and a type. If a method is being declared, the source code must also give the method signature (the type of the method and the identifiers and types of any parameters), as well as the method body:

```
int i;    // declare an integer
         with the identifier i

int doAdd( int first, int second)
    // declare a method
{
    return first + second;
}
```

Variables can be local to a block or members of a class or structure. Local variables must be declared in a block before they can be used. Methods are members of a particular class or structure and are declared within it.

delegate A delegate is a type-safe reference to a method. A delegate is created for a particular method signature (for example, “this method accepts two integers and returns a float”). It can then refer to a method that matches that signature. Note that the delegate instance holds two items: a reference to the instance of the class which contains the method and a reference to the method itself. The fact that a delegate is an object means that it can be passed around like any other.

Delegates are used to inform event generators (things like network sessions or timers) of the method that is to be called when the event they generate takes place.

Directive A directive is a command in the source of a program that tells the compiler to do something. The `#define` directive tells the compiler that a symbol is being defined. The `using` directive tells the compiler to look in a particular namespace for objects.

Directory A directory is a place in a file store where you can store a file. It is sometimes called a folder. Directories can contain directories so that file storage can be arranged in a hierarchy. The path to a file identifies all the directories that must be traversed to get to that file. Each directory name is separated from the next by the backslash character, as in `c:\code\program\progfile.cs`.

do – while The `do – while` construction allows a program to repeat a block of code until a controlling condition at the end becomes `false`. Note that the test is performed after the statement or block; that is, even if the test is bound to fail, the statement is performed at least once, as follows:

```
do
    statement or block
while (condition) ;
```

This form of loop can be used as an alternative to the `for` loop constructions. It is very useful in programs where you want to request something, check that it is okay, and then repeat the process if it is not. There is an alternative form where the condition is tested before the statement:

```
while (condition)
    statement or block
```

In this looping construction, the statement is not performed at all if the condition is `false` at the beginning of the `while` loop.

You don’t have to use these constructions if you have no need to; it’s simply provided for situations where a loop is required but there is no need for a counter as would be used in a `for` loop.

Element (of an array) An element is an individual item in an array. Each element is identified by its subscript value.

Encapsulation This is the creation of objects that encapsulate a set of behaviors and data for a particular purpose. The object performs all the functions required for that

purpose and can be regarded as a “black box,” with no need for outsiders to actually know how it works. An example would be an `AlienSprite` object that would perform all its drawing, updating, and initialization behavior without needing the involvement of any other classes.

Enumerated type An enumerated type is one for which you specify the set of values that it can have. Here is an example:

```
enum SeaState {
    EmptySea,
    Attacked,
    Battleship,
    Cruiser,
    Submarine
};

SeaState openSea;
openSea = SeaState.EmptySea;
```

The type `SeaState` could be used to hold the state of the sea in a battleship game. It has five possible values, which are created as shown. The variable `openSea` is of type `SeaState` and is set to `EmptySea` in the previous code.

Exception An exception is a way that a C# program can signal that something has gone wrong when it runs. The exception itself is an object that is created when the exception is “thrown” and can be “caught” by an exception handler. The C# language provides the `try – catch` construction, which can be used to deal with exceptions that might be thrown. Your program gets exceptions if it calls things that create a bad result. For example, if a running program tries to get the Content Manager to load a nonexistent resource, the Content Manager signals its displeasure by throwing an exception. If your program doesn’t catch the exception, it fails at that point.

Expression An expression is a collection of operands and operators that can be evaluated to produce a result. You have seen numeric expressions, logical

expressions, and text expressions, as shown in this code example:

```
int i = 0;
i = i + 1;
// arithmetic expression adding
// 1 to i
bool iIsPositive;
iIsPositive = i > 0;
// logical expression
string IValue;
IValue = "Value of i is : " +
i.ToString(); // text expression
```

Field A field is a member of a class or structure that stores data within an instance:

```
class Player
{
    public string Name;
    public int Score;
}
```

The `Player` class contains two fields: the `Name` of the player, which is a string, and the `Score` the player has reached, which is an integer. A program uses a field by giving the identifier of the instance, followed by a period (`.`), followed by the name of the field:

```
Player p = new Player();
p.Name = "rob";
p.Score = 100;
```

The `Name` and `Score` fields can be accessed in this way because they have been made public. Fields can also be made private, in which case they are not visible to code outside the class or structure.

File extension Files on a computer system have filenames that are used to locate them. The file extension is information on the end of the filename made up of a number of characters after a period (`.`) character. The Microsoft Windows operating system uses the file extension to select the application to be used to open a particular file. “`Program.cs`” identifies a C# program file, for example, while “`Background.png`” would identify a Portable Network Graphics (PNG) file.

Folder See *Directory*.

Framework A framework is a set of software resources that programmers can fit together and extend to create solutions to problems. The Microsoft .NET Framework provides a way that programs can run on a computer platform. It also provides a comprehensive set of resources that can be used to create general-purpose applications. The XNA Framework provides resources for the creation of games.

Fully qualified name A fully qualified name is one that provides a complete path to the resource that is being identified. It identifies all the namespaces in the path to the resource with that name:

```
Microsoft.Xna.Framework.Graphics.  
Color background;
```

You can avoid having to use the fully qualified name of a resource by adding a using directive at the top of your program source. A set of using directives is inserted automatically into the Game1.cs file when XNA Game Studio creates a new game project.

Garbage collector The garbage collector is a process that runs as part of a .NET application and searches for and removes resources that are no longer used.

Generic method A C# method is supplied with parameters for the method to act on. In a generic method, the parameters are not restricted to one particular type. Generic methods are used when the programmer wants to create a method to perform a particular action but wants the action to be performed on variables of different types. In Microsoft XNA, the Content Manager provides a generic method called Load, which is supplied with the type of the item to be loaded.

```
Texture2D cheeseTexture =  
Content.Load<Texture2D>  
("Images/Cheese");
```

```
SoundEffect cymbolTing =  
Content.Load<SoundEffect>  
("cymbolTing");
```

The Load method can then perform the appropriate load action and deliver a result of the required type.

The List collection class also uses this mechanism so that it can manage a list of whatever type you give it.

```
public List<BaseSprite>  
GameSprites =  
new List<BaseSprite>();
```

This creates a List that can hold references to BaseSprite instances.

Header (of a method) A C# method can be broken into two parts: the block of code, which is the body of the method and contains the statements that the method performs, and the header, which indicates the type returned by the method, the identifier (which is the name of the method), and the parameters that the method accepts. Look at this code example:

```
int doAdd(int first, int second)  
// declare a method  
{  
    return first + second;  
}
```

The header of the method doAdd is int doAdd(int first, int second).

IDE See Integrated Development Environment (IDE).

Identifier An identifier is a name chosen by the programmer to identify something in a program. This includes the names of variables and the names of classes, structures, and methods. The C# compiler has rules concerning the construction of identifiers; they can contain letters (*a–z* or *A–Z*), digits (*0–9*), and the underscore (*_*) character. An identifier must not start with a digit. The case of the letters in an identifier is significant in that the identifiers

count and Count could both be used in the same program to refer to different variables:

```
int count;
double Count;
// legal C# - but the Great
// Programmer wouldn't approve
```

C# has a convention that local variables, parameters, and private members of a class or structure should have identifiers that start with a lowercase letter. Identifiers for classes and structures and public members of classes and structures should have identifiers that start with an uppercase letter.

Instance Instances of objects are created as a program runs. If the object is manipulated by value, there is no need to use `new` to create an instance of it, although you can use `new` if you wish to call the constructor for that type.

Integer An integer is a numerical value that has no fractional part. The C# language provides a number of integer types; the programmer should choose the type that provides the most appropriate range of values for the program being written.

Integrated Development

Environment (IDE) An Integrated Development Environment (IDE) combines an editor for creating the source code, a compiler, and a debugger in a single tool that can be used for development. XNA Game Studio is based on the Microsoft Visual Studio IDE.

Intellisense Intellisense is the name given to the feature of XNA Game Studio that provides context-sensitive help and suggestions to you as you write your program source. The system constantly monitors what you are typing and suggests appropriate items on the basis of what it sees.

Interface An interface defines a set of actions. The actions are defined in terms of a number of method definitions. A class that

implements an interface must contain code for each of the methods defined in the interface. Look at this code:

```
interface ISinger
{
    void SingSong(int loudNess);
}

class OperaSinger : ISinger
{
    public void SingSong(int
    loudNess)
    {
    }

    public void SingAria
        (int loudness, int vibrato)
    {
    }
}

class PoliceMan : ISinger
{
    public void SingSong
        (int loudNess)
    {
    }

    public void MakeArrest ()
    {
    }
}

ISinger singer = new PoliceMan();
```

The interface `ISinger` contains a single method called `SingSong`, which is supplied with a parameter to indicate how loudly the song is to be sung. Both `OperaSinger` and `PoliceMan` implement the interface, meaning that either of them can be asked to sing (although you might get a better tune out of `OperaSinger`). This means that you can regard `PoliceMan` and `OperaSinger` in terms of their singing ability, even though they are completely different classes. A reference to `ISinger` could be made to refer to either an `OperaSinger` or a `PoliceMan` interface and ask it to sing by calling the `SingSong` method. Viewing classes in

terms of what they can do is a large part of component-based development.

Keyword A keyword is a word that is part of the C# language. Keywords that you have seen include `for`, `if`, `new`, `class`, `struct`, `switch`, and `case`. Keywords have a particular meaning, and you cannot create an identifier that is the same as a keyword. The XNA Game Studio editor displays keywords in bright blue.

Literal A literal is something in a program that is literally just there. Examples of literals include values in expressions and strings:

```
width = width + 2;
playerName = "rob";
```

In the preceding statements, the literals are the value "rob" and the value 2.

Local A variable that is local to a block is declared in the block and is discarded when the execution of the program leaves that block. Local variables are used in the situation where you want a variable for a very short part of the program.

Localization Localization is the name for the process of making a program work in a manner appropriate to a particular part of the world. It includes aspects such as the language used for the user interface, the character set, and how dates, times, and currency values are displayed.

Logical Logical values can be either true or false. C# provides the `bool` type to hold logical values, it provides comparison operators (for example, *LESS THAN*) that compare values and produce logical results, and it provides logical operators (for example, *OR*) that allow logical values to be combined.

Machine code This is a generic term for low-level instructions that can be processed by a computer. This is in contrast with source code, which contains the program instructions that are written by the

programmer and that contain a high-level description of a solution to a problem in a form that can be read by humans.

The compiler takes the high-level source code and converts this into a form that is eventually made into machine code for execution on a target device.

Member A member of a class is declared within that class. It can either do something (if it is a method) or hold some data (if it is a variable). Methods are sometimes called *behaviors*. Data members are sometimes called *fields*.

Method A method is a block of code preceded by a method header. The method has a particular identifier and may return a value. It may also accept one or more parameters to work on. Methods are used to break a large program up into a number of smaller units, each of which performs one part of the task. They are also used to allow the same piece of program to be used in lots of places in a large development. If a method is public, it can be called by code in other classes. An object exposes its behaviors by using a public method.

Microsoft XNA The best game development environment in the world, bar none.

Modifier A modifier is used to modify a declaration. It gives the compiler additional information about the thing that is being declared. Examples of modifiers are `public`, `private`, and `static`.

Namespace A namespace is a way of categorizing related resources. Each resource provided by a framework must have a unique name. Putting all the names at the same level would result in confusion; for example, the name `Device` could have many possible meanings—you might want to have audio devices, graphics devices, and so on. A namespace is a space where particular names have meaning. You could create a `Graphics` namespace and an

Audio namespace, each of which could hold a Device resource:

```
namespace Graphics
{
    class Device
    {
    }
}

namespace Audio
{
    class Device
    {
    }
}
```

You would refer to the devices created by this code as `Graphics.Device` and `Audio.Device`. It is possible for a namespace to contain a namespace, allowing a hierarchy of names to be created. A particular source file can contain a number of different namespaces, and a namespace can be spread over several source files.

The XNA Framework is organized into a series of namespaces, each of which holds a set of related resources. You can access them by using a particular namespace or by giving a fully qualified name.

Narrowing Narrowing can occur when a variable of one type is assigned to another. C# provides a number of different data types that are used to hold values in programs. Each type has a particular range and precision. For example, the byte type can hold values in the range 0 to 255, whereas an integer can hold values in the range $-2,147,483,648$ to $2,147,483,647$. Narrowing would occur if a program assigned a value from an integer variable into a byte. If the integer had a value greater than 255, the narrowing would result in the corruption of the value. The C# compiler insists the programmer use a cast to confirm that a narrowing operation is valid.

null The C# keyword `null` allows a program to express the fact that a reference points nowhere. Newly created reference variables are set automatically to refer to `null`, and it is possible to test for this condition in your programs as follows:

```
Player p;
if ( p == null )
{
    // will get here because p is
    // initially null
}
```

You can actually assign the value `null` to a reference to indicate that the reference is not set to refer anywhere.

Object An object is an instance of a given data type. Many types are provided by C# and Microsoft XNA, and you can create your own types by declaring classes (`class`) and structures (`struct`).

Operand An operand is something that is worked on in an expression by an operator. Operands are either literals, variables, or expressions.

Operator An operator is used in an expression and identifies an operation to be performed on one or more operands. Arithmetic operators that you have seen include plus (+), minus (-), multiply (*) and divide (/). Relational operators include less than (<), greater than (>), equals (==) and not equals (!=). Logical operators that you have seen include logical AND (&&) and logical OR (||).

Overflow Overflow occurs if the capacity of a variable is exceeded when a program is running. Variables are declared as being of a particular type, and the programmer must be careful to use the type appropriately. For example, the byte type is able to hold values that range from 0 to 255. If a program put 255 into a byte variable and then added 1 to this variable, the result would cause the variable

to overflow because the byte type is not able to represent that value. While some forms of program error, such as exceeding the array bounds, cause an exception to be thrown, this is not always the case with overflow.

Overload A method is overloaded when a method with the same name but a different set of parameters is declared in the same class. Methods are overloaded when there is more than one way of providing information for a particular action; for example, a date can be set by providing day, month, and year information, or by a text string or by a single integer that is the number of days since January 1. Three different overloaded methods could be provided to set the date, each with the name `SetDate`. In that case, the `SetDate` method could be said to have been overloaded.

Override Sometimes you may want to make a more specialized version of an existing class. This may entail providing updated versions of methods in the class. You do this by creating a child class that extends the parent and then overriding the methods that need to be changed. When the method is called on instances of the child class, the new method is called, not the overridden one in the parent. You can use the `base` keyword to get access to the overridden method if necessary.

Parameter A parameter is supplied by a call to a method to give the method something to work on. A parameter that is a value type is passed into the method by value. A parameter that is a reference type is passed into the method by the value of the reference. If you want to pass a value type by reference, you must mark the parameter as a reference type using the `ref` qualifier. A special kind of reference that can only be used to deliver a result (that is, you can't follow the reference to read the thing it

refers to) can be specified by using the `out` qualifier.

Pixel A pixel, or "picture element," gives the color of a single small area of the display screen. The more pixels that a screen contains, the higher the quality of the picture, but more memory will be used, and it will take longer to create an image.

Precision C# provides several types that can hold numbers with fractional parts, and these types have different precisions. The precision of a type determines how accurately that type can represent a particular value. Because computer storage is finite, the precision to which numbers are stored is limited. The float type can represent values to a precision of 7 digits, whereas the double type provides 15 to 16 digits of precision.

Private A private member of a class is visible to code only in methods inside that class. It is conventional to make data members of a class private so that they cannot be changed by code outside the class. The programmer then can provide methods or C# properties to manage the values that can be assigned to the private members. The only reason for not making a data member private is to remove the performance hit of using a method to access the data.

Program A program is a description of a solution to a problem. The program sets out the steps to be taken and decisions to be made and that ultimately are to be performed by some sort of computer hardware.

Programming language A programming language is a special form of language that has a simple and unambiguous syntax and grammar. It is designed so that programs written in the language can be converted easily into forms that can be executed by computer hardware.

Project A project is a collection of program files and other resources that can be brought together to produce a single assembly that can be deployed as part of a solution to a problem. XNA Game Studio manages projects and also brings a number of projects together to create a single solution.

Property Properties are extremely useful and make your code a lot cleaner. Essentially, you can have code like the following:

```
x.Width = 99;
```

This looks like an assignment to a member of a class, but it can be much more than that and can result in additional code running. The `Width` property could be managed like this:

```
class ThingWithWidth {
    private int widthValue;
    public int Width
    {
        get
        {
            return widthValue;
        }

        set
        {
            widthValue = value;
        }
    }
}
```

When a program performs the assignment to the property, the set portion (the “setter”) runs. The `value` keyword is set to the value of the incoming property. This set code performs a simple assignment to the `widthValue` data member, but you could validate the value and throw an exception if you don’t like it. I’ve decoupled the name of the property value from the value of the property (one convention is to put the word `value` on the end of the name of the internal value). Of course, you don’t actually have to have a value inside the class; you could calculate a result rather than return a member.

When setting the value, you can run additional code whenever the value of your property changes. This makes creating state machines easy. Furthermore, you don’t have to implement both a get and a set behavior; you can have just one so that you can create write-only (or read-only) properties. You can have lots of getters for the same property; perhaps you would like to read the speed in kilometers per hour as well as miles per hour.

The only downside is that you must be aware that substantial amounts of code can run when you perform innocent-looking assignments.

Protected A protected member of a class is visible to methods in the class and to methods in classes that extend this class. It is kind of a halfway house between private (no access to methods outside this class) and public (everyone has access). It lets you designate members in parent classes as being visible in the child classes.

public A public member of a class is visible to methods outside the class. It is conventional to make the method members of a class public so that they can be used by code in other classes. A public method is how a class provides services to other classes.

Range The range of a given type sets out the largest and smallest values that can be held in a variable of that type. Each C# type has a particular range, and one of the tasks for programmers is to select a type with a range that is appropriate for the data they wish to store.

Reference A reference is like a tag that can be attached to an instance of a class and has a particular name. C# uses a reference to find its way to an instance of the class and use its methods and data:

```
class Player
{
    public string Name;
    public int Score;
}
```

```
Player p = new Player();
p.Score = 100;
```

The variable `p` is a reference variable that can refer to instances of the class `Player`. It is set to refer to a new `Player` instance. The reference is then used to access the `Score` field inside the instance referred to by `p`.

One reference can be assigned to another. If you do this, the result is that there are now two references that refer to a single object in memory. In `C#`, references are type-safe in that a reference to one particular object, such as a `Texture2D`, would not be allowed to refer to any other type of texture. This means that when the reference is followed to an object, the actions performed with that object are always appropriate.

SDK See Software Development Kit (SDK).

Signature A given `C#` method has a particular signature that allows it to be identified uniquely in a program. The signature is the name of the method and the type and order of the parameters to that method:

- `void Silly(int a, int b)` has the signature of the name `Silly` and two `int` parameters.
- `void Silly(float a, int b)` has the signature of the name `Silly` and a `float` parameter followed by an integer parameter.

This means that the code

```
Silly(1, 2) ;
```

would call the first method, whereas

```
Silly(1.0f, 2) ;
```

would call the second.

Note that in `C#`, the return type of the method is not part of the method signature.

Software Development Kit (SDK) A Software Development Kit (SDK) is a collection of tools and library resources that can be used to create software on a particular platform.

Solution XNA Game Studio brings together one or more project files to produce a single solution. The same project file can be used in more than one solution, which allows libraries of code to be created and reused. Within a solution, one of the projects is designated the startup project and will be the one that runs when the system produced by the solution is started.

Source code Source code is the text written by programmers. It is stored in plain text on the development computer and converted by a compiler into the machine code that actually performs the program instructions on the target machine.

State At any given instant, a running program is in a particular state. Many game programs contain variables that explicitly manage the state of items in the game. It is often the case that an enumerated type is created to represent a particular state.

Statement A statement is a single action that a program performs. Statements in `C#` programs are separated by the semicolon (`;`) character.

static In the context of `C#`, the `static` keyword makes a member of a class part of a class rather than part of an instance of the class. This means that you don't need to create an instance of a class to use a static member. It also means that static members are accessed by means of the name of their class rather than a reference to an instance. Static members are useful for creating class members that are to be shared with all the instances, such as currency conversion rates for all the accounts in a bank.

string The `string` data type lets programs work with strings of text. The `string` is held as a one-dimensional array of characters. Strings can be used with the `+` operator, which cause them to be concatenated together. String literals are denoted in a program enclosed in

double quotes. A string literal can contain control characters; see the *Char entry* in this glossary for details of these. Here's an example of strings in code:

```
string firstname = "Rob";
string surname = "Miles";
string fullname =
    firstname + " " + surname;
```

Structure A structure is a collection of data items. It is managed by value, not by reference, and struct contents are copied on assignment:

```
struct Particle
{
    public int X;
    public int Y;
}

Particle position;
position.X = 99;
position.Y = 00;
Particle[] Smoke = new
Particle[1000];
```

The `Particle` structure simply holds the `X` and `Y` positions of a particle. Because it is a struct, I can declare a variable of type `Particle`, and an instance is created automatically. The `Smoke` array, which contains 1,000 particles, is also created automatically. There is no need to use `new` to create any `Particle` instance.

Structures are also passed by value into methods. Structures are useful for holding a simple set of related data in a single unit. They are not as flexible as objects (which are managed by reference), but they can be more efficient to use because accessing structure items does not require a reference to be followed in the same way as for an object. An array of struct values is stored in a single block of memory that contains a row of the items. An array of items managed by reference (for example, instances of a class) is stored as an array of references, with each element in the array able to refer to one instance.

Subscript A subscript is a value that is used to identify the element in an array. It must be an integer value. Subscripts in C# always start at 0 (this identifies the initial element of the array) and extend up to the size of the array minus 1. This means that if you create a four-element array, you get hold of elements in the array by subscript values of 0, 1, 2, or 3. The best way to regard a subscript is that it is the distance down the array that you are going to move to get the element that you want. This means that the first element in the array must have a subscript value of 0.

switch The `switch` construction allows a program to select one option from several based on a control expression. Switches are often used to select particular behavior based on the value of an enumerated type. Here's an example:

```
switch (state)
{
    case GameState.titleScreen:
        drawTitle ();
        break;
    case GameState.playingGame:
        drawGame();
        break;
    case GameState.highScoreDisplay:
        drawHighScore();
        break;
    default:
        doShowError();
        break;
}
```

The `switch` construction uses the value of the control expression to decide which option to perform. It executes the case that matches the value of the control expression. The `break` statement after the call of the relevant method is used to stop the program running on and performing the code that immediately follows. In the same way as you break out of a loop, when the `break` is reached, the `switch` is finished and the program continues running at the statement after the `switch`.

Another useful feature is the default option, which gives the switch somewhere to go if the switch value doesn't match any of the cases available.

this The `this` keyword means "a reference to the current instance." Its use is implied within methods in classes:

```
class Player
{
    public string Name;
    public int Score;

    public void IncreaseScore ()
    {
        this.Score = this.Score + 1;
    }
}
```

It would be possible to write `Score` rather than `this.Score` in the `IncreaseScore` method because the compiler inserts `this` automatically if required.

The `this` reference can also be used to pass an instance as a parameter in a call to another method:

```
DisplayScore(this);
```

The `DisplayScore` method accepts a reference to a `Player` as a parameter. It can be called from a method in the `Player` class to display the score of that player instance.

Type In C#, all data items have a particular type associated with them. Some types are built into the C# language. These types, such as `int`, `float`, and `bool`, are available to all programs written in the language. Other types can be added from libraries, such as `DateTime`. Finally, you can create your own types to hold a collection of data and behaviors that are specific to the problem at hand.

The C# compiler ensures that whenever variables of different types are used together, there is no potential for errors to occur or data to be lost. For example, an attempt to move a value from a variable of

floating-point type into an integer results in the compiler generating an error unless programmers use a cast to indicate that they are aware of the issue, and in this context, the action is valid. Type checking is performed at compile time (which is called *static type checking*) and also when the program runs. This means that even if the programmer uses a cast to force one thing to be used as another, at run time any inappropriate mixing of types would be rejected. This extra stage makes C# programs much safer, but the extra run-time type checking slows down the program.

Type-safe We have seen that C# is quite fussy about combining things that should not be combined. Try to put a `float` value into an `int` variable, and the compiler rejects the code. The reason for this is that the designers of the language have noticed a few common programming mistakes and have designed for these mistakes to be detected before the program runs, not afterwards when it has crashed. One of these mistakes is to use values or items in contexts where it is either not meaningful to do so (such as putting a `string` into a `bool`) or where doing so could result in losing data or accuracy (such as putting a `double` into a `byte`). This kind of fussiness is called type safety, and C# is very big on it. Some other languages are much more relaxed when it comes to combining things, working on the assumption that the programmer knows best. They assume that just because code has been written to do something, that thing must be the right thing. But C# is not that way; and neither am I. I think it is important that developers get all the help they can to stop them doing stupid things, and a language that stops you from combining things in a way that might not be sensible is a good thing in my book.

Of course, if you really want to impose your will on the compiler and force it to compile your code in spite of any type-safety issues, you can do this by using casting.

using The word `using` can serve as either a compiler directive or a keyword in a program.

C# provides the `using` directive, which you can use as follows:

```
using Audio;
```

The `using` directive must appear at the start of a source file. It identifies a namespace that is to be used to resolve the names of classes in that file. If the `Audio` namespace contains a class called `Device`, I could add a `using` directive to my program so that I can create instances of `Device` without having to add `Audio` to qualify the name.

I can still use other `Device` classes, such as `Graphics.Device`, but I need to give its fully qualified name. You can add multiple `using` directives at the start of a source file; when you create a new project, you often find that a number of them have been added automatically. If there is a name clash (for example, you use two namespaces that each contain a class called `Device`), the compiler requires you to use the fully qualified name for that particular class. It can also be sensible to use the fully qualified name in circumstances where you want a reader of the program source to identify easily where a class is defined.

C# provides the `using` keyword, which lets you state precisely where in a program a variable is being used:

```
using (PongGame game = new
PongGame())
{
    game.Run();
}
```

The `using` keyword is followed by the declaration of a variable to be used in the block which follows the `using` statement. When the block is complete, the garbage collector knows the variable is no longer

required and can be removed. Without the `using` statement, the Garbage Collector would have to deduce that there were no remaining references to the variable `game` in the preceding code.

Value type A value type holds a simple value. Value types are passed as values into method calls, and their values are copied on assignment; that is, `x = y` causes the value in `y` to be copied into `x`. Subsequent changes to the value in `x` do not affect the value of `y`. Note that this is in contrast to reference types, where the result of this assignment would be that `x` and `y` refer to the same instance.

Variable A variable holds a value that is being used by a program. A given variable has a unique identifier and is declared as having a particular type. Variables can be local to a block or they can be members of a class.

Virtual method I can call a method (a member of a class) to do a job. Sometimes I may want to extend a class to produce a child class that is a more specialized version of that class. In that case, I may want to replace (override) the method in the parent with a new one in the child class. For this to take place, the method in the parent class must have been marked as `virtual`. Only virtual methods can be overridden. Making a method virtual slightly slows down access to it because the program must look for any overrides of the method before calling it. This is why not all methods are made virtual initially.

void A `void` method performs a task but does not return a value. A programmer who wants to create a method that does not return a value can tell the compiler this by making the type of the method `void`.

while The `while` keyword is used in looping constructions which are described in the *do – while* item in this glossary.

Widening Widening is the reverse of narrowing. When a value is widened, it is moved from a type with a narrower range and precision into one that has a wider range, such as from the byte type (with a range of 0 to 255) into an integer type (with a range of 2,147,483,648 to 2,147,483,647). The compiler is quite able to produce code that performs this conversion because there is no chance of data being lost.

Workspace A workspace is analogous to an XNA Game Studio solution in that it contains programming resources and projects that are used to create a solution.

Xbox Live Xbox Live is a networking solution for Xbox 360 and PC games. Gamers pay a subscription that gives them an identity on the Xbox Live network and allows them to engage in network play using Xbox games.

They can also download game demos and other content that is then stored on the hard disk of their Xbox 360. An Xbox Live account is required if you wish to obtain an XNA Creators Club membership.

XNA See Microsoft XNA.

XNA Creators Club If you want to run your Microsoft XNA programs on an Xbox 360, you must be a member of the XNA Creators Club. Members of the club pay a membership fee, and their Xbox Live account is extended to include XNA game development. XNA Creators Club membership also gives you access to extra sample programs and the Creators Club forums. You can find out more at <http://creators.xna.com>. If you want to create and run your XNA programs on a Microsoft Windows PC or Zune, you don't have to be a member of the Creators Club.

Index

Symbols and Numbers

-- operator, 82, 84
!(NOT) logical operator, 124
command, preprocessor, 113
&& (AND) logical operator, 109, 174
* (multiplication operator), 174
/ forward slash character, 23–24, 194, 241
/y1#/y0define directive, 113
/y1#/y0endif directive, 113
/y1#/y0if directive, 113
/y1#/y0region compiler directive, 73
; (semicolon), 23, 61
[] (square brackets) array value, 133
[] property, 146
|| (OR) logical operator, 54, 109
: (colon), 269
++ operator, 34
+= operator, 324
< (less than) logical operator, 98
= (equals operator), 25–26, 40, 145
= (comparison operator), 40, 49–50
> (greater than) logical operator, 55
2-D vectors, 89–92
3-D text creation, 95–99, 101–03

A

Abs method, 222
absolute value, 222
abstract classes, 278–81
abstraction, 277–78, 281
AbstractSprite class, 278–81
access modifiers, 213
actions, 277
Add Existing Item - Content dialog box, 70–71
 adding sounds, 117–19
 linking to resources, 72
Add method, 290
addresses
 broadcast, 308
 network, 308
AI (artificial intelligence), 293
algorithms, 36, 130, 152–53
alpha channel value, 102
AND (&&) logical operator, 109, 174
architecture, 70
 code design, 111

args (argument) parameter, 197–98
array references, 144–45, 154, 223
arrays, 132
 as lookup tables, 136–37
 as offices, 145–47
 bounds, 134
 data, 133–34
 elements, 132–34
 one-dimensional, 132
 references and, 149
 registering key presses, 143
 scanning, 134–35
 structures, 145–47
artificial intelligence (AI), 293
aspect ratio, 80, 203
aspectRatio variable, 203
assets, 67, 191–94
attract mode. *See* title screens
Audacity (program), 115–25
audio. *See* sound
avatars, 311

B

Back button, 14, 33–34, 53, 56–57, 59, 331
background, 242–43, 259
background color, 25–27, 32–35
background music, 121–26
Background reference variable, 262
BackgroundSpriteClass, 261–62
BackgroundSpriteStruct
 structure, 260
backslash (\) character, 157
base (key word), 272–73
base method, 285
BaseSprite Class, 266–69
 constructors, 282–85
BatSpriteStruct, 251–53
behaviors
 classes and, 27–28, 251, 266, 280
 interfaces and, 301
 looping, 98
bits, 35, 307
blocks, 50–51, 277. *See also* method body
 for loop, 97–98
blue screen, 14, 23, 123
BMP (Windows Bitmap) images, 66
body, method. *See* method body
bool variables, 37, 153–54, 244
Boolean expressions, 37–38, 54

bouncing behavior, 206–08, 218–20
Bouncing Cheese, 206
braces ({}) and blocks, 23
brackets and blocks, 23
Bread and Cheese Pong project, 312
 states, 319
Bread and Cheese project, 189–91
 methods in, 256–57
Bread and Cheese Sprite
 Structures, 257
break (key word)
 for loops, 154–55
 switch statement with, 156
breakpoints, 175–76, 220–21
broadcast addresses, 308
Broken Jake Center Zoom, 184–86
Broken Reaction Timer Game, 130
bugs, 98–99
 finding, 42–43, 59–61
 floating point number, 179–80
 reaction timer, 130–31
Button-Bash Test sample project, 113
Button-Bashing Mob project, 105
 counting presses, 107–09
 data, 106
 displaying values on screen, 107
 starting, 106
 Update method, 106
ButtonState.Pressed value, 50–52
byte variables, 31
bytes, 31, 35, 143

C

C#, 5
 array bounds, 134
 arrays, 132
 backslash (\) character, 157
 break (key word), 154–56
 classes. *See* classes
 compiler. *See* compiler
 creating methods in, 169–71
 debugging. *See* debugging
 file extensions, 22, 199
 l convention, 302
 interfaces, 301–04
 Main method, 50
 null reference, 123
 reference types, 149
 references, 145
 removing unwanted objects, 147
 to start game, 194

- call statements
 - Update method, 37
 - XNA engine and, 34
 - calls, 309–10
 - constructors, 286–88
 - methods and performance, 28
 - of methods, 30
 - casting, 181–82, 202, 204
 - character designs and font files, 85–86
 - Chat messages, 328
 - CheckCollision method, 27, 254–56, 274
 - child classes, 266–67, 269, 278
 - constructors, 284–85
 - class files, renaming, 199–200
 - class hierarchies. *See* hierarchies, class
 - class members
 - key words and, 251
 - static, 288
 - classes, 27, 46–47. *See also* specific classes
 - abstract, 278–81
 - behaviors and, 27, 251, 266, 280
 - creating, 261
 - games and, 27
 - implementation of interfaces, 302
 - members, 29–30
 - references and, 263
 - renaming, 199
 - static, 196
 - structures and, 260
 - Clear method, 24, 26–27, 29
 - client behavior, 330
 - clock project. *See* Giant Clock project
 - code
 - compilation, 13–14. *See also* compiler
 - reuse of, 69–70, 260
 - testing, 111–14, 173–74
 - turning on and off lines of, 321
 - well-written, 241
 - code design, 235–36
 - code regions, 240–41
 - code review, 281–82
 - cohesion, 250–51, 253
 - collisions
 - checking for, 27, 256, 274
 - client/server checking for, 327, 330
 - creating, 254–56
 - handling, 218–20
 - colon (:), 269
 - Color Nerve game, 51–54, 83
 - Color structure, 27
 - color values
 - assigning, 25–27
 - controlling, 27
 - storing, 24–25
 - colors
 - drawing, with intensity variables, 32–33
 - making different, 24–27
 - transparent, 101–03
 - transparent vs. solid, 97
 - updating, 33–34
 - comments, 23–24, 241
 - comparative condition, 39–40
 - comparison operators, 40, 49–50
 - compilation
 - conditional, 113, 321
 - source code, 13–14
 - compilation errors, 13
 - abstract class, 278
 - constructor, 284
 - naming, 195–96
 - narrowing, 180–81, 202
 - compiler, 13–14, 25, 106
 - C# types, 180
 - commands, 113
 - error messages, 179–80
 - errors, 13
 - memory, 31
 - preprocessor, 113
 - using directive, 195–96, 198, 208, 222
 - warnings, 38–39
 - compiler code, 60
 - compiler directive, 195
 - components, 300–01
 - conditional compilation, 113, 321
 - conditional statements
 - else part, 39
 - if condition, 37–38
 - IsKeyDown method, 52
 - testing, 39–40
 - constructors, 282–85
 - content, 67, 75
 - Content directory, adding to, 70–72
 - content folder, 192
 - content management, 10
 - Content Management Pipeline, 73
 - Content Manager, 10
 - folders, 193
 - font loading, 87, 89
 - reference file, 88
 - sound files, 119
 - continue button, 177
 - control characters, 157
 - control expressions, 156
 - control keys, 53
 - controls, designing and input
 - detectors, 109
 - copyright law, sound sample, 116
 - costs, game development, 114
 - Count method, 290–91
 - counter variable, 134
 - coupling, 253–54
 - Create Directory For Solution option, 68
 - Create New Profile, 314–16
 - Creators Club, XNA, 6–8, 11, 311
 - cs. file extension, 22, 199. *See also* Program cs. file
 - cumulative errors, 187
- ## D
- data, 31
 - arrays, 133–34
 - game world, 28–31
 - memory overflow, 35–36
 - private, 251, 270
 - reading, from player, 329
 - storing in memory, 31
 - data entry shortcuts, 82–83
 - data integrity, 328
 - data protection, 270
 - data signals, 307
 - data types, 265
 - data values, 35. *See also* values
 - datagrams, 309–10
 - date and time values, 93–94
 - DateTime class, 195
 - DateTime string methods, 94
 - DateTime structure, 93–94
 - DateTime.Now property, 93–94, 102
 - DeadlySprite class, 270–75
 - debugging, 42–43, 59
 - breakpoints, 175–79
 - C# programs, 175–79
 - running program, 220–23
 - decision making, program, 37
 - declaration, variables, 24–25, 31, 145
 - of delegates, 323
 - decoding, 156
 - delegates, 323–24
 - destination, 96
 - detectors. *See* edge detectors; level detectors
 - directives, 113
 - compiler, 195–96, 198, 208
 - directories, 70, 191
 - directory structure, 68
 - display adapter viewpoint
 - properties, 201
 - display creation, 21–22
 - color value setting, 25–27
 - color value storage, 24–25
 - full screen, 81–82, 201
 - statements, Draw method, 23–24
 - display, overscan, 83
 - displayHeight variable, 185–87, 201–02, 207–08

displayWidth variable, 185–87,
201–02, 207–08

Dispose method, 324

division
integer, 182–83
operator (/), 174

do...while loop construction, 99

DoAdd method, 323

double precision floating-point
numbers, 202–03

double type, 202, 265

D-pad
role selection, 322, 325
Zune, 51, 119

Draw behavior, 27

Draw method, 89–92, 164
background color, 26
BatSpriteStruct, 251
color updating, 32–33
DeadlySprite class, 271
for added objects, 224
game class, 80
game world data, 28–29
image textures, 73
messageString, 150
multiple text strings, 95
spriteBatch variable, 79–80
statements in, 23–24
textures, 80
using member variables, 32–33
vs. Update method, 27–28
winner name display, 137

DrawBackground, 244–45

drawing ratio, 203

DrawString method
loop construction, 98, 100
multiple text strings, 95–96
new line, 157

DrawText method, 89–92
message display, 230–31

Drum Pad project, 115
creating, 115

Drum Sounds, 119

Drumpad with Music project, 124

E

edge behavior, 220

edge detectors, 109
code, 108–09
multiplayer games, 109–11
sound playback, 120

edge-triggered events, 142

elements, array, 132–34

else part, conditional statements,
39, 56

encapsulation, 253

EndGame method, 324

ending programs, 33–34

enumerated types
game state, 244, 319
overview, 144

equals operator (=), 25–26,
40, 145

error messages, 35, 179–80
out-of-memory, 100

errors
casting, 181–82
compilation. *See* compilation
errors
compiler, 38
cumulative, 187
exception, 76

escape key, 53

EventHandler method, 323–24

events, 142, 322–24

exceptions, 76, 100. *See also* bugs;
also errors
NullReference, 123, 261, 280

Exit method, 53, 56–57

expressions
Boolean, 37–38, 54
control, 156
gozzinta, 96
types, 182–83

Extensible Markup Language (XML)
file format, 88–89, 92–93

Extract Method, 236–37

F

Fade from Black sample code, 36

false values. *See* true/false values

fields
C#, 78
data, 265
in structures, 212–13
modifiers, 213
objects, 145, 250
public and private, 213
width and height, 164

file directory, 70

file extensions, 22, 199. *See also*
Program cs. file
sound files, 117

Fixed Reaction Timer project, 131

flags, 153, 232–33

float type, 179, 187, 202, 265

floating-point numbers, 179,
181–82, 186, 202
double precision, 202–03

floating-point values, 181–83,
186–87

folders, 191–94

font
changing properties, 92–93
drawing, 89–92
files, 85–86

loading, 89
resource addition, 86–87

FontName, 92–93

for loops
added objects, 224
array subscripts in, 133–34
debugging, 99–100
drawing, 97
nesting, 152
neverending, 99–100
repeating statements, 97–99

foreach loop construction, 291, 325

forward (/) slash character,
comments and, 194, 241

foundIt, 152–53

fraction value, 179

fraction variable, 176–79

fractions, 174, 179, 181–82

framework, 5

fully qualified names, 196

G

game design, 254

game lobby, 319, 325–26

game objects, 256–57
as classes, 266–67
as structures, 266

game world data, 28–31

Game.ico, 69

gamepad
as input device, 21
Back button, 14, 33–34, 53, 56–57,
59, 331
classes, 46–47
controlling sound playback,
121–22
keyboards and, 53–54
movement control, 214–15
PC connection, 7
reading, 46–47
role selection, 322
Start Button, 106
status, 48–49
stopping a program, 14, 33–34
testing status, 49–50
USB (Universal Serial Bus), 21
vibration, 54–59
wireless, 7, 21, 57–58

GamePad class, 48–49, 55

GamePad Racer, 58–59

GamePadState class, 46

GamePadState structure, 48–50
button state, 49–50
IsConnected property, 110–11
Thumbsticks property, 214–15

game play, networked, 311

Gamer class, 317

gamer profiles, 313

GamerJoined property, 324
 GamerServicesComponent, 313–14
 gamertags, 311, 317–18, 325
 games
 classes and, 27
 creating in XNA Game Studio, 68
 deploying to devices, 18
 ending programs, 79
 playing the, 326
 programming, 22
 startup, 78
 stopping a, 53
 storing, 15
 GameSprites list, 291–92
 GameSpriteStruct structure, 212–13,
 216–17, 226, 251
 GameState, 244–45, 319–20
 GameThumbnail.png, 69
 garbage collector, 147, 198, 264
 generic methods, 75–76
 getPercentage method, 169–75
 GetPressedKey method, 143
 GetPressedKeys method,
 144–45, 149
 GetState method, 48–49
 Giant Clock project, 85, 95
 gozzinta operators, 26, 40, 96
 GPU (graphics processor unit), 79
 graphics, 66
 creating game, 190
 loading, 73
 sprite, 76
 graphics processor unit (GPU), 79
 GraphicsDevice, 81–82, 250
 GraphicsDevice class, 22, 27
 GraphicsDevice variable, 82
 zooming
 greater than (>) logical operator, 55
 grouping, 212–14
 Guide, 313, 317–18, 321

H

header, method. *See* method header
 hierarchies, class, 266–67
 base (key word) in, 273
 building, 269
 constructors in, 284
 high score
 code, 88–89
 namespaces, 196
 high-resolution images, 66
 hitting. *See* breakpoints; collisions
 Home key, 313–14, 316
 host system, 326
 role selection, 322
 waiting for, 325
 hostSessionGamerJoined
 method, 323

I

I convention, 302
 icons, game program file, 69
 IDE (Integrated Development
 Environment), 6
 identifiers
 lowercase/uppercase letters in, 79
 method header, 170
 namespaces, 195
 refactoring, 201, 237–39
 variables, 25, 145
 if statements, 33–34. *See also*
 conditional statements
 blocks, 50
 else part, 39, 56
 testing, 49–50
 true/false values, 38
 image manipulation, 67, 163–68
 images, 65
 formats, 66–67
 high-resolution, 66
 lossy, 66
 percent calculation method,
 168–79
 placement on screen, 164
 retrieving, 73
 scaling, 77, 203–04
 sizing, 81–82
 sprite. *See* sprites
 storing, 66
 textures, 73–76
 transparent, 103
 zooming in, 163–64
 zooming out, 165–68
 Zune, 225
 Images directory, 192
 index, element, 133
 Initialize method
 instances in, 262
 overscan display, 208
 parameters and, 170
 rectangle, 78–79
 rectangle size, 170
 screen size, 201
 InOrder message, 328
 input, player, 45
 InputValue, 174
 installation, IDE and XNA, 6
 instances, 47
 array, 132–33
 new (key word), 145
 references to, 263–64
 int type, 265
 int variable, 106, 143, 148, 178
 integer type errors, 181
 integers, 132, 202
 Integrated Development
 Environment (IDE), 6
 Intellisense, 82–83, 241, 272

interfaces, 301–04
 behaviors and, 301
 implementation, 303
 Internet connection, 7
 Internet service provider (ISP), 309
 internetwork protocol (IP), 310
 Intersects method, 218
 IP (internetwork protocol), 311
 IsConnected property, 111
 IsDataAvailable property, 329–30
 isDeadly property, 271–72
 IsKeyDown method, 52, 142–43
 ISP (Internet service provider), 309
 ISpriteBasedGame, 302

J

JakeDisplay Bad Zoom Out sample
 code, 167–68
 JakeDisplay sample code, 80
 JPEG (Joint Photographic Experts
 Group) format, 66

K

key presses, 142–43
 key word, 145
 keyboards
 arrays, objects. and references,
 144–56
 gamepad and, 53–54
 keys type, 143–44
 PC, 7
 programming code, 52
 rollover, 142
 USB (Universal Serial Bus), 70, 141
 KeyboardState, 52
 KeyboardState structure, 143
 keyCount integer, 146
 keys
 character decoding, 155–56
 displaying, 149–50
 presses, detecting, 143, 151–54
 presses, registering, 142–43
 shift, 156
 keys type, 143, 156
 keys values, 156
 keyState variable, 143
 keyString, 156
 KeyViewer, 150
 KillerSprite Class, 286–88
 chase, 295
 random number generator, 288
 Kootenay, 87

L

layer++ update statement, 98
 layers, loop construction, 97–99

LED (light emitting diode), 307
 Length property, 146, 291
 less than (<) logical operator, 98
 level detectors, 109, 142
 life counter, 231–32
 light emitting diode (LED), 307
 links, adding to resources, 72–73
 list collection, 289–91
 Remove method, 292
 Load method, 75
 LoadContent method, 74–75, 78,
 193. *See also* Initialize method
 BatSpriteStruct, 251
 font loading, 89, 230–31
 sound cues, 119
 LoadGraphicsContent, 204
 loading screen, Xbox 360, 32
 lobby display, 319, 325–26
 local level networks, 310–11
 localhost, 329
 localization, 94
 LocalNetworkGamer reference, 328
 logical operators
 AND (&&), 109, 174
 greater than (>), 55
 less than (<), 98
 NOT (!), 124
 OR (|), 54, 109
 lookup tables
 arrays as, 136–37
 player, 136
 loops. *See also* for loops; also
 foreach loop construction
 do while and while, 99
 in Play method, 124
 lossy images, 66
 lowercase/uppercase letters
 identifiers, 79
 variables, 144

M

Main method, 194, 197
 parameters, 197–98
 XNA game, 198–99
 Math class, 222
 media, streaming, 310
 MediaPlayer class, 125–26
 members, class, 29–31, 270
 memory
 allocation, 147
 data storage, 31
 object storage, 24, 145–49
 overflow, 35–36
 Message Board project, 141, 158
 message boards, 141
 messages
 addressing, 308
 objects and, 256–57
 on computer networks, 308–09

 routing, 309
 settings, 328
 method body, 169–71
 getPercentage method, 174–75
 method header, 170
 getPercentage method, 172
 methods, 22–23, 31, 145. *See also*
 specific methods
 adding to game class, 169–70
 calling, 170–71
 generic, 75
 organization of, 256
 overriding, 269, 272
 parameters, 197–98
 percent calculation, 169–75
 public, 251
 renaming, 236–39
 static, 197
 testing, 172–74
 microphone, sound recording, 115
 Microsoft .NET Framework
 DateTime structure, 93–94
 random and pseudorandom
 numbers, 286
 Microsoft Cross-Platform Audio
 Creation Tool (XACT), 115, 124
 Microsoft Paint, 67
 Microsoft Visual C# 2008 Express
 edition, 6
 Microsoft Visual Studio, 10
 debugging using, 60
 Intellisense, 82–83, 241, 272
 toolbars, 14
 Microsoft Windows PC Game.ico, 69
 mistakes. *See* errors
 Mob Reaction Timer project, 127
 modifiers, 213
 MoodLight project, 12–13
 code for, 40–41
 movement, controlling, 206,
 222–23, 273–74
 Thumbsticks property, 214–15
 MP3 sound files, 117, 125
 multiplayer games, 110–14, 311–13
 multiplication operator (*), 174
 music, playing, 125–26
 musicInstance variable, 122–24
 MyAge class, 147–48
 MySprite class, 278–80

N

namespaces, 195–96
 fully qualified names, 196
 high score, 196
 identifiers, 195
 narrowing, 180–81, 202
 nesting, for loops, 152
 Networked Pong Game, 331
 new (key word)

 array creation, 133, 262
 instances, 145
 newline character, 157–58
 Next method, 287–88
 None message, 328
 NOT (!) logical operator, 124
 NOW property, 93–94
 nowColor, 101–02
 null references, 121, 123, 262
 numbers. *See* floating-point
 numbers; fractions; integers

O

objects, 145, 250
 adding, 211, 223
 connecting, 253
 container, 257–59
 creating, 201
 designing interactions of, 256
 game. *See* game objects
 graphical. *See* sprites
 linking, 254–56, 304
 removing unwanted, 147
 oldKeys array reference, 151–54
 oldKeyState variable, 143, 148, 154
 operand, 34
 operators, 174
 comparison, 40, 49–50
 defined, 34
 gozzinta, 26, 40, 96
 logical. *See* logical operators
 OR (|) logical operator, 54, 109
 organization
 in XNA Game Studio, 191–94
 programming, 257
 out parameter, 329
 overflow, 35–36
 overscan, display, 83, 206–08

P

PacketReader class, 327, 329
 PacketWriter class, 327
 Paint.NET, 67, 190
 pan, sound, 124
 parameters
 argument, 197–98
 defined, 48–49
 Initialize method, 170
 out, 329
 value and reference, 216–17
 parent class, 266–67, 269
 abstract, 279–80
 constructors, 284–85
 pausing, 122–23
 PC
 gamepad, 7
 localization, 94
 networking to Xbox 360, 311

- running XNA games, 313
 - sign in for networked play, 313–14
 - System Link, 311
 - Xbox connection, 10
 - Zune connection, 10
 - peer-to-peer network play, 326
 - percent calculation method, 168–79
 - picture display, 65–67
 - picture elements. *See* pixels
 - Pictures directory, 70
 - Pipeline, Content Management, 73
 - pitch, 124
 - pixels, 66, 77
 - platforms, selecting, 18
 - Play method, 120–21
 - looping, 124
 - MediaPlayer class, 125
 - play mode, 144
 - playback control, sound, 121
 - MediaPlayer class, 125–26
 - parameters, 124
 - pausing, 122–23
 - starting, 121–22
 - player, role selection, 325
 - PlayingAsHost state, 326
 - PlayingAsPlayer state, 326
 - playingGame state, 244–45
 - PNG (Portable Network Graphics)
 - format, 66
 - preprocessor, compiler, 113
 - pressedKeys array reference,
 - 145–48, 151–54
 - pressedKeys variable, 147, 152–53
 - pressedKeys.length, 146
 - pressedKeys[i], 156
 - private (key word), 213, 251
 - class members, 270
 - profiles, gamer, 314–17
 - Program.cs file, 194–95
 - programming, 3–4, 22
 - breaking down complicated tasks, 168
 - ego and, 282
 - problems. *See* bugs; debugging; errors
 - programs, computer, 15, 21
 - progression, 232–34
 - project directory, 70
 - project file
 - in XNA Game Studio, 69
 - project templates, 11
 - projects
 - adding resources, 86
 - copying, 15–16
 - creating, 10–12
 - empty, 14
 - organizing, 191–92
 - running, 12–14
 - stopping, 14
 - properties, 93, 145, 294–95
 - protected (key word), 270
 - protocols, 308, 310
 - pseudorandom numbers, 287
 - public (key word), 213, 251
 - class members, 270
- ## R
- radio signals, 307
 - Random class, 287
 - random numbers, 286–88
 - reaction timer, 127
 - real numbers. *See* floating-point numbers
 - ReceiveData method, 329
 - rectangle class, collisions and, 218
 - Rectangle instance, 81–82
 - Rectangle structure, 78
 - Rectangle type
 - creating, 76–78
 - Intersects method, 218
 - rectangles, drawing, 163–68
 - Red Screen of Anger sample
 - code, 24
 - ref modifier, 217, 329
 - refactoring, 200–01
 - changing identifiers, 201, 237–39
 - creating methods from code, 236–37
 - reference, 123, 146
 - font file, 85–86
 - to parent/child classes, 281
 - Reference changes, 238
 - reference parameters, 216–17
 - reference types, 145, 149, 265
 - reference variables, 147–48
 - in classes, 261–62
 - references, 68
 - adding, 88
 - array, 132–33
 - classes and, 263
 - in programs, 264–65
 - interface, 303
 - multiple to an instance, 263
 - no, to an instance, 264
 - to abstract parent classes, 280–81
 - to methods, 323
 - regions, code, 240–41
 - registering key presses, 142, 151
 - Reliable message, 328
 - ReliableInOrder message, 328
 - Remove method, 157, 292
 - renaming methods, 236–39
 - resources, 73
 - adding, 70
 - adding as copies, 70–72
 - adding as links, 72–73
 - sharing, 72
 - results, 96
 - return (key word), 171
 - returning nothing, 171
 - role selection, 322, 325
 - roles, in network play, 322
 - selecting, 325
 - rollover, 142
 - Run method, 199
 - running a program, 12–14
- ## S
- scanning, arrays, 134–35
 - scores, 274–75
 - adding, 229
 - displaying, 135–37, 230–31
 - setting, in StartGame method, 275
 - screen size
 - filling, 81, 201
 - title, 243
 - SDK (Software Development Kit), 5
 - Secret Vibration messages, 57–58
 - seed value, 287, 289
 - SelectingRole state, 322
 - semicolon (;)
 - extra, 61
 - in statements, 23
 - SendData method, 328–29
 - server, 326
 - set behavior, 294–95
 - setupScreen method, 208
 - setupSprite method, 216
 - array creation, 224
 - sprite visibility, 226–27
 - SetVibration method, 55–58
 - Shadow Clock project, 101–03
 - shadow effect, 101–03
 - shadows, creating, 101–03
 - shift keys, 156
 - sign in, network play
 - automatic, 316
 - creating a profile, 314–16
 - state, 321
 - signals, data, 307
 - signature, 170
 - SignedInGamers, 317–18
 - Silver Xbox Live, 7
 - sizing
 - fonts, 92–93
 - images, 81–82
 - sprites, 77, 201, 203
 - Software Development Kit (SDK), 5
 - Solution Explorer, 22, 69, 191, 199
 - solution file, in XNA Game Studio,
 - 68–69
 - Song value, 125
 - sound, 115, 124
 - adding game, 298–300
 - background music, 125–26
 - capturing, 115–16

- copyright law, 116
- file types, 117, 125
- playing, 120–21
- storing, 117–19
- XACT (Microsoft Cross-Platform Audio Creation Tool), 124
- sound playback, 121
 - pausing, 122–23
 - starting, 121
- SoundEffect variable type, 119
- SoundEffectInstance, 121–22
- SoundInstance class, 122–23
- source code. *See also* code
 - compilation, 13–14
 - renaming, 239
- spacing, objects, 224
- SpriteBatch class, 79–80
- spriteBatch variable, 79–80
- SpriteFont, 87, 89
- sprites, 201
 - drawing, 79–80
 - moving, 204–06
 - positioning, 76–79
 - sizing, 77, 201, 203
 - tinting, 83–84
- Starter Kits, 11
- StartGame method, 259
 - DeadlySprite class, 271–72
 - setting scores in, 275
- starting values, changing, 41–42
- StartUp Project, 16–18
- state machines, 245–47
- State property, in MediaPlayer class, 126
- state, game
 - changes, 244–45
 - enumerated types, 244–45
 - network games, 319
- statements, 23, 277
 - blocks, 50
 - blocks and, 23
 - call, 34, 37
 - conditional. *See* conditional statements
 - Draw method, 23–24
 - empty, 61
 - repeating, 97–99
 - switch, 156
- static classes, 196–97, 288
- static methods, 222
- stopping, game activity, 14, 53
- storing
 - floating-point numbers, 179
 - keys type, 143
 - programs, 15
- stretching images, 164, 167–68
- strings
 - control characters, 157
 - drawing multiple text, 95
 - message, 149–50

- structures, 24, 212, 260–61
- subscript, element, 133, 146, 290
- survival, adding, 231–32
- switch statement, 156
- symbols, test, 113–14
- synchronization, 328
- System Link, 311–12
- System namespace, 195

T

- target collections, 258–59
- TargetRowStruct, 258
- TargetVisibility, 258
- TCP (Transport Control Protocol), 311
- TCP/IP protocol, 311
- television screens, overscan display, 206–07
- tempAge variable, 148
- templates, 241, 280
- test symbols, 113–14
- test-driven development, 172
- testing
 - code for, 111–14
 - costs, 114
 - design, 173
 - getPercentage method, 172–75
 - importance of, 154
 - method, 172–75
 - multi-player game, 112–14
 - timer code, 131
 - values, 39–40
 - vibration intensity, 55
- text
 - /y1as a/y0 resource, 85–86
 - creation, 3-D, 95–99, 101–03
 - decoding, 155–57
 - drawing, in game, 230–31
 - editing, 157–58
 - layout control, 157–58
 - reading, from a keyboard, 142–43
 - strings, drawing multiple, 95–101
- Texture2D type, 73–75, 149
- textures, 223
 - background, 242–43
 - loading, 73–74
 - name errors, 76
- this (key word), 255–56
- Thumbsticks property, 214–15
- ticks, 205
- time and date values, 93–94
- timer creation, 127–30, 331
 - arrays, 132–37
- timer variable, 127
- title screens, 243–45, 259, 320
- TitleSprite, 268, 284–85
- TitleUpdate, 247
- TODO comment, 23, 79
- ToLongDateStringMethod, 94
- ToLongTimeStringMethod, 94

- ToLower method, 157
- toolbars, Visual Studio, 14
- ToShortDateStringMethod, 94
- ToShortTimeStringMethod, 94
- ToString method, 94, 150
- ToUpper method, 157
- transparent images, 103
- transparent colors, 97, 101–03
- Transport Control Protocol (TCP), 311
- true/false values, 35, 39–40. *See also* conditional statements
- truncation, 202
- type-safe, 323

U

- Ultimate Mood Light sample code, 42
- Undo command, 239
- Universal Serial Bus (USB), 70
 - gamepad, 21
 - keyboards, 141
- UnloadContent method, 78–79
- Update behavior, 211
 - DeadlySprite class, 273
 - TitleSprite, 268
- Update method
 - BatSpriteStruct, 251
 - call statements, 37
 - DeadlySprite class, 274
 - display program, 164
 - for added objects, 224
 - game world data, 28–29
 - gamepad and keyboard, 53–54
 - Gamepad Racer, 58–59
 - gamepad status, 49–51
 - GetPressedKeys method, 149
 - keys, 149
 - life counter, 231–32
 - on network, 325
 - overview, 27–28
 - scoring, 229
 - state changes, 107–09
 - timers, 127–30
 - TitleSpriteStruct method, 259
 - using member variables, 33–34
 - vibration intensity, 55–56
 - width and height, 166
 - winners, 137
 - XNA Game Studio, 28–29
- UpdateTitle method, 247
- updating variables, 96
- uppercase/lowercase letters
 - identifiers, 79
 - variables, 144
- USB (Universal Serial Bus)
 - gamepad, 21
 - keyboards, 70, 141
- user display, 317

user profiles, 314–16
 using (compiler directive), 195–96,
 198, 208, 222
 using (key word)
 in C# program, 197–98
 with directives, 196
 using statement, 198

V

value parameters, 216–17
 value types, 145, 148–49,
 265–66, 283
 values
 changing starting, 41–42
 relationship to structures, 212
 testing, 39–40
 variable types, 119
 variables, 73, 217, 277
 declaring, 24–25
 in structures, 213
 local, 28
 lowercase/uppercase letters, 144
 reference, 147
 types of, 25
 unused, 50
 updating, 96
 viewing, 176
 vectors, 89–91
 vibration, 54–59
 Viewport, 81–82
 virtual method, 269
 visibility
 controlling, 226–28
 sprite, 226–27
 Visible field, 226–28
 Visual C# 2008 Express edition.
 See Microsoft Visual C# 2008
 Express edition
 Visual Studio. *See* Microsoft
 Visual Studio
 void type, 171
 volume, 124

W

WaitingAsPlayer state, 325–26
 warnings. *See also* bugs; also errors
 compiler, 38–39
 debugging using, 60–61
 WAV files, 120, 125
 Drum Pad project, 120
 while loop construction, 99
 Width property, 184
 WiFi, 311
 Windows Bitmap (BMP) format, 66

Windows Media Player, 118
 Windows PCs. *See* PC
 Windows Vista, 7
 Windows XP, 7
 WinnerName variable, 138
 winners
 determining, 132–38
 displaying, 137
 winnerSubscript variable, 136
 WinnerSubscript variable, 136–37
 winningValue variable, 135, 138
 wire connections, 312
 WMA files, 117, 125
 wraparound values, 35
 Write method, 328

X

X coordinate, 76–77, 89–92, 221
 XACT (Microsoft Cross-Platform
 Audio Creation Tool), 115, 124
 Xbox 360, 7
 adding to XNA Game Studio
 Device Center, 8
 gamepad. *See* gamepad
 GameThumbnail.png, 69
 image requirements, 66
 keyboard and, 52
 memory capacity, 31
 multiple player sign ins, 317
 networking to Windows PCs, 311
 pixels, 77
 running XNA games, 12
 sign in, using XNA Game
 Studio, 313
 Xbox Live, 311
 XML (Extensible Markup Language)
 file format, 88–89, 92–93
 XNA Creators Club. *See* Creators
 Club, XNA
 XNA Framework, 6, 117, 124
 XNA Game Studio, 22
 content, 68
 creating a project in, 10–13
 debugging in, 220
 Draw method, 28–29
 GamerServicesComponent,
 313–14
 GraphicsDevice, 81–82
 Implement Class option, 278–79
 Intellisense, 82–83, 272
 keyboard, 141
 Kootenay, 87
 Main method, 198
 managing gamer profiles, 313
 MediaPlayer class, 125

organization, 191–92
 PacketReader class, 327
 PacketWriter class, 327
 Program.cs file, 194–95
 projects, 191
 reading text from a keyboard,
 142–43
 refactoring, 200–01, 236–39
 sign in, for networked play, 321
 Solution Explorer, 69
 solutions, 191
 stopping a program, 14
 templates, 241
 Undo command, 239
 Update method, 28–29
 XNA Game Studio Connect, 7–8,
 10, 12
 XNA Game Studio Device Center,
 8, 10
 XNA Game Studio
 breakpoints, 175
 check, 6
 continue button, 177

Y

Y coordinate, 76–77, 89–92,
 215, 221
 Yellow Screen of Peril sample
 code, 27

Z

zero, setting gamepad to, 106
 zoom
 from center, 184–86
 in, images, 163–64
 out, images, 165–68
 stopping, 184
 zoom path behavior, 168
 Zune, 4, 7–8, 321
 adding to XNA Game Studio
 Device Center, 8
 button programming, 51
 connecting to Windows PC, 10
 drum sounds, 119
 game sounds on, 300
 GameThumbnail.png, 69
 image requirements, 66, 80
 image sizing, 225
 image storage in, 72
 multiple user profiles on, 318
 network games, 331
 running a program, 12
 System Link and, 311–12
 wireless adapter, 331

About the Author

Rob Miles



I wrote my first computer game on the original Commodore PET in Microsoft Basic, having learned to program some time before that at school, where I began by writing my first programs on cards using a hand punch, posting them off to a distant mainframe, and getting a message back (two weeks later) that I'd omitted a semicolon. A good many years have gone by since then. I'm still omitting semicolons, but the turnaround has improved quite a bit. I've been at the University of Hull in the United Kingdom for over 25 years now, moving from the Computer Center to Electronic

Engineering to Computer Science departments where I teach programming (in C#, of course) and software engineering, amongst other subjects. In my time, I've also had a hand in quite a few industrial projects, and it is a matter of great personal pride to be the man who wrote the software that puts the date stamps on Budweiser beer cans, among many other products. I've also been known to turn out bad verse, the highlight of this being a whole page of poetry for the *Independent* newspaper in Britain. I'm a Microsoft Most Valuable Professional (MVP) for embedded devices, and I live happily in East Yorkshire with number-one wife Mary (she calls me "husband zero"). Number-one children David and Jenny return home every now and then so that we can play happy families properly. You can find out more about my interesting life at <http://www.robmiles.com>.

What's Next?

If you have made it this far, well done! At this point you know enough to write and run XNA games. So now is the time to take your skills to the next level and start to make a name for yourself. By now you should be a member of the Creators Club. If not you can join at creators.xna.com. If you want to deploy games to your Xbox 360 you will have to upgrade your club membership. If you are a student there are lots of ways you can do this for free. Start by taking a look at project DreamSpark at www.dreamspark.com. You can find all kinds of good stuff there, including copies of Visual Studio 2008 Professional edition. You can also get a free one year Trial membership of the XNA Creators Club which lets you run XNA games on your Xbox but doesn't let you distribute games via Xbox Live. If you are not a student you can also get a Trial membership by entering the Dream-Build-Play contest at www.dreambuildplay.com.

And don't forget that your C# expertise can be applied in lots of other ways too. Find out how you can control robots using Microsoft Robotics Studio from www.microsoft.com/robotics/. The Academic version of this development environment is a free download, and it is based on the familiar Visual Studio environment. If you want to create web based C# business applications (or perhaps even games) for use by anyone with a browser, get hold of Visual Web Developer which is another free download at www.microsoft.com/express/vwd/. Finally, if really small devices are your thing, take a look at the embedded development possibilities of the .NET Micro Framework, a free download that lets you put your C# code into tiny platforms. Find out more at www.microsoft.com/netmf. And remember that the copy of Visual Studio you already have on your system can also create fully fledged applications that can run on Windows PCs.

At the start of the book I said that programming lets you bring your ideas to life. I hope that by now you have seen how this is true, and I wish you all the best in taking your ideas and making great programs out of them.

Rob Miles

