

The
Pragmatic
Programmers

Android
1.5 to 2.1

Hello, Android

Introducing Google's Mobile
Development Platform

Third Edition

Edited by Susannah Davidson Pfalzer

Ed Burnette

ANDROID





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► **Andy & Dave**

Hello, Android

Introducing Google's Mobile Development Platform, 3rd Edition

Ed Burnette

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Changes in the Beta Releases

Beta 5—April 20

The final draft of the book is now complete.

Beta 4—March 31

The Compatibility chapter (Chapter 13, *Write Once, Test Everywhere*, on page 259) has been expanded with information on how to handle API differences between versions of Android. I also addressed all errata except for typesetting issues. The first draft of the book is now complete.

Beta 3—March 12

This beta finishes up the Home screen chapter (Chapter 12, *There's No Place Like Home*, on page 236) with an entirely new section and example on Live Wallpaper. Note that the wallpaper example will only run on Android 2.1 phones that support Live Wallpaper, which right now means it will only run on the Nexus One. Of course, it runs fine in the emulator too.

Beta 2—February 24

This new beta includes a chapter on multi-touch (Chapter 11, *Multi-touch*, on page 223). It wasn't until I dug deeper into the API and wrote the example that I realized how hard the interface is to use. Hopefully this chapter will make it a bit more approachable so more developers can use it despite all the problems in the implementation.

Beta 1—February 10

The first beta of Hello, Android 3e is now available. We decided to put out betas while new content was being written so we could get your feedback early. Besides, if you're targeting Android versions 2.0 and 2.1 you need the info right now. Because this is a beta, keep in mind it's incomplete and subject to change.

For Beta 1, I started with the final version of the 2nd edition and updated it for 2.0 and 2.1. Some of the changes were minor—for example I had to retake most of the screenshots (fun, fun). Other changes took a bit longer. In particular, the book was changed to:

1. Reflect new tools. The Quick Start chapter was redone to reflect Google's reorganization of the Android SDK tools. Now the SDK comes in two parts: the starter package and the platform package(s). You install the starter package first, run the Android SDK and AVD Manager, and let it install the platforms you wish to support.
2. Fix broken examples. I got my new Motorola Droid phone with Android 2.0 and discovered the Audio, OpenGL, and Widget examples didn't work right. So those have been redone so they're compatible with all versions from 1.5 to 2.1 (and hopefully beyond). For Audio, I switched to using just one MediaPlayer. For OpenGL, I moved the texture image into a different directory so it wouldn't get stretched on high-density displays, and for Widget, I made it into a Date widget instead of a Time widget to reflect slower updates enforced starting in 1.6.
3. Apply your feedback. There were a few errata in the 2nd edition that I fixed, of course, but more importantly, every time somebody has a problem understanding a section in the book I go back and look at how I could explain it better. Your feedback here in the forums is very important, so keep it coming!

Missing from the first beta are the chapters on multi-touch and live wallpaper. Those will be added in betas 2 and 3, respectively. (You may see something about gestures in Beta 1 but I plan to remove that because I don't think many people will need it.)

Acknowledgments

I'd like to thank the many people who made this book possible, including the readers of the previous editions for all their great suggestions; my editor Susannah Pfalzer for her attention to detail; Javier Collado, Marilynn Huret, and Staffan Nöteberg for providing valuable review comments, and especially Lisa, Michael, and Christopher for their continued patience and support.

Preface

Android is an open source software toolkit for mobile phones that was created by Google and the Open Handset Alliance. It's inside millions of cell phones and other mobile devices, making Android a major platform for application developers. Whether you're a hobbyist or a professional programmer, whether you are doing it for fun or for profit, it's time to learn more about developing for Android. This book will help you get started.

What Makes Android Special?

There are already many mobile platforms on the market today, including Symbian, iPhone, Windows Mobile, BlackBerry, Java Mobile Edition, Linux Mobile (LiMo), and more. When I tell people about Android, their first question is often, Why do we need another mobile standard? Where's the "wow"?

Although some of its features have appeared before, Android is the first environment that combines the following:

- *A truly open, free development platform based on Linux and open source:* Handset makers like it because they can use and customize the platform without paying a royalty. Developers like it because they know that the platform "has legs" and is not locked into any one vendor that may go under or be acquired.
- *A component-based architecture inspired by Internet mashups:* Parts of one application can be used in another in ways not originally envisioned by the developer. You can even replace built-in components with your own improved versions. This will unleash a new round of creativity in the mobile space.
- *Tons of built-in services out of the box:* Location-based services use GPS or cell tower triangulation to let you customize the user experience depending on where you are. A full-powered SQL database

lets you harness the power of local storage for occasionally connected computing and synchronization. Browser and map views can be embedded directly in your applications. All these built-in capabilities help raise the bar on functionality while lowering your development costs.

- *Automatic management of the application life cycle:* Programs are isolated from each other by multiple layers of security, which will provide a level of system stability not seen before in smart phones. The end user will no longer have to worry about what applications are active or close some programs so that others can run. Android is optimized for low-power, low-memory devices in a fundamental way that no previous platform has attempted.
- *High-quality graphics and sound:* Smooth, antialiased 2D vector graphics and animation inspired by Flash are melded with 3D accelerated OpenGL graphics to enable new kinds of games and business applications. Codecs for the most common industry-standard audio and video formats are built right in, including H.264 (AVC), MP3, and AAC.
- *Portability across a wide range of current and future hardware:* All your programs are written in Java and executed by Android's Dalvik virtual machine, so your code will be portable across ARM, x86, and other architectures. Support for a variety of input methods is included such as keyboard, touch, and trackball. User interfaces can be customized for any screen resolution and orientation.

Android offers a fresh take on the way mobile applications interact with users, along with the technical underpinnings to make it possible. But the best part of Android is the software that you are going to write for it. This book will help you get off to a great start.

Who Should Read This Book?

The only requirement is a basic understanding of programming in Java or a similar object-oriented language (C# will do in a pinch). You don't need any prior experience developing software for mobile devices. In fact, if you do, it's probably best if you try to forget that experience. Android is so different that it's good to start with an open mind.

What's in This Book?

Hello, Android is divided into four parts. Roughly speaking, the book progresses from less advanced to more advanced topics, or from more common to less common aspects of Android.

Several chapters share a common example: an Android Sudoku game. By gradually adding features to the game, you'll learn about many aspects of Android programming including user interfaces, multimedia, and the Android life cycle.

In Part I, we'll start with an introduction to Android. This is where you'll learn how to install the Android emulator and how to use an integrated development environment (IDE) to write your first program. Then we'll introduce a few key concepts like the Android life cycle. Programming in Android is a little different from what you're probably used to, so make sure you get these concepts before moving on.

Part II talks about Android's user interface, two-dimensional graphics, multimedia components, and simple data access. These features will be used in most programs you write.

Part III digs deeper into the Android platform. Here you'll learn about connecting to the outside world, location-based services, the built-in SQLite database, and three-dimensional graphics.

Part IV wraps things up with a discussion on using advanced input techniques including multi-touch, and extending your home screen with widgets and live wallpaper. Finally, we'll explore making your app compatible with multiple Android devices and versions, and then publishing it on the Android Market.

At the end of the book, you'll find an appendix that covers the differences between Android and Java Standard Edition (SE), along with a bibliography.

What's New in the Third Edition?

The third edition has been updated to support all versions of Android from 1.5 up through 2.1 and beyond. Here's a summary of the new features introduced in each version, and the corresponding sections that cover those features.

New for Cupcake

Android 1.5 (Cupcake) introduced a large number of enhancements to the Android platform including support for soft (on-screen) keyboards, video recording, and application widgets. Under the covers, there were more than 1,000 changes to the Android API between 1.1 and 1.5.¹ Widgets are covered in Section 12.1, *Hello, Widget*, on page 236.

New for Donut

Android 1.6 (Donut) added support for high- and low-density displays, plus a number of minor changes that don't affect most developers.² You can learn how to support these different device form-factors in Section 13.5, *All Screens Great and Small*, on page 270

New for Eclair

Android 2.0 (Eclair) added support for multi-touch, virtual keys, centralized account management, synchronization APIs, docking, HTML5, and more.³ The 2.0 version was quickly replaced by Android 2.0.1 (also called Eclair), which contains all the changes in the 2.0 version plus a few bug fixes.⁴ Multi-touch is covered in Chapter 11, *Multi-touch*, on page 223.

New for Eclair MR1

Android 2.1 (Eclair Maintenance Release 1) added support for live wallpapers, more HTML5 support, and other minor improvements.⁵ Home screen enhancements, including live wallpapers and widgets, are covered in Chapter 12, *There's No Place Like Home*, on page 236.

New for FroYo and beyond

The next version of Android is code named “FroYo” (for Frozen Yogurt). There is no telling what culinary delights it will contain, but be sure to stop by the website for this book, <http://pragprog.com/titles/eband3>, for the latest information.

Android 1.5 (or later) is now available for all shipping Android devices. All new devices have it installed, and Google says that almost all older

-
1. http://d.android.com/sdk/api_diff/3/changes.html
 2. http://d.android.com/sdk/api_diff/4/changes.html
 3. http://d.android.com/sdk/api_diff/5/changes.html
 4. http://d.android.com/sdk/api_diff/6/changes.html
 5. http://d.android.com/sdk/api_diff/7/changes.html

devices have upgraded. See the Android Device Dashboard⁶ for the latest market share of active Android devices in the wild. This edition of the book does not cover version 1.1 or earlier.

Note: It may be a while before all devices are upgraded to to the latest version of Android (if ever), so Chapter 13, *Write Once, Test Everywhere*, on page 259 covers how to create a single program that supports multiple versions. All the examples in this book have been tested on versions 1.5 through 2.1.

Online Resources

At the website for this book, you'll find the following:

- The full source code for all the sample programs used in this book
- An errata page, listing any mistakes in the current edition (let's hope that will be empty!)
- A discussion forum where you can communicate directly with the author and other Android developers (let's hope that will be full!)

You are free to use the source code in your own applications as you see fit. Note: If you're reading the e-book, you can also click the little gray rectangle before the code listings to download that source file directly.

Fast-Forward >>

Although most authors expect you to read every word in their books, I know you're not going to do that. You want to read just enough to let you get something done, and then maybe you'll come back later and read something else to let you get another piece done. So, I've tried to provide you with a little help so you won't get lost.

Each chapter in this book ends with a "Fast-Forward >>" section. These sections will provide some guidance for where you should go next when you need to read the book out of order. You'll also find pointers to other resources such as books and online documentation here in case you want to learn more about the subject.

So, what are you waiting for? The next chapter—Chapter 1, *Quick Start*, on page 21—drops you right into the deep end with your first Android

6. <http://d.android.com/resources/dashboard/platform-versions.html>

program. Chapter 2, *Key Concepts*, on page 34 takes a step back and introduces you to the basic concepts and philosophy of Android, and Chapter 3, *Designing the User Interface*, on page 48 digs into the user interface, which will be the most important part of most Android programs.

Your ultimate goal will be to make your apps available for sale or free download in the Android Market. When you're ready, Chapter 14, *Publishing to the Android Market*, on page 272 will show you how to take that final step.

Part I

Introducing Android

Chapter 1

Quick Start

Android combines the ubiquity of cell phones, the excitement of open source software, and the corporate backing of Google and other Open Handset Alliance members like Motorola, HTC, Verizon, and AT&T. The result is a mobile platform you can't afford *not* to learn.

Luckily, getting started developing with Android is easy. You don't even need access to an Android phone—just a computer where you can install the Android SDK and phone emulator.

In this chapter, I'll show you how to get all the development tools installed, and then we'll jump right in and create a working application: Android's version of "Hello, World."

1.1 Installing the Tools

The Android software development kit (SDK) works on Windows, Linux, and Mac OS X. The applications you create, of course, can be deployed on any Android devices.

Before you start coding, you need to install Java, an IDE, and the Android SDK.

Java 5.0+

First you need a copy of Java. All the Android development tools require it, and programs you write will be using the Java language. JDK 5 or 6 is required.

It's not enough to just have a runtime environment (JRE); you need the full development kit. I recommend getting the latest Sun JDK SE 6.0

update from the Sun download site.¹ The 32-bit version seems to work best (see sidebar). Mac OS X users should get the latest version of Mac OS X and the JDK from the Apple website.

To verify you have the right version, run this command from your shell window. Here's what I get when I run it:

```
C:\> java -version
java version "1.6.0_14"
Java(TM) SE Runtime Environment (build 1.6.0_14-b08)
Java HotSpot(TM) Client VM (build 14.0-b16, mixed mode, sharing)
```

You should see something similar, with version “1.6.something” or later.

Eclipse

Next, you should install a Java development environment if you don't have one already. I recommend Eclipse, because it's free and because it's used and supported by the Google developers who created Android.

The minimum version of Eclipse is 3.3.1, but you should always use whatever is the most up-to-date production version. Go to the Eclipse downloads page,² and pick “Eclipse IDE for Java Developers.” Note that you need more than just the standard Eclipse SDK “classic” platform. Download the package into a temporary directory, unpack it (usually this is just a matter of double-clicking on it), and move the entire unpacked directory to a permanent location (like C:\Eclipse on Windows or /Applications/Eclipse on Mac OS X).

If you don't want to use Eclipse (there's always one in every crowd), support for other IDEs such as NetBeans and JetBrains IDEA is available from their respective communities. Or if you're really old-school, you can forgo an IDE entirely and just use the command-line tools.³ The rest of the book will assume you're using Eclipse so if you're not, you'll need to make adjustments as necessary.

Android SDK Starter Package

Starting with Android 2.0, the Android SDK has been broken into two parts: the SDK Starter Package and SDK Components. First, use your web browser to get the starter package. The Android download page⁴

1. <http://java.sun.com/javase/downloads>

2. <http://www.eclipse.org/downloads>

3. See <http://d.android.com/guide/developing/tools/index.html> for documentation on the command-line tools.

4. <http://d.android.com/sdk>

32-bit vs. 64-bit

If you're using a 64-bit version of Windows you may be tempted to install the 64-bit version of the Java Development Kit instead of the 32-bit version. Unfortunately, Eclipse does not currently provide a 64-bit version of the Eclipse IDE for Java Developers package (see bug 293969).^{*} There is a workaround (unzip the main package first and then unzip the 64-bit "classic" platform on top of that), but unless you really need 64-bit Java it's easier to just use the 32-bit version of the JDK for now. Hopefully a 64-bit package will be available in the next release of Eclipse so this whole problem will go away.

^{*}. https://bugs.eclipse.org/bugs/show_bug.cgi?id=293969

has packages for Windows, Mac OS X, and Linux. After downloading the package that's right for you, unpack the .zip file to a temporary directory

By default, the SDK will be expanded into a subdirectory like `android-sdk-windows`. Move that subdirectory underneath a permanent directory such as `C:\Google` or `/Applications/Google`. Then make a note of the full path so you can refer to it later as your *SDK install directory*.

No special install program is needed for either Eclipse or the SDK, but I do recommend you add the SDK's bin directory to your PATH.

Android SDK Components

Next, invoke the SDK Setup program. On Windows, run `SDK Setup.exe`. On Linux and Mac OS X, run the `tools/android` program, select Available Packages, put a check mark next to every package, and click Install Selected.

The setup program will now display a list of available components including documentation, platforms, add-on libraries, and USB drivers (see Figure 1.1, on the following page). Select Accept All and then click Install. All the components listed will be downloaded and installed into your SDK install directory. Note: this can take a long time to complete. To make it go faster, you can accept or reject the individual components separately instead of installing them all.

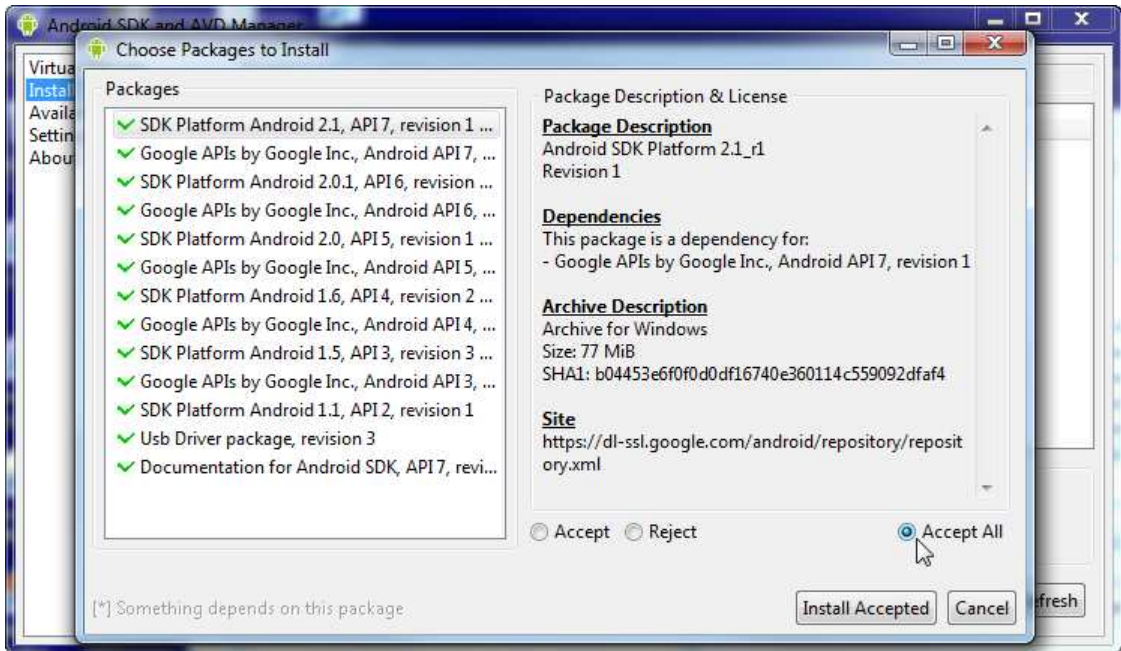


Figure 1.1: Installing the Android SDK Components

If you get an HTTPS SSL error, then cancel the window and select Settings from the main SDK and AVD Manager window. Select the option to Force https:// sources to be fetched using http://, then click Save & Apply. Exit the setup program and start it again.

The next step is to start Eclipse and configure it.

Eclipse Plug-In

To make development easier, Google has written a plug-in for Eclipse called the Android Development Toolkit (ADT). To install the plug-in, follow these steps (note these directions are for Eclipse 3.5—different versions may have slightly different menus and options):

1. Start Eclipse by running `eclipse.exe` on Windows or `eclipse` on Mac OS X or Linux. If you're prompted for a workspace directory, just accept the default and click OK.

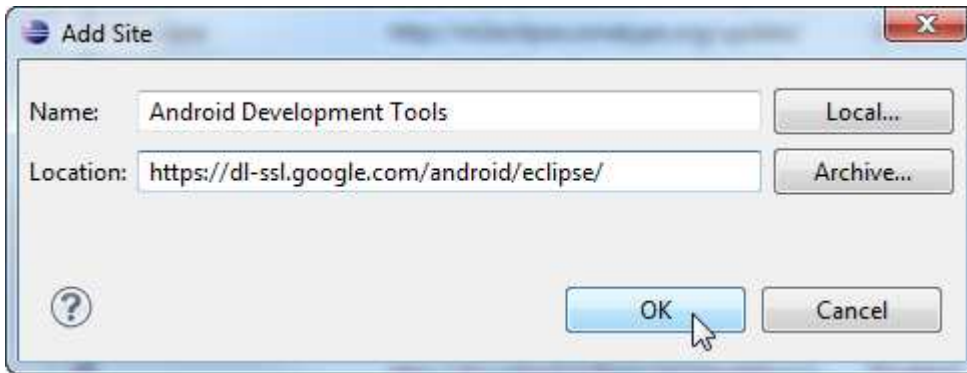


Figure 1.2: Installing the Android Development Toolkit

2. Select the Help menu and then select Install New Software.... (Help > Install New Software....) See the sidebar the *Joe Asks...* on page 27 if you get a connection error.
3. Click the Available Software Sites link in the dialog that appears.
4. Click the Add... button.
5. Enter the location of the Android Development Tools update site: <https://dl-ssl.google.com/android/eclipse/>.

Once you've filled it out, the dialog box should look like Figure 1.2.

6. Click OK to return to the Sites list, and click Test Connection to verify the site you just entered. If you have trouble with this address, try using **http** in the location instead of **https**. Once you're satisfied the address is correct, press OK again to return to the Install New Software dialog.
7. Type the word "android" in the Work With field and press Return. "Developer Tools" should now appear in the list below.
8. Select the checkbox next to Developer Tools, and then click Next. If you get an error message at this point, then you may not have the right version of Eclipse. I strongly recommend using either the prebuilt Eclipse IDE for Java or the Eclipse IDE for Java EE Development packages, version 3.5 or newer.

If you have a custom install of Eclipse, then to use the Android editors you will also need to install the Web Standard Tools (WST) plug-in and all its prerequisites.

See the Web Tools platform home page⁵ for more details and download links. These are already built into the recommended packages mentioned earlier.

9. Review the list of items to be installed, click Next again, accept the license agreements, and then click Finish to start the download and install process.
10. Once the install is done, restart Eclipse.
11. When Eclipse comes back up, you may see a few error messages because you need to tell it where the Android SDK is located. Select Window > Preferences > Android (Eclipse > Preferences on Mac OS X), and enter the SDK install directory you noted earlier. Click OK.

Whew! Luckily, you have to do that only once (or at least once every time a new version of ADT or Eclipse comes out). Now that everything is installed, it's time to write your first program.

1.2 Creating Your First Program

ADT comes with a built-in example program, or template, that we're going to use to create a simple "Hello, Android" program in just a few seconds. Get your stopwatch ready. Ready? Set? Go!

Select File > New > Project... to open the New Project dialog box. Then select Android > Android Project, and click Next.

Enter the following information:

```
Project name: HelloAndroid
Build Target: Android 2.1
Application name: Hello, Android
Package name: org.example.hello
Create Activity: Hello
Min SDK Version: 7
```

When you're done, it should look something like Figure 1.3, on page 28.

5. <http://www.eclipse.org/webtools>



Joe Asks...

It Says “Connection Error,” So Now What?

If you get a connection error, the most likely cause is some kind of firewall erected by your system administrators. To get outside the firewall, you’ll need to configure Eclipse with the address of your proxy server. This is the same proxy server you use for your web browser, but unfortunately Eclipse isn’t smart enough to pick up the setting from there.

To tell Eclipse about the proxy, select Window > Preferences > General > Network Connections (Eclipse > Preferences on Mac OS X), turn on the option for Manual proxy configuration, enter the server name and port number, and click OK. If you don’t see the option, you may be running an older version of Eclipse. Try looking under Preferences > Install/Update, or search the preferences for the word *proxy*.

Click Finish. The Android plug-in will create the project and fill it in with some default files. Eclipse will build it and package it up so it will be ready to execute. If you get an error about missing source folders, select Project > Clean to fix it.

OK, that takes care of writing the program; now all that’s left is to try running it. First we’ll run it under the Android Emulator.

1.3 Running on the Emulator

To run your Android program, go to the Package Explorer window, right-click the HelloAndroid project, and select Run As > Android Application. If you’re following along in Eclipse you may see an error dialog like the one in Figure 1.4, on page 29. This indicates we haven’t told the Emulator what kind of phone to emulate.

Creating an AVD


To do this, you need to create an Android Virtual Device (AVD), using either Eclipse or the `android avd` command.⁶ It’s easier to use Eclipse,

6. <http://d.android.com/guide/developing/tools/avd.html>

New Android Project

New Android Project

Creates a new Android Project resource.



Project name:

HelloAndroid

Contents

☒ Create new project in workspace

☐ Create project from existing source

☒ Use default location

Location:

C:/Development/workspace/HelloAndroid

Browse...

☐ Create project from existing sample

Samples:

ApiDemos

Build Target

Target Name	Vendor	Platform	API...
<input type="checkbox"/> Android 2.0.1	Android Open Source Project	2.0.1	6
<input checked="" type="checkbox"/> Android 2.1	Android Open Source Project	2.1	7
<input type="checkbox"/> Google APIs	Google Inc.	1.5	3
<input type="checkbox"/> Google APIs	Google Inc.	1.6	4

Standard Android platform 2.1

Properties

Application name:

Hello, Android

Package name:

org.example.hello

☒ Create Activity:

Hello

Min SDK Version:

7

?

< Back

Next >

Finish

Cancel

Keeping Up with the Plug-In

The Android Eclipse plug-in is a work in progress that changes much more often than the Android SDK. The version you download may be different than the one I used when writing this book, and it may contain a few, shall we say, idiosyncrasies. I recommend you check the plug-in site monthly to pick up any new features and fixes.

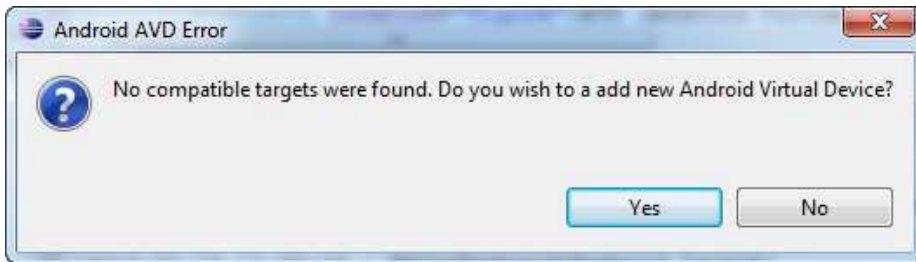


Figure 1.4: Missing Android Virtual Device (AVD)

so select Yes in the AVD Error dialog to open the AVD Manager. You can open the manager again later by selecting Window > Android SDK and AVD Manager.

Click on the New... button, then fill out the fields for the new AVD as follows:

Name: em21
 Target: Android 2.1 - API Level 7
 SDCard: 64
 Skin: Default (HVGA)

This tells Eclipse to set up a generic device called “em21,” which has the Android 2.1 (Eclair MR1) firmware installed. A 64MB virtual Secure Digital (SD) Card will be allocated, along with a half-VGA (320×480) display.

When you’re done you should see something like Figure 1.5, on page 31. Due to updates in the SDK tools since this was written your screen may look slightly different.

Cupcake vs. Donut vs. Eclair

The version of Android running on your emulator (or real phone) must be compatible with your program's Build Target. For example, if you try to run an Android 2.1 (Eclair MR1) program on an Android 1.5 (Cupcake) phone, it won't work because Android 1.5 phones can only run 1.5 or earlier programs. Android 2.1 phones, on the other hand, can run programs built for 2.1, 2.0.1, 2.0, 1.6, 1.5, and earlier. But it may be a while before most phones have been upgraded (if ever).

So why not just target Android 1.5? Unfortunately applications built for 1.5 don't always display correctly on the larger and smaller screens found on 1.6 phones. Luckily there's an easy way to make your programs compatible with all versions of Android. See Chapter 13, *Write Once, Test Everywhere*, on page 259 for instructions.

Click Create AVD to create the virtual device. A few seconds later you should see a message that the device has been created. Click OK, and then select the AVD and click Start... and then Launch to bring it up. Close the AVD Manager window when you're done.

Let's Try That Again

Once you have a valid AVD, the Android emulator window will start up and boot the Android operating system. The first time you do this, it may take a minute or two, so be patient. You may need to right-click on the project and select Run As > Android Application again. If you see an error message saying that the application is not responding, select the option to continue waiting.

Eclipse will send a copy of your program over to the emulator to execute. The application screen comes up, and your "Hello, Android" program is now running (see Figure 1.6, on page 32). That's it! Congratulations on your first Android program.

1.4 Running on a Real Phone

Running an Android program on a physical device such as the Droid or Nexus One during development is almost identical to running it on the emulator. You need to enable USB debugging on the phone itself (start

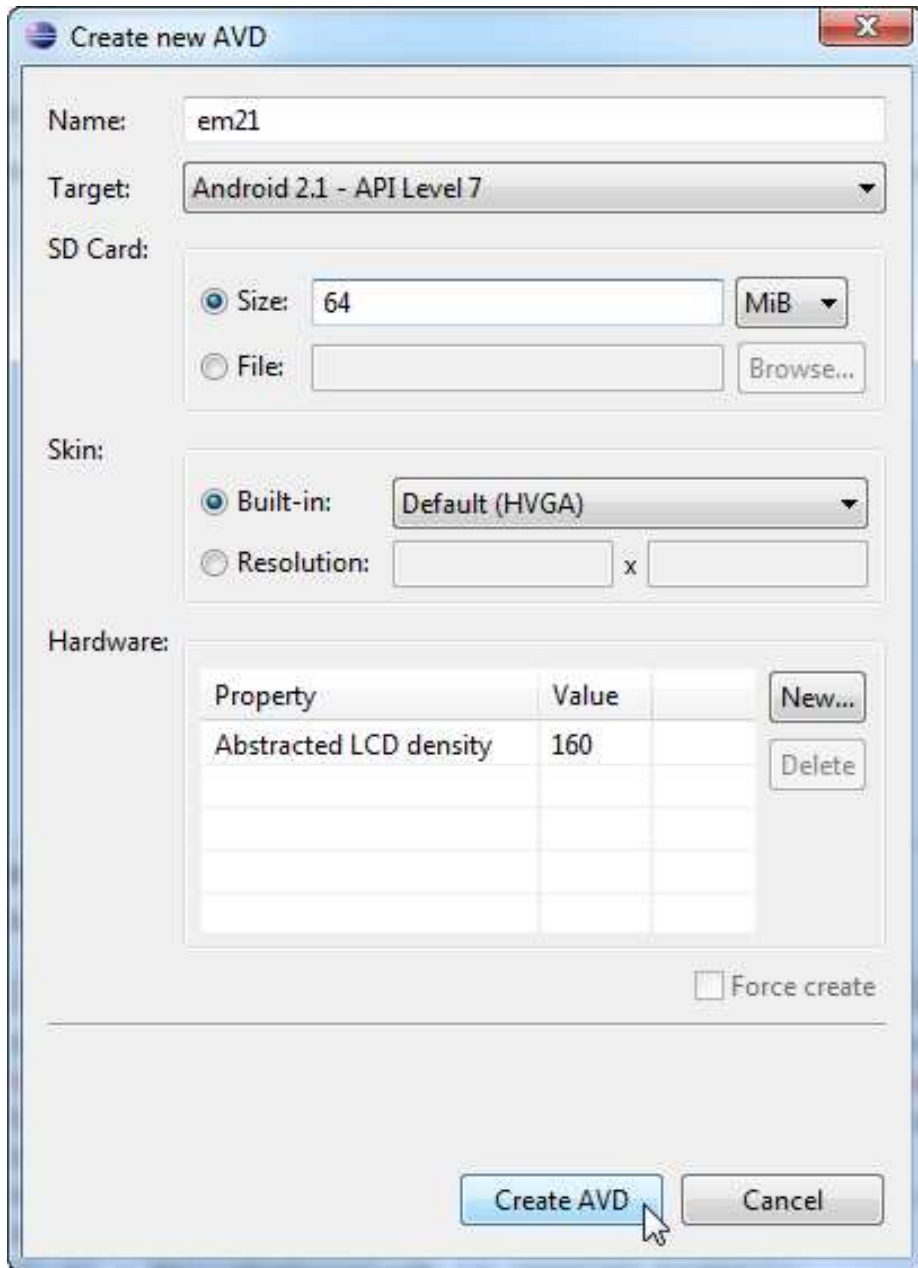


Figure 1.5: Creating an AVD in Eclipse



Figure 1.6: Running the “Hello, Android” program

Shortening the Turnaround

Starting the emulator is expensive. Think about it this way—when you first turn on your phone, it needs to boot up just like any computer system. Closing the emulator is just like turning off the phone or pulling the batteries out. So, don’t turn it off!

Leave the emulator window running as long as Eclipse is running. The next time you start an Android program, Eclipse will notice the emulator is already there and will just send it the new program to run.

the Settings application and select Applications > Development > USB Debugging), install the Android USB device driver if you haven't already (Windows only), and then plug the phone into your computer using the USB cable that came with the phone.⁷

Close the emulator window if it's already open. As long as the phone is plugged in, Eclipse will load and run applications on the phone instead.

When you're ready to publish your application for others to use, there are a few more steps you'll need to take. Chapter 14, *Publishing to the Android Market*, on page 272 will cover that in more detail.

1.5 Fast-Forward >>

Thanks to the Eclipse plug-in, creating a skeletal Android program takes only a few seconds. In Chapter 3, *Designing the User Interface*, on page 48, we'll begin to flesh out that skeleton with a real application—a Sudoku game. This sample will be used in several chapters to demonstrate Android's API.

But before delving into that, you should take a few minutes to read Chapter 2, *Key Concepts*, on the following page. Once you grasp the basic concepts such as activities and life cycles, the rest will be much easier to understand.

Although the use of Eclipse to develop Android programs is optional, I highly recommend it. If you've never used Eclipse before, you may want to invest in a quick reference such as the *Eclipse IDE Pocket Guide* [Bur05].

7. See <http://d.android.com/guide/developing/device.html> for the latest device driver and installation instructions.

Chapter 2

Key Concepts

Now that you have an idea of what Android is, let's take a look at how it works. Some parts of Android may be familiar, such as the Linux kernel, OpenGL, and the SQL database. Others will be completely foreign, such as Android's idea of the application life cycle.

You'll need a good understanding of these key concepts in order to write well-behaved Android applications, so if you read only one chapter in this book, read this one.

2.1 The Big Picture

Let's start by taking a look at the overall system architecture—the key layers and components that make up the Android open source software stack. In Figure 2.1, on the next page, you can see the “20,000-foot” view of Android. Study it closely—there will be a test tomorrow.

Each layer uses the services provided by the layers below it. Starting from the bottom, the following sections highlight the layers provided by Android.

Linux Kernel

Android is built on top of a solid and proven foundation: the Linux kernel. Created by Linus Torvalds in 1991, Linux can be found today in everything from wristwatches to supercomputers. Linux provides the hardware abstraction layer for Android, allowing Android to be ported to a wide variety of platforms in the future.

Internally, Android uses Linux for its memory management, process management, networking, and other operating system services. The

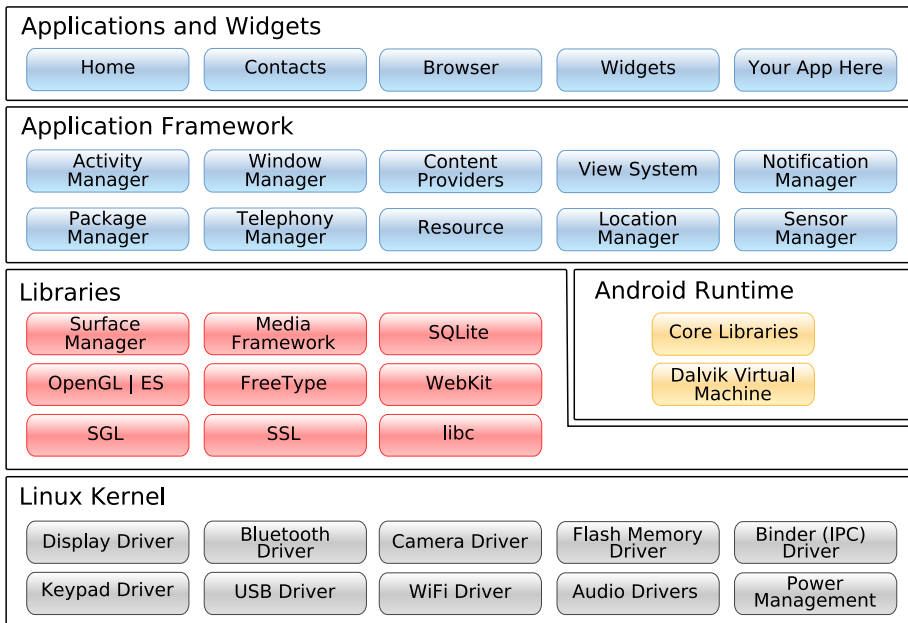


Figure 2.1: Android system architecture

Android phone user will never see Linux and your programs will not make Linux calls directly. As a developer, though, you'll need to be aware it's there.

Some utilities you need during development interact with Linux. For example, the `adb shell` command¹ will open a Linux shell in which you can enter other commands to run on the device. From there you can examine the Linux file system, view active processes, and so forth, subject to security restrictions.

Native Libraries

The next layer above the kernel contains the Android native libraries. These shared libraries are all written in C or C++, compiled for the particular hardware architecture used by the phone, and preinstalled by the phone vendor.

Some of the most important native libraries include the following:

1. <http://d.android.com/guide/developing/tools/adb.html>

- *Surface Manager*: Android uses a compositing window manager similar to Vista or Compiz, but it's much simpler. Instead of drawing directly to the screen buffer, your drawing commands go into offscreen bitmaps that are then combined with other bitmaps to form the display the user sees. This lets the system create all sorts of interesting effects such as see-through windows and fancy transitions.
- *2D and 3D graphics*: Two- and three-dimensional elements can be combined in a single user interface with Android. The library will use 3D hardware if the device has it or a fast software renderer if it doesn't. See Chapter 4, *Exploring 2D Graphics*, on page 77 and Chapter 10, *3D Graphics in OpenGL*, on page 201.
- *Media codecs*: Android can play video and record and play back audio in a variety of formats including AAC, AVC (H.264), H.263, MP3, and MPEG-4. See Chapter 5, *Multimedia*, on page 108 for an example.
- *SQL database*: Android includes the lightweight SQLite database engine,² the same database used in Firefox and the Apple iPhone.³ You can use this for persistent storage in your application. See Chapter 9, *Putting SQL to Work*, on page 181 for an example.
- *Browser engine*: For the fast display of HTML content, Android uses the WebKit library.⁴ This is the same engine used in the Google Chrome browser, Apple's Safari browser, the Apple iPhone, and Nokia's S60 platform. See Chapter 7, *The Connected World*, on page 133 for an example.

These libraries are not applications that stand by themselves. They exist only to be called by higher level programs. Starting in Android 1.5, you can write and deploy your own native libraries using the Native Development Toolkit (NDK). Native development is beyond the scope of this book, but if you're interested you can read all about it online.⁵

2. <http://www.sqlite.org>

3. See <http://blogs.zdnet.com/Burnette/?p=682> for a comparison of iPhone and Android development.

4. <http://www.webkit.org>

5. <http://d.android.com/sdk>



Joe Asks...

What's a Dalvik?

Dalvik is a virtual machine (VM) designed and written by Dan Bornstein at Google. Your code gets compiled into machine-independent instructions called *bytecodes*, which are then executed by the Dalvik VM on the mobile device.

Although the bytecode formats are a little different, Dalvik is essentially a Java virtual machine optimized for low memory requirements. It allows multiple VM instances to run at once and takes advantage of the underlying operating system (Linux) for security and process isolation.

Bornstein named Dalvik after a fishing village in Iceland where some of his ancestors lived.

Android Runtime

Also sitting on top of the kernel is the Android runtime, including the Dalvik virtual machine and the core Java libraries.

The Dalvik VM is Google's implementation of Java, optimized for mobile devices. All the code you write for Android will be written in Java and run within the VM.

Dalvik differs from traditional Java in two important ways:

- The Dalvik VM runs `.dex` files, which are converted at compile time from standard `.class` and `.jar` files. `.dex` files are more compact and efficient than class files, an important consideration for the limited memory and battery-powered devices that Android targets.
- The core Java libraries that come with Android are different from both the Java Standard Edition (Java SE) libraries and the Java Mobile Edition (Java ME) libraries. There is a substantial amount of overlap, however. In Appendix A, on page 279, you'll find a comparison of Android and standard Java libraries.

Application Framework

Sitting above the native libraries and runtime, you'll find the Application Framework layer. This layer provides the high-level building blocks

you will use to create your applications. The framework comes preinstalled with Android, but you can also extend it with your own components as needed.

The most important parts of the framework are as follows:

- *Activity manager*: This controls the life cycle of applications (see Section 2.2, *It's Alive!*, on the following page) and maintains a common “backstack” for user navigation.
- *Content providers*: These objects encapsulate data that needs to be shared between applications, such as contacts. See Section 2.3, *Content Providers*, on page 44.
- *Resource manager*: Resources are anything that goes with your program that is not code. See Section 2.4, *Using Resources*, on page 44.
- *Location manager*: An Android phone always knows where it is. See Chapter 8, *Locating and Sensing*, on page 164.
- *Notification manager*: Events such as arriving messages, appointments, proximity alerts, alien invasions, and more can be presented in an unobtrusive fashion to the user.

Applications and Widgets

The highest layer in the Android architecture diagram is the Applications and Widgets layer. Think of this as the tip of the Android iceberg. End users will see only these programs, blissfully unaware of all the action going on below the waterline. As an Android developer, however, you know better.

Applications are programs that can take over the whole screen and interact with the user. On the other hand, Widgets (sometimes called gadgets), only operate in a small rectangle of the Home screen application.

The majority of this book will cover application development, because that's what most of you will be writing. Widget development is covered in Chapter 12, *There's No Place Like Home*, on page 236.

When someone buys an Android phone, it will come prepackaged with a number of standard system applications, including the following:

- Phone dialer
- Email

Embrace and Extend

One of the unique and powerful qualities of Android is that all applications have a level playing field. What I mean is that the system applications have to go through the same public API that you use. You can even tell Android to make your application replace the standard applications if you want.

- Contacts
- Web browser
- Android Market

Using the Android Market, the user will be able to download new programs to run on their phone. That's where you come in. By the time you finish this book, you'll be able to write your own killer applications for Android.

Now let's take a closer look at the life cycle of an Android application. It's a little different from what you're used to seeing.

2.2 It's Alive!

On your standard Linux or Windows desktop, you can have many applications running and visible at once in different windows. One of the windows has keyboard focus, but otherwise all the programs are equal. You can easily switch between them, but it's your responsibility as the user to move the windows around so you can see what you're doing and close programs you don't need anymore.

Android doesn't work that way.

In Android, there is one foreground application, which typically takes over the whole display except for the status line. When the user turns on their phone, the first application they see is the Home application (see Figure 2.2, on the next page). This program typically shows a background image, a search or clock widget, and a scrollable list of other applications the user can invoke.

When the user runs an application, Android starts it and brings it to the foreground. From that application, the user might invoke another application, or another screen in the same application, and then another and

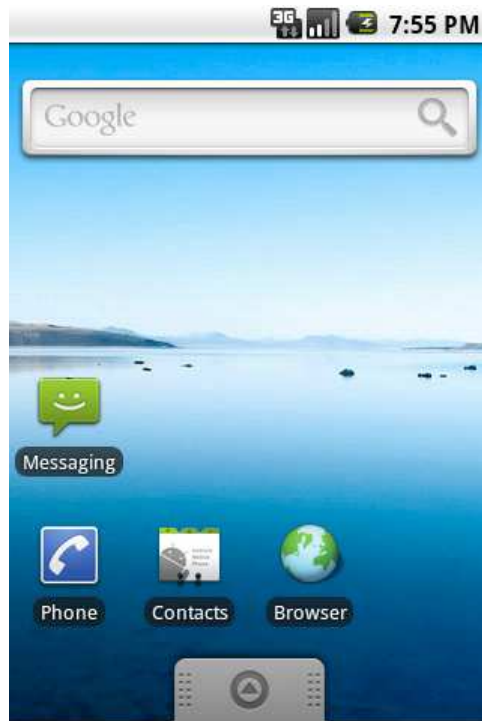


Figure 2.2: The Home application

another. All these programs and screens are recorded on the *application stack* by the system's Activity Manager. At any time, the user can press the Back button to return to the previous screen on the stack. From the user's point of view, it works a lot like the history in a web browser. Pressing Back returns them to the previous page.

Process != Application

Internally, each user interface screen is represented by an Activity class (see Section 2.3, *Activities*, on page 43). Each activity has its own life cycle. An application is one or more activities plus a Linux process to contain them. That sounds pretty straightforward, doesn't it? But don't get comfortable yet; I'm about to throw you a curve ball.

In Android, an application can be “alive” even if its process has been killed. Put another way, the activity life cycle is not tied to the process life cycle. Processes are just disposable containers for activities. This is

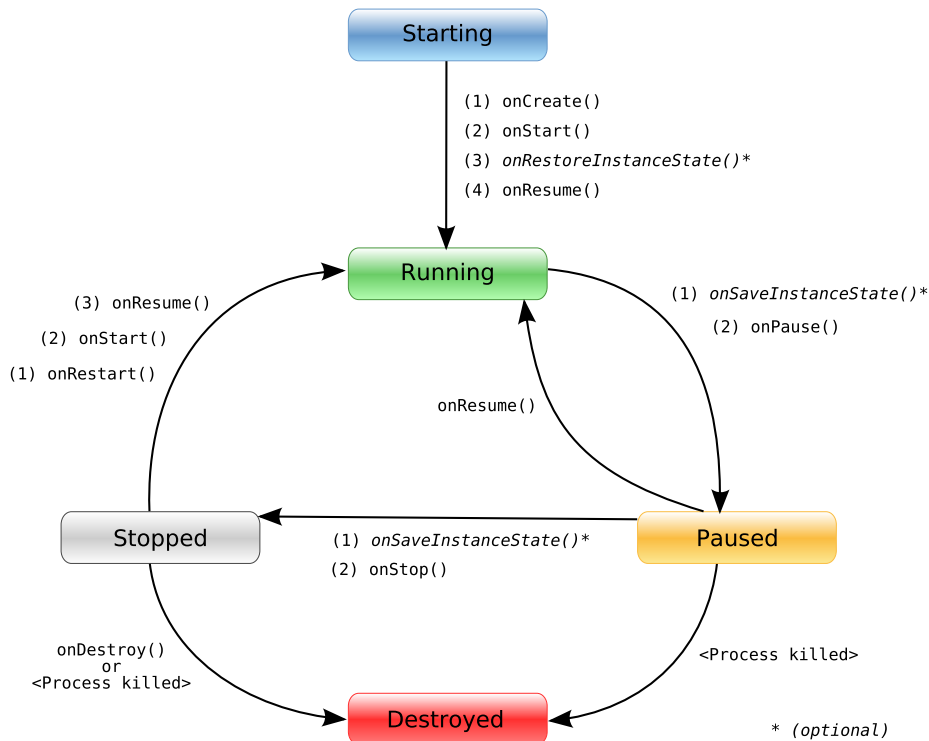


Figure 2.3: Life cycle of an Android activity

probably different from every other system you're familiar with, so let's take a closer look before moving on.

Life Cycles of the Rich and Famous

During its lifetime, each activity of an Android program can be in one of several states, as shown in Figure 2.3. You, the developer, do not have control over what state your program is in. That's all managed by the system. However, you do get notified when the state is about to change through the `onXX()` method calls.

You override these methods in your Activity class, and Android will call them at the appropriate time:

- `onCreate(Bundle)`: This is called when the activity first starts up. You can use it to perform one-time initialization such as creating the user interface. `onCreate()` takes one parameter that is either

null or some state information previously saved by the `onSaveInstanceState()` method.

- `onStart()`: This indicates the activity is about to be displayed to the user.
- `onResume()`: This is called when your activity can start interacting with the user. This is a good place to start animations and music.
- `onPause()`: This runs when the activity is about to go into the background, usually because another activity has been launched in front of it. This is where you should save your program's persistent state, such as a database record being edited.
- `onStop()`: This is called when your activity is no longer visible to the user and it won't be needed for a while. If memory is tight, `onStop()` may never be called (the system may simply terminate your process).
- `onRestart()`: If this method is called, it indicates your activity is being redisplayed to the user from a stopped state.
- `onDestroy()`: This is called right before your activity is destroyed. If memory is tight, `onDestroy()` may never be called (the system may simply terminate your process).
- `onSaveInstanceState(Bundle)`: Android will call this method to allow the activity to save per-instance state, such as a cursor position within a text field. Usually you won't need to override it because the default implementation saves the state for all your user interface controls automatically.
- `onRestoreInstanceState(Bundle)`: This is called when the activity is being reinitialized from a state previously saved by the `onSaveInstanceState()` method. The default implementation restores the state of your user interface.

Activities that are not running in the foreground may be stopped or the Linux process that houses them may be killed at any time in order to make room for new activities. This will be a common occurrence, so it's important that your application be designed from the beginning with this in mind. In some cases, the `onPause()` method may be the last method called in your activity, so that's where you should save any data you want to keep around for next time.

Flipping the Lid

Here's a quick way to test that your state-saving code is working correctly. In current versions of Android, an orientation change (between portrait and landscape modes) will cause the system to go through the process of saving instance state, pausing, stopping, destroying, and then creating a new instance of the activity with the saved state. On the T-Mobile G1 phone, for example, flipping the lid on the keyboard will trigger this, and on the Android emulator pressing `Ctrl+F11` or the `[7]` or `[9]` key on the keypad will do it.

In addition to managing your program's life cycle, the Android framework provides a number of building blocks that you use to create your applications. Let's take a look at those next.

2.3 Building Blocks

A few objects are defined in the Android SDK that every developer needs to be familiar with. The most important ones are activities, intents, services, and content providers. You'll see several examples of them in the rest of the book, so I'd like to briefly introduce them now.

Activities

An *activity* is a user interface screen. Applications can define one or more activities to handle different phases of the program. As discussed in Section 2.2, *It's Alive!*, on page 39, each activity is responsible for saving its own state so that it can be restored later as part of the application life cycle. See Section 3.3, *Creating the Opening Screen*, on page 50 for an example.

Intents

An *intent* is a mechanism for describing a specific action, such as "pick a photo," "phone home," or "open the pod bay doors." In Android, just about everything goes through intents, so you have plenty of opportunities to replace or reuse components. See Section 3.5, *Implementing an About Box*, on page 61 for an example of an intent.

For example, there is an intent for “send an email.” If your application needs to send mail, you can invoke that intent. Or if you’re writing a new email application, you can register an activity to handle that intent and replace the standard mail program. The next time somebody tries to send an email, they’ll get the option to use your program instead of the standard one.

Services

A *service* is a task that runs in the background without the user’s direct interaction, similar to a Unix daemon. For example, consider a music player. The music may be started by an activity, but you want it to keep playing even when the user has moved on to a different program. So, the code that does the actual playing should be in a service. Later, another activity may bind to that service and tell it to switch tracks or stop playing. Android comes with many services built in, along with convenient APIs to access them. Section 12.2, *Live Wallpaper*, on page 246 uses a service to draw an animated picture behind the Home screen.

Content Providers

A *content provider* is a set of data wrapped up in a custom API to read and write it. This is the best way to share global data *between applications*. For example, Google provides a content provider for contacts. All the information there—names, addresses, phone numbers, and so forth—can be shared by any application that wants to use it. See Section 9.5, *Using a ContentProvider*, on page 195 for an example.

2.4 Using Resources

A *resource* is a localized text string, bitmap, or other small piece of noncode information that your program needs. At build time all your resources get compiled into your application. This is useful for internationalization and for supporting multiple device types (see Section 3.4, *Using Alternate Resources*, on page 58).

You will create and store your resources in the `res` directory inside your project. The Android resource compiler (`aapt`)⁶ processes resources according to which subfolder they are in and the format of the file. For example, PNG and JPG format bitmaps should go in a directory

6. <http://d.android.com/guide/developing/tools/aapt.html>

starting with `res/drawable`, and XML files that describe screen layouts should go in a directory starting with `res/layout`. You can add suffixes for particular languages, screen orientations, pixel densities, and more (see Section 13.5, *All Screens Great and Small*, on page 270).

The resource compiler compresses and packs your resources and then generates a class named `R` that contains identifiers you use to reference those resources in your program. This is a little different from standard Java resources, which are referenced by key strings. Doing it this way allows Android to make sure all your references are valid and saves space by not having to store all those resource keys. Eclipse uses a similar method to store and reference the resources in Eclipse plug-ins.

We'll see an example of the code to access a resource in Chapter 3, *Designing the User Interface*, on page 48.

2.5 Safe and Secure

As mentioned earlier, every application runs in its own Linux process. The hardware forbids one process from accessing another process's memory. Furthermore, every application is assigned a specific user ID. Any files it creates cannot be read or written by other applications.

In addition, access to certain critical operations are restricted, and you must specifically ask for permission to use them in a file named `AndroidManifest.xml`. When the application is installed, the Package Manager either grants or doesn't grant the permissions based on certificates and, if necessary, user prompts. Here are some of the most common permissions you will need:

- `INTERNET`: Access the Internet.
- `READ_CONTACTS`: Read (but don't write) the user's contacts data.
- `WRITE_CONTACTS`: Write (but don't read) the user's contacts data.
- `RECEIVE_SMS`: Monitor incoming SMS (text) messages.
- `ACCESS_COARSE_LOCATION`: Use a coarse location provider such as cell towers or wifi.
- `ACCESS_FINE_LOCATION`: Use a more accurate location provider such as GPS.

For example, to monitor incoming SMS messages, you would specify this in the manifest file:

```
<manifest xmlns:android="http://schemas.android.com/apk/res/android"
```

```

package="com.google.android.app.myapplication" >
<uses-permission android:name="android.permission.RECEIVE_SMS" />
</manifest>

```

Android can even restrict access to entire parts of the system. Using XML tags in `AndroidManifest.xml`, you can restrict who can start an activity, start or bind to a service, broadcast intents to a receiver, or access the data in a content provider. This kind of control is beyond the scope of this book, but if you want to learn more, read the online help for the Android security model.⁷

2.6 Fast-Forward >>

The rest of this book will use all the concepts introduced in this chapter. In Chapter 3, *Designing the User Interface*, on page 48, we'll use activities and life-cycle methods to define a sample application. Chapter 4, *Exploring 2D Graphics*, on page 77 will use some of the graphics classes in the Android native libraries. Media codecs will be explored in Chapter 5, *Multimedia*, on page 108, and content providers will be covered in Chapter 9, *Putting SQL to Work*, on page 181.

7. <http://d.android.com/guide/topics/security/security.html>

Part II

Android Basics

Designing the User Interface

In Chapter 1, *Quick Start*, on page 21, we used the Android Eclipse plug-in to put together a simple “Hello, Android” program in a few minutes. In Part II, we’ll create a more substantial example: a Sudoku game. By gradually adding features to the game, you’ll learn about many aspects of Android programming. We’ll start with the user interface.

You can find all the sample code used in this book at <http://pragprog.com/titles/eband3>. If you’re reading the PDF version of this book, you can click the little gray rectangle before the code listings to download that file directly.

3.1 Introducing the Sudoku Example

Sudoku makes a great sample program for Android because the game itself is so simple. You have a grid of eighty-one tiles (nine across and nine down), and you try to fill them in with numbers so that each column, each row, and each of the three-by-three boxes contains the numbers 1 through 9 only once. When the game starts, some of the numbers (the *givens*) are already filled in. All the player has to do is supply the rest. A true Sudoku puzzle has only one unique solution.

Sudoku is usually played with pencil and paper, but computerized versions are quite popular too. With the paper version, it’s easy to make a mistake early on, and when that happens, you have to go back and erase most of your work. In the Android version, you can change the tiles as often as you like without having to brush away all those pesky eraser shavings.

Sudoku Trivia

Most people think Sudoku is some kind of ancient Japanese game, but it's not. Although similar puzzles can be traced to 19th-century French magazines, most experts credit retired American architect Howard Garns with the invention of modern Sudoku. Number Place, as it was known at the time, was first published in the United States in 1979 by Dell Magazines.

Android Sudoku (see Figure 3.1, on the next page) will also offer a few hints to take some of the grunt work out of puzzle solving. At one extreme, it could just solve the puzzle for you, but that wouldn't be any fun, would it? So, we have to balance the hints against the challenge and not make it too easy.

3.2 Designing by Declaration

User interfaces can be designed using one of two methods: procedural and declarative. *Procedural* simply means in code. For example, when you're programming a Swing application, you write Java code to create and manipulate all the user interface objects such as `JFrame` and `JButton`. Thus, Swing is procedural.

Declarative design, on the other hand, does not involve any code. When you're designing a simple web page, you use HTML, a markup language similar to XML that describes what you want to see on the page, not how you want to do it. HTML is declarative.

Android tries to straddle the gap between the procedural and declarative worlds by letting you create user interfaces in either style. You can stay almost entirely in Java code, or you can stay almost entirely in XML descriptors. If you look up the documentation for any Android user interface component, you'll see both the Java APIs and the corresponding declarative XML attributes that do the same thing.

Which should you use? Either way is valid, but Google's advice is to use declarative XML as much as possible. The XML code is often shorter and easier to understand than the corresponding Java code, and it's less likely to change in future versions.

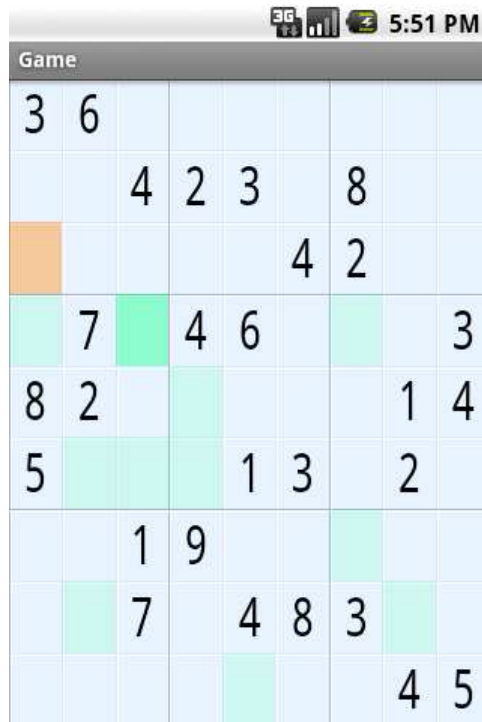


Figure 3.1: The Sudoku example program for Android

Now let's see how we can use this information to create the Sudoku opening screen.

3.3 Creating the Opening Screen

We'll start with a skeleton Android program created by the Eclipse plug-in. Just as you did in Section 1.2, *Creating Your First Program*, on page 26, create a new "Hello, Android" project, but this time use the following values:

```
Project name: Sudoku
Build Target: Android 2.1
Application name: Sudoku
Package name: org.example.sudoku
Create Activity: Sudoku
Min SDK Version: 7
```

In a real program, of course, you would use your own names here. The package name is particularly important. Each application in the system must have a unique package name. Once you choose a package name, it's a little tricky to change it because it's used in so many places.

I like to keep the Android emulator window up all the time and run the program after every change, since it takes only a few seconds. If you do that and run the program now, you'll see a blank screen that just contains the words "Hello World, Sudoku." The first order of business is to change that into an opening screen for the game, with buttons to let the player start a new game, continue a previous one, get information about the game, or exit. So, what do we have to change to do that?

As discussed in Chapter 2, *Key Concepts*, on page 34, Android applications are a loose collection of activities, each of which define a user interface screen. When you create the Sudoku project, the Android plug-in makes a single activity for you in `Sudoku.java`:

[Download](#) `Sudokuv0/src/org/example/sudoku/Sudoku.java`

```
package org.example.sudoku;

import android.app.Activity;
import android.os.Bundle;

public class Sudoku extends Activity {
    /** Called when the activity is first created. */
    @Override
    public void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.main);
    }
}
```

Android calls the `onCreate()` method of your activity to initialize it. The call to `setContentView()` fills in the contents of the activity's screen with an Android view widget.

We could have used several lines of Java code, and possibly another class or two, to define the user interface procedurally. But instead, the plug-in chose the declarative route, and we'll continue along those lines. In the previous code, `R.layout.main` is a resource identifier that refers to the `main.xml` file in the `res/layout` directory (see Figure 3.2, on the following page). `main.xml` declares the user interface in XML, so that's the file we need to modify. At runtime, Android parses and instantiates (*inflates*) the resource defined there and sets it as the view for the current activity.

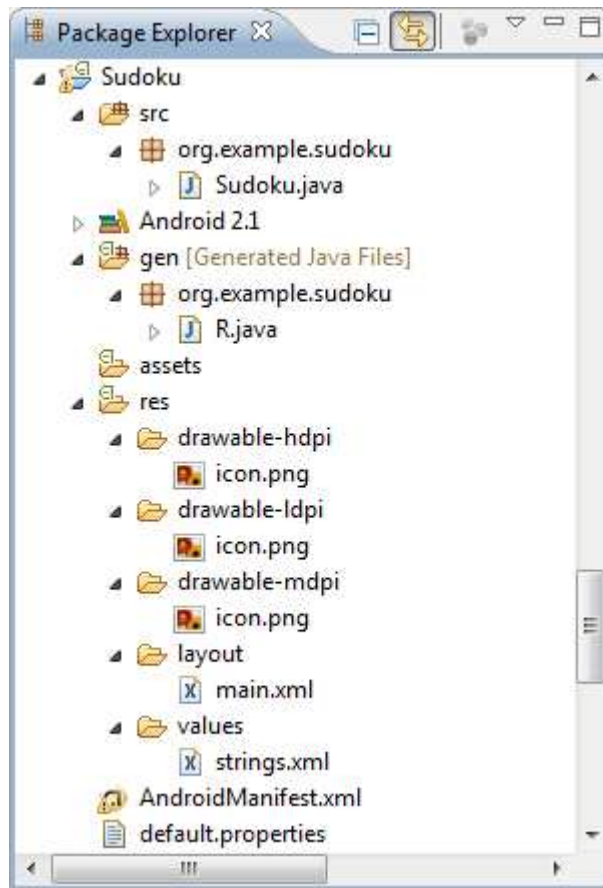


Figure 3.2: Initial resources in the Sudoku project

It's important to note that the R class is managed automatically by the Android Eclipse plug-in. When you put a file anywhere in the res directory, the plug-in notices the change and adds resource IDs in R.java in the gen directory for you. If you remove or change a resource file, R.java is kept in sync. If you bring up the file in the editor, it will look something like this:

[Download](#) `Sudoku\0\gen\org\example\sudoku\R.java`

```
/* AUTO-GENERATED FILE. DO NOT MODIFY.
 *
 * This class was automatically generated by the
 * aapt tool from the resource data it found. It
 * should not be modified by hand.
```

```

*/

package org.example.sudoku;

public final class R {
    public static final class attr {
    }
    public static final class drawable {
        public static final int icon=0x7f020000;
    }
    public static final class layout {
        public static final int main=0x7f030000;
    }
    public static final class string {
        public static final int app_name=0x7f040001;
        public static final int hello=0x7f040000;
    }
}

```

The hex numbers are just integers that the Android resource manager uses to load the real data, the strings, and the other assets that are compiled into your package. You don't need to worry about their values. Just keep in mind that they are handles that refer to the data, not the objects that contain the data. Those objects won't be inflated until they are needed. Note that almost every Android program, including the base Android framework itself, has an `R` class. See the online documentation on `android.R` for all the built-in resources you can use.¹

So, now we know we have to modify `main.xml`. Let's dissect the original definition to see what we have to change. Double-click `main.xml` in Eclipse to open it. Depending on how you have Eclipse set up, you may see either a visual layout editor or an XML editor. In current versions of ADT, the visual layout editor isn't that useful, so click `main.xml` or Source tab at the bottom to see the XML. The first line of `main.xml` is as follows:

```
<?xml version="1.0" encoding="utf-8"?>
```

All Android XML files start with this line. It just tells the compiler that the file is XML format, in UTF-8 encoding. UTF-8 is almost exactly like regular ASCII text, except it has escape codes for non-ASCII characters such as Japanese glyphs.

Next we see a reference to `<LinearLayout>`:

```
<LinearLayout
    xmlns:android="http://schemas.android.com/apk/res/android"
```

1. <http://d.android.com/reference/android/R.html>



Joe Asks...

Why Does Android Use XML? Isn't That Inefficient?

Android is optimized for mobile devices with limited memory and horsepower, so you may find it strange that it uses XML so pervasively. After all, XML is a verbose, human-readable format not known for its brevity or efficiency, right?

Although you see XML when writing your program, the Eclipse plug-in invokes the Android resource compiler, `aapt`, to preprocess the XML into a compressed binary format. It is this format, not the original XML text, that is stored on the device.

```
android:orientation="vertical"
android:layout_width="fill_parent"
android:layout_height="fill_parent">
<!-- ... -->
```

</LinearLayout>

A layout is a container for one or more child objects and a behavior to position them on the screen within the rectangle of the parent object. Here is a list of the most common layouts provided by Android:

- `FrameLayout`: Arranges its children so they all start at the top left of the screen. This is used for tabbed views and image switchers.
- `LinearLayout`: Arranges its children in a single column or row. This is the most common layout you will use.
- `RelativeLayout`: Arranges its children in relation to each other or to the parent. This is often used in forms.
- `TableLayout`: Arranges its children in rows and columns, similar to an HTML table.

Some parameters are common to all layouts:

```
xmlns:android="http://schemas.android.com/apk/res/android"
```

Defines the XML namespace for Android. You should define this once, on the first XML tag in the file.

```
android:layout_width="fill_parent", android:layout_height="fill_parent"
```

Takes up the entire width and height of the parent (in this case, the window). Possible values are `fill_parent` and `wrap_content`.

Inside the `<LinearLayout>` tag you'll find one child widget:

```
<TextView
    android:layout_width="fill_parent"
    android:layout_height="wrap_content"
    android:text="@string/hello" />
```

This defines a simple text label. Let's replace that with some different text and a few buttons. Here's our first attempt:

Download Sudokuv1/res/layout/main1.xml

```
<?xml version="1.0" encoding="utf-8"?>
<LinearLayout
    xmlns:android="http://schemas.android.com/apk/res/android"
    android:orientation="vertical"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent">
    <TextView
        android:layout_width="fill_parent"
        android:layout_height="wrap_content"
        android:text="@string/main_title" />
    <Button
        android:layout_width="fill_parent"
        android:layout_height="wrap_content"
        android:text="@string/continue_label" />
    <Button
        android:layout_width="fill_parent"
        android:layout_height="wrap_content"
        android:text="@string/new_game_label" />
    <Button
        android:layout_width="fill_parent"
        android:layout_height="wrap_content"
        android:text="@string/about_label" />
    <Button
        android:layout_width="fill_parent"
        android:layout_height="wrap_content"
        android:text="@string/exit_label" />
</LinearLayout>
```

If you see warnings in the editor about missing grammar constraints (DTD or XML schema), just ignore them. Instead of hard-coding English text into the layout file, we use the `@string/resid` syntax to refer to strings in the `res/values/strings.xml` file. You can have different versions of this and other resource files based on the locale or other parameters such as screen resolution and orientation. Open that file now, switch to the `strings.xml` tab at the bottom if necessary, and enter this:

Download Sudokuv1/res/values/strings.xml

```
<?xml version="1.0" encoding="utf-8"?>
<resources>
    <string name="app_name">Sudoku</string>
    <string name="main_title">Android Sudoku</string>
    <string name="continue_label">Continue</string>
```

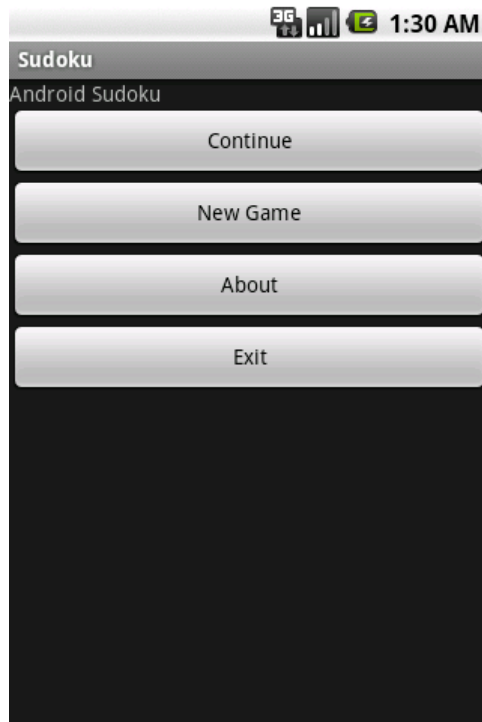


Figure 3.3: First version of the opening screen

```
<string name="new_game_label">New Game</string>
<string name="about_label">About</string>
<string name="exit_label">Exit</string>
</resources>
```

Save strings.xml so Eclipse will rebuild the project. When you run the program now, you should see something like Figure 3.3. It's readable, but it could use some cosmetic changes.

Let's make the title text larger and centered, make the buttons smaller, and use a different background color. Here's the color definition, which you should put in res/values/colors.xml:

[Download](#) Sudokuv1/res/values/colors.xml

```
<?xml version="1.0" encoding="utf-8"?>
<resources>
  <color name="background">#3500ffff</color>
</resources>
```

And here's the new layout:

Download Sudokuv1/res/layout/main.xml

```
<?xml version="1.0" encoding="utf-8"?>
<LinearLayout
    xmlns:android="http://schemas.android.com/apk/res/android"
    android:background="@color/background"
    android:layout_height="fill_parent"
    android:layout_width="fill_parent"
    android:padding="30dip"
    android:orientation="horizontal">
    <LinearLayout
        android:orientation="vertical"
        android:layout_height="wrap_content"
        android:layout_width="fill_parent"
        android:layout_gravity="center">
        <TextView
            android:text="@string/main_title"
            android:layout_height="wrap_content"
            android:layout_width="wrap_content"
            android:layout_gravity="center"
            android:layout_marginBottom="25dip"
            android:textSize="24.5sp" />
        <Button
            android:id="@+id/continue_button"
            android:layout_width="fill_parent"
            android:layout_height="wrap_content"
            android:text="@string/continue_label" />
        <Button
            android:id="@+id/new_button"
            android:layout_width="fill_parent"
            android:layout_height="wrap_content"
            android:text="@string/new_game_label" />
        <Button
            android:id="@+id/about_button"
            android:layout_width="fill_parent"
            android:layout_height="wrap_content"
            android:text="@string/about_label" />
        <Button
            android:id="@+id/exit_button"
            android:layout_width="fill_parent"
            android:layout_height="wrap_content"
            android:text="@string/exit_label" />
    </LinearLayout>
</LinearLayout>
```

In this version, we introduce a new syntax, `@+id/resid`. Instead of referring to a resource ID defined somewhere else, this is how you create a new resource ID to which others can refer. For example, `@+id/about_button` defines the ID for the About button, which we'll use later to make something happen when the user presses that button.

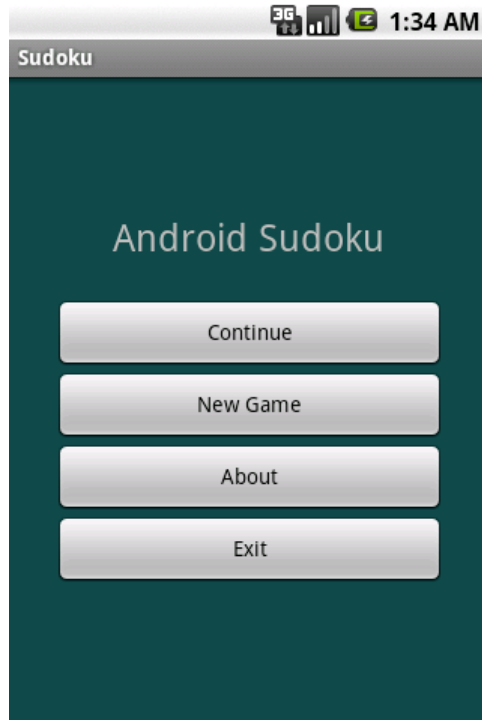


Figure 3.4: Opening screen with new layout

The result is shown in Figure 3.4. This new screen looks good in portrait mode (when the screen is taller than it is wide), but how about landscape mode (wide-screen)? The user can switch modes at any time, for example, by flipping out the keyboard or turning the phone on its side, so you need to handle that.

3.4 Using Alternate Resources

As a test, try switching the emulator to landscape mode (`Ctrl+F11` or the `[7]` or `[9]` key on the keypad). Oops! The Exit button runs off the bottom of the screen (see Figure 3.5, on page 60). How do we fix that?

You could try to adjust the layout so that it works with all orientations. Unfortunately, that's often not possible or leads to odd-looking



Joe Asks...

What Are Dips and Sps?

Historically, programmers always designed computer interfaces in terms of pixels. For example, you might make a field 300 pixels wide, allow 5 pixels of spacing between columns, and define icons 16-by-16 pixels in size. The problem is that if you run that program on new displays with more and more dots per inch (dpi), the user interface appears smaller and smaller. At some point, it becomes too hard to read.

Resolution-independent measurements help solve this problem. Android supports all the following units:

- **px** (pixels): Dots on the screen.
- **in** (inches): Size as measured by a ruler.
- **mm** (millimeters): Size as measured by a ruler.
- **pt** (points): 1/72 of an inch.
- **dp** (density-independent pixels): An abstract unit based on the density of the screen. On a display with 160 dots per inch, 1dp = 1px.
- **dip**: Synonym for dp, used more often in Google examples.
- **sp** (scale-independent pixels): Similar to **dp** but also scaled by the user's font size preference.

To make your interface scalable to any current and future type of display, I recommend you always use the **sp** unit for text sizes and the **dip** unit for everything else. You should also consider using vector graphics instead of bitmaps (see Chapter 4, *Exploring 2D Graphics*, on page 77).

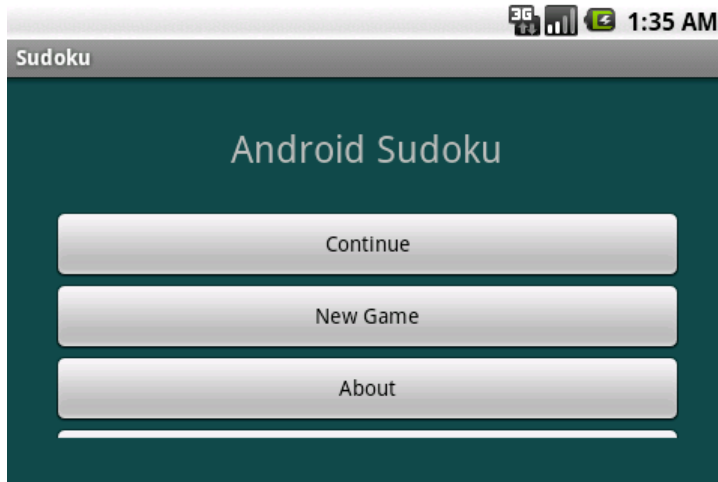


Figure 3.5: In landscape mode, we can't see the Exit button.

screens. When that happens, you'll need to create a different layout for landscape mode. That's the approach we'll take here.

Create a file called `res/layout-land/main.xml` (note the `-land` suffix) that contains the following layout:

[Download](#) `Sudoku1/res/layout-land/main.xml`

```
<?xml version="1.0" encoding="utf-8"?>
<LinearLayout
    xmlns:android="http://schemas.android.com/apk/res/android"
    android:background="@color/background"
    android:layout_height="fill_parent"
    android:layout_width="fill_parent"
    android:padding="15dip"
    android:orientation="horizontal">
    <LinearLayout
        android:orientation="vertical"
        android:layout_height="wrap_content"
        android:layout_width="fill_parent"
        android:layout_gravity="center"
        android:paddingLeft="20dip"
        android:paddingRight="20dip">
        <TextView
            android:text="@string/main_title"
            android:layout_height="wrap_content"
            android:layout_width="wrap_content"
            android:layout_gravity="center"
```

```

        android:layout_marginBottom="20dip"
        android:textSize="24.5sp" />
<TableLayout
    android:layout_height="wrap_content"
    android:layout_width="wrap_content"
    android:layout_gravity="center"
    android:stretchColumns="*">
    <TableRow>
        <Button
            android:id="@+id/continue_button"
            android:text="@string/continue_label" />
        <Button
            android:id="@+id/new_button"
            android:text="@string/new_game_label" />
    </TableRow>
    <TableRow>
        <Button
            android:id="@+id/about_button"
            android:text="@string/about_label" />
        <Button
            android:id="@+id/exit_button"
            android:text="@string/exit_label" />
    </TableRow>
</TableLayout>
</LinearLayout>
</LinearLayout>

```

This uses a `TableLayout` to create two columns of buttons. Now run the program again (see Figure 3.6, on the next page). Even in landscape mode, all the buttons are visible.

You can use resource suffixes to specify alternate versions of any resources, not just the layout. For example, you can use them to provide localized text strings in different languages. Android's screen density support depends heavily on these resource suffixes (see Section 13.5, *All Screens Great and Small*, on page 270).

3.5 Implementing an About Box

When the user selects the About button, meaning that either they touch it (if they have a touch screen) or they navigate to it with the D-pad (directional pad) or trackball and press the selection button, we want to pop up a window with some information about Sudoku.

After scrolling through the text, the user can press the Back button to dismiss the window.

We can accomplish this in several ways:



Figure 3.6: Using a landscape-specific layout lets us see all the buttons.

- Define a new Activity and start it.
- Use the AlertDialog class and show it.
- Subclass Android's Dialog class, and show that.

For this example, let's define a new activity. Like the main Sudoku activity, the About activity will need a layout file. We will name it `res/layout/about.xml`:

[Download](#) `SudokuV1/res/layout/about.xml`

```
<?xml version="1.0" encoding="utf-8"?>
<ScrollView
    xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent"
    android:padding="10dip">
    <TextView
        android:id="@+id/about_content"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        android:text="@string/about_text" />
</ScrollView>
```

We need only one version of this layout because it will look fine in both portrait and landscape modes.

Now add strings for the title of the About dialog box and the text it contains to `res/values/strings.xml`:

Download `Sudoku1/res/values/strings.xml`

```
<string name="about_title">About Android Sudoku</string>
<string name="about_text">\
Sudoku is a logic-based number placement puzzle.
Starting with a partially completed 9x9 grid, the
objective is to fill the grid so that each
row, each column, and each of the 3x3 boxes
(also called <i>blocks</i>) contains the digits
1 to 9 exactly once.
</string>
```

Note how a string resource can contain simple HTML formatting and can span multiple lines. In case you're wondering, the backslash character (`\`) in `about_text` prevents an extra blank from appearing before the first word.

The About activity should be defined in `About.java`. All it needs to do is override `onCreate()` and call `setContentView()`. To create a new class in Eclipse, use `File > New > Class`. Specify:

Source folder: `Sudoku/src`
 Package: `org.example.sudoku`
 Name: `About`

Edit the class so it looks like this:

Download `Sudoku1/src/org/example/sudoku/About.java`

```
package org.example.sudoku;

import android.app.Activity;
import android.os.Bundle;

public class About extends Activity {
    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.about);
    }
}
```

Next we need to wire all this up to the About button in the Sudoku class. Start by adding a few imports we'll need to `Sudoku.java`:

Download `Sudoku1/src/org/example/sudoku/Sudoku.java`

```
import android.content.Intent;
import android.view.View;
import android.view.View.OnClickListener;
```

In the `onCreate()` method, add code to call `findViewById()` to look up an Android view given its resource ID and `setOnClickListener()` to tell Android which object to tickle when the user touches or clicks the view:

Download `Sudoku\src\org\example\sudoku\Sudoku.java`

```
@Override
public void onCreate(Bundle savedInstanceState) {
    super.onCreate(savedInstanceState);
    setContentView(R.layout.main);

    // Set up click listeners for all the buttons
    View continueButton = findViewById(R.id.continue_button);
    continueButton.setOnClickListener(this);
    View newButton = findViewById(R.id.new_button);
    newButton.setOnClickListener(this);
    View aboutButton = findViewById(R.id.about_button);
    aboutButton.setOnClickListener(this);
    View exitButton = findViewById(R.id.exit_button);
    exitButton.setOnClickListener(this);
}
```

While we're in here, we do the same for all the buttons. Recall that constants like `R.id.about_button` are created by the Eclipse plug-in in `R.java` when it sees `@+id/about_button` in `res/layout/main.xml`.

The `setOnClickListener()` method needs to be passed an object that implements the `OnClickListener` Java interface. We're passing it the `this` variable so we had better make the current class (`Sudoku`) implement that interface or we'll get a compiler error. `OnClickListener` has one method in it called `onClick()` so we have to add that method to our class as well.²

Download `Sudoku\src\org\example\sudoku\Sudoku.java`

```
public class Sudoku extends Activity implements OnClickListener {
    // ...
    public void onClick(View v) {
        switch (v.getId()) {
            case R.id.about_button:
                Intent i = new Intent(this, About.class);
                startActivity(i);
                break;
            // More buttons go here (if any) ...
        }
    }
}
```

2. If you're a Java expert, you may be wondering why we didn't use an anonymous inner class to handle the clicks. You could, but according to the Android developers, every new inner class takes up an extra 1KB of memory.



Figure 3.7: Mountain View, we have a problem

To start an activity in Android, we first need to create an instance of the Intent class. There are two kinds of intents: *public* (named) intents that are registered with the system and can be called from any application and *private* (anonymous) intents that are used within a single application. For this example, we just need the latter kind. If you run the program and select the About button now, you will get an error (see Figure 3.7). What happened?

We forgot one important step: every activity needs to be declared in AndroidManifest.xml. To do that, double-click the file to open it, switch to XML mode if necessary by selecting the AndroidManifest.xml tab at the bottom, and add a new `<activity>` tag after the closing tag of the first one:

```
<activity android:name=".About"
    android:label="@string/about_title">
</activity>
```

Now if you save the manifest, run the program again, and select the About button, you should see something like Figure 3.8, on the following page. Press the Back button (`Esc` on the emulator) when you're done.

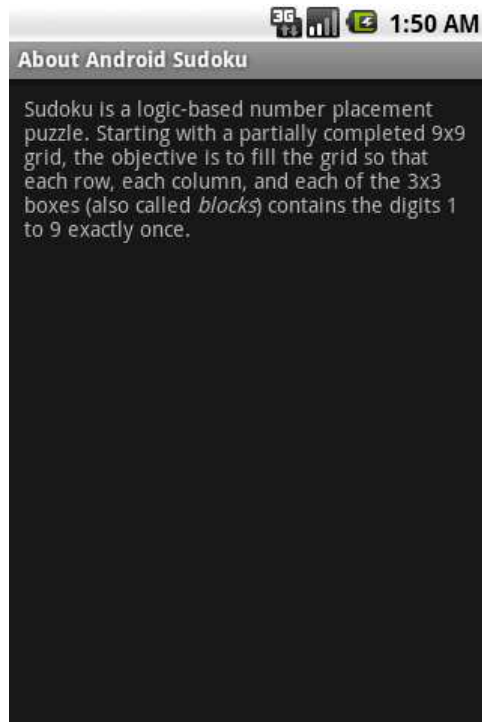


Figure 3.8: First version of the About screen

That looks OK, but wouldn't it be nice if we could see the initial screen behind the About text?

3.6 Applying a Theme

A *theme* is a collection of styles that override the look and feel of Android widgets. Themes were inspired by Cascading Style Sheets (CSS) used for web pages—they separate the content of a screen and its presentation or style. Android is packaged with several themes that you can reference by name,³ or you can make up your own theme by subclassing existing ones and overriding their default values.

3. See <http://d.android.com/reference/android/R.style.html> for symbols beginning with “Theme_.”

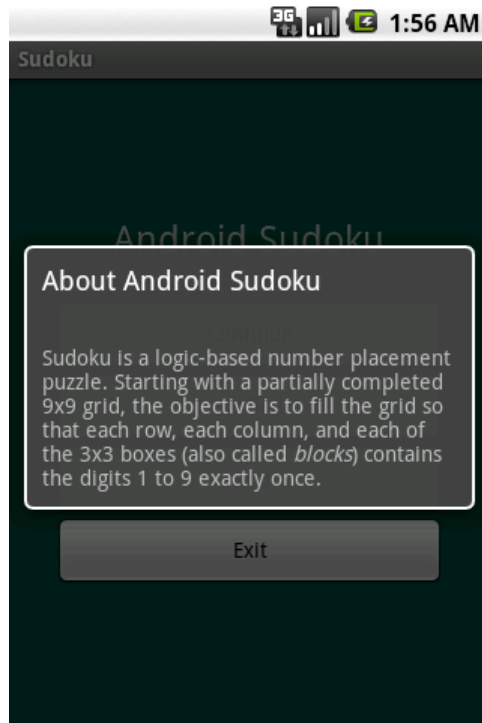


Figure 3.9: About screen after applying the dialog box theme

We could define our own custom theme in `res/values/styles.xml`, but for this example we'll just take advantage of a predefined one. To use it, open the `AndroidManifest.xml` editor again, and change the definition of the About activity so it has a theme property.

[Download](#) `SudokuV1/AndroidManifest.xml`

```
<activity android:name=".About"
    android:label="@string/about_title"
    android:theme="@android:style/Theme.Dialog">
</activity>
```

The `@android:` prefix in front of the style name means this is a reference to a resource defined by Android, not one that is defined in your program.

Running the program again, the About box now looks like Figure 3.9.

Many programs need menus and options, so the next two sections will show you how to define them.



Joe Asks...

Why Not Use an HTML View?

Android supports embedding a web browser directly into a view through the `WebView` class (see Section 7.2, *Web with a View*, on page 138). So, why didn't we just use that for the About box?

Actually, you could do it either way. A `WebView` would support far more sophisticated formatting than a simple `TextView`, but it does have some limitations (such as the inability to use a transparent background). Also, `WebView` is a heavyweight widget that will be slower and take more memory than `TextView`. For your own applications, use whichever one makes the most sense for your needs.

3.7 Adding a Menu

Android supports two kinds of menus. First, there is the menu you get when you press the physical Menu button. Second, there is a context menu that pops up when you press and hold your finger on the screen (or press and hold the trackball or the D-pad center button).

Let's do the first kind so that when the user presses the Menu key, they'll open a menu like the one in Figure 3.10, on the next page. First we need to define a few strings that we'll use later:

Download `Sudoku\res/values/strings.xml`

```
<string name="settings_label">Settings...</string>
<string name="settings_title">Sudoku settings</string>
<string name="settings_shortcut">s</string>
<string name="music_title">Music</string>
<string name="music_summary">Play background music</string>
<string name="hints_title">Hints</string>
<string name="hints_summary">Show hints during play</string>
```

Then we define the menu using XML in `res/menu/menu.xml`:

Download `Sudoku\res/menu/menu.xml`

```
<?xml version="1.0" encoding="utf-8"?>
<menu xmlns:android="http://schemas.android.com/apk/res/android">
    <item android:id="@+id/settings"
        android:title="@string/settings_label"
```

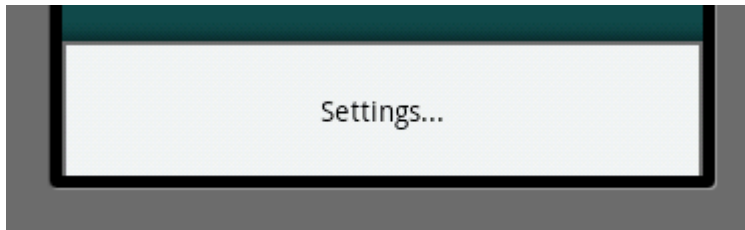


Figure 3.10: The options menu contains one item for changing the Settings

```

        android:alphabeticShortcut="@string/settings_shortcut" />
</menu>

```

Next we need to modify the Sudoku class to bring up the menu we just defined. To do that, we'll need a few more imports:

[Download](#) `Sudoku\src\org\example\sudoku\Sudoku.java`

```

import android.view.Menu;
import android.view.MenuInflater;
import android.view.MenuItem;

```

Then we override the `Sudoku.onCreateOptionsMenu()` method:

[Download](#) `Sudoku\src\org\example\sudoku\Sudoku.java`

```

@Override
public boolean onCreateOptionsMenu(Menu menu) {
    super.onCreateOptionsMenu(menu);
    MenuInflater inflater = getMenuInflater();
    inflater.inflate(R.menu.menu, menu);
    return true;
}

```

`getMenuInflater()` returns an instance of `MenuInflater` that we use to read the menu definition from XML and turns it into a real view.

When the user selects any menu item, `onOptionsItemSelected()` will be called. Here's the definition for that method:

[Download](#) `Sudoku\src\org\example\sudoku\Sudoku.java`

```

@Override
public boolean onOptionsItemSelected(MenuItem item) {
    switch (item.getItemId()) {
        case R.id.settings:
            startActivity(new Intent(this, Prefs.class));
            return true;
        // More items go here (if any) ...
    }
}

```

```

    }
    return false;
}

```

Prefs is a class that we're going to define that displays all our preferences and allows the user to change them.

3.8 Adding Settings

Android provides a nice facility for defining what all your program preferences are and how to display them using almost no code. You define the preferences in a resource file called `res/xml/settings.xml`:

Download `SudokuV1/res/xml/settings.xml`

```

<?xml version="1.0" encoding="utf-8"?>
<PreferenceScreen
    xmlns:android="http://schemas.android.com/apk/res/android">
    <CheckBoxPreference
        android:key="music"
        android:title="@string/music_title"
        android:summary="@string/music_summary"
        android:defaultValue="true" />
    <CheckBoxPreference
        android:key="hints"
        android:title="@string/hints_title"
        android:summary="@string/hints_summary"
        android:defaultValue="true" />
</PreferenceScreen>

```

The Sudoku program has two settings: one for background music and one for displaying hints. The keys are constant strings that will be used under the covers in Android's preferences database.

Next define the Prefs class, and make it extend `PreferenceActivity`:

Download `SudokuV1/src/org/example/sudoku/Prefs.java`

```

package org.example.sudoku;

import android.os.Bundle;
import android.preference.PreferenceActivity;

public class Prefs extends PreferenceActivity {
    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        addPreferencesFromResource(R.xml.settings);
    }
}

```

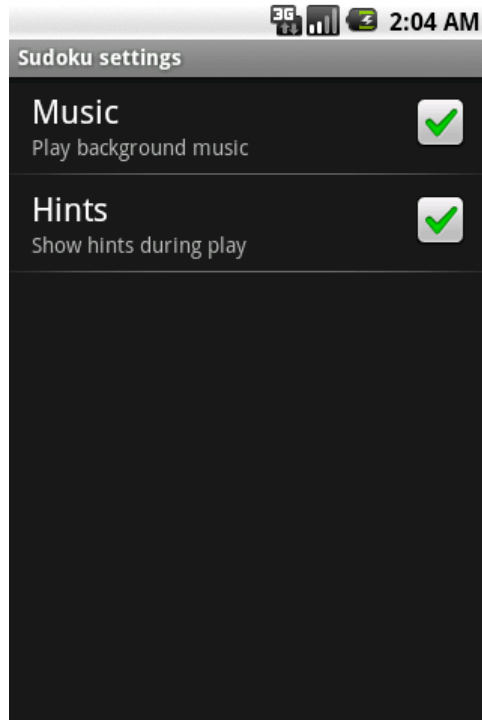


Figure 3.11: It's not much to look at, but we got it for free.

The `addPreferencesFromResource()` method reads the settings definition from XML and inflates it into views in the current activity. All the heavy lifting takes place in the `PreferenceActivity` class.

Don't forget to register the Prefs activity in `AndroidManifest.xml`:

[Download](#) `SudokuV1/AndroidManifest.xml`

```
<activity android:name=".Prefs"
    android:label="@string/settings_title">
</activity>
```

Now rerun Sudoku, press the Menu key, select the Settings... item, and watch with amazement as the Sudoku settings page appears (see Figure 3.11). Try changing the values there and exiting the program, and then come back in and make sure they're all still set.

Code that reads the settings and does something with them will be discussed in a different chapter (Chapter 6, *Storing Local Data*, on page 123). For now let's move on to the New Game button.

3.9 Starting a New Game

If you've played any Sudoku games, you know that some are easy and some are maddeningly hard. So when the user selects New Game, we want to pop up a dialog box asking them to select between three difficulty levels. Selecting from a list of things is easy to do in Android. First we'll need a few more strings in `res/values/strings.xml`:

Download `SudokuV1/res/values/strings.xml`

```
<string name="new_game_title">Difficulty</string>
<string name="easy_label">Easy</string>
<string name="medium_label">Medium</string>
<string name="hard_label">Hard</string>
```

Create the list of difficulties as an array resource in `res/values/arrays.xml`:

Download `SudokuV1/res/values/arrays.xml`

```
<?xml version="1.0" encoding="utf-8"?>
<resources>
    <array name="difficulty">
        <item>@string/easy_label</item>
        <item>@string/medium_label</item>
        <item>@string/hard_label</item>
    </array>
</resources>
```

We'll need a few more imports in the Sudoku class:

Download `SudokuV1/src/org/example/sudoku/Sudoku.java`

```
import android.app.AlertDialog;
import android.content.DialogInterface;
import android.util.Log;
```

Add code in the switch statement of the `onClick()` method to handle clicking the New Game button:

Download `SudokuV1/src/org/example/sudoku/Sudoku.java`

```
case R.id.new_button:
    openNewGameDialog();
    break;
```

The `openNewGameDialog()` method takes care of creating the user interface for the difficulty list.

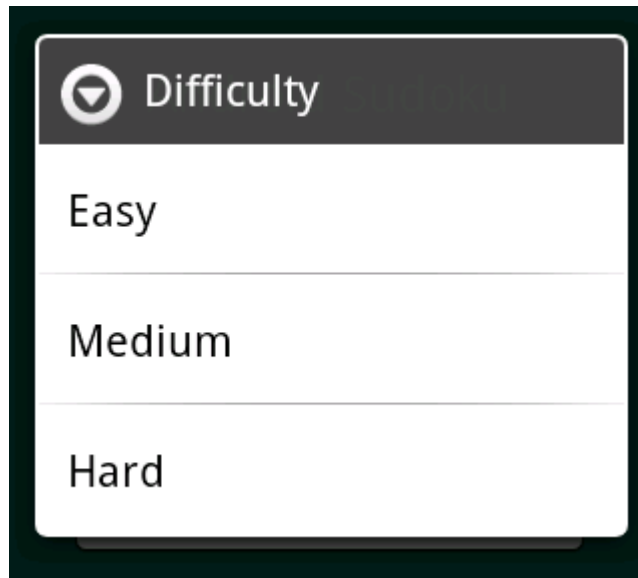


Figure 3.12: Difficulty selection dialog box

[Download](#) `Sudoku\src\org\example\sudoku\Sudoku.java`

```
private static final String TAG = "Sudoku";

private void openNewGameDialog() {
    new AlertDialog.Builder(this)
        .setTitle(R.string.new_game_title)
        .setItems(R.array.difficulty,
            new DialogInterface.OnClickListener() {
                public void onClick(DialogInterface dialoginterface,
                    int i) {
                    startGame(i);
                }
            })
        .show();
}

private void startGame(int i) {
    Log.d(TAG, "clicked on " + i);
    // Start game here...
}
```

The `setItems()` method takes two parameters: the resource ID of the item list and a listener that will be called when one of the items is selected.

When you run the program now and press New Game, you'll get the dialog box in Figure 3.12, on the preceding page.

We're not actually going to start the game yet, so instead when you select a difficulty level, we just print a debug message using the `Log.d()` method, passing it a tag string and a message to print.

3.10 Debugging

The same techniques you use to debug programs on other platforms can be applied to Android. These include printing messages to the log and stepping through your program in a debugger.

Debugging with Log Messages

The `Log` class provides several static methods to print messages of various severity levels to the Android system log:

- `Log.e()`: Errors
- `Log.w()`: Warnings
- `Log.i()`: Information
- `Log.d()`: Debugging
- `Log.v()`: Verbose

Users will never see this log, but as a developer you can view it in a couple ways. In Eclipse, open the LogCat view by selecting Window > Show View > Other... > Android > LogCat (see Figure 3.13, on the next page). The view can be filtered by severity or by the tag you specified on the method call.

If you're not using Eclipse, you can see the same output by running the `adb logcat` command.⁴ I recommend you start this command in a separate window and leave it running all the time that the emulator is running. It won't interfere with any other monitors.

I can't stress enough how useful the Android log will be during development. Remember that error we saw earlier with the About box (Figure 3.7, on page 65)? If you had opened the LogCat view at that point, you would have seen this message: "ActivityNotFoundException: Unable to find explicit activity class...have you declared this activity in your AndroidManifest.xml?" It doesn't get any plainer than that.

4. <http://d.android.com/guide/developing/tools/adb.html>

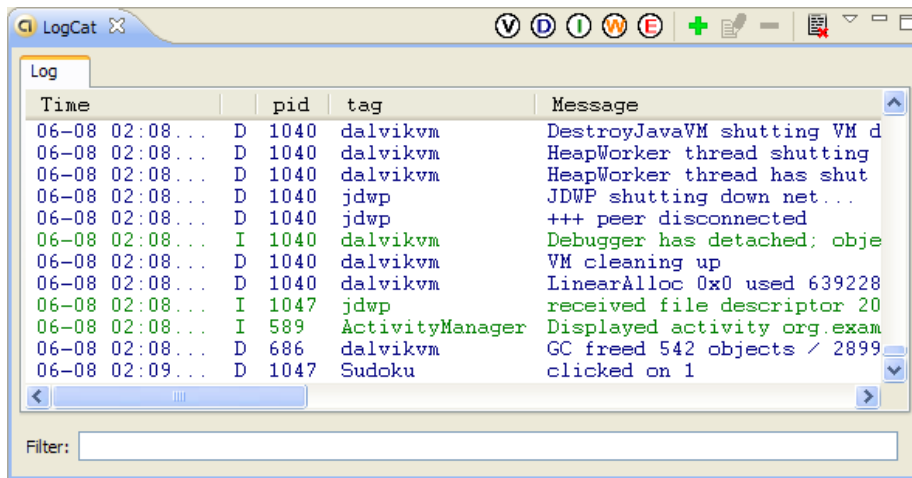


Figure 3.13: Debugging output in the LogCat view

Debugging with the Debugger

In addition to log messages, you can use the Eclipse debugger to set breakpoints, single step, and view the state of your program. First, enable your project for debugging by adding the `android:debuggable="true"` option in your `AndroidManifest.xml` file:⁵

[Download](#) Sudokuv1/AndroidManifest.xml

```
<application android:icon="@drawable/icon"
    android:label="@string/app_name"
    android:debuggable="true">
```

Then, simply right-click the project, and select **Debug As > Android Application**.

3.11 Exiting the Game

This game doesn't really need an Exit button, because the user can just press the Back key or the Home key to do something else. But I wanted to add one to show you how to terminate an activity.

Add this to the switch statement in the `onClick()` method:

5. This is optional if you're using the emulator but required on a real device. Just remember to remove the option before releasing your code to the public.

Download `Sudoku\src\org\example\sudoku\Sudoku.java`

```
case R.id.exit_button:
    finish();
    break;
```

When the Exit button is selected, we call the `finish()` method. This shuts down the activity and returns control to the next activity on the Android application stack (usually the Home screen).

3.12 Fast-Forward >>

Whew, that was a lot to cover in one chapter! Starting from scratch, you learned how to use layout files to organize your user interface and how to use Android resources for text, colors, and more. You added controls such as buttons and text fields, applied themes to change the program's appearance, and even added menus and preferences for good measure.

Android is a complex system, but you don't have to know all of it to get started. When you need help, the hundreds of pages of reference material online go into more depth on all the classes and methods used here.⁶ Another great source for tips and tricks is Planet Android.⁷ And of course, if you get stuck you can always drop by the discussion forum for this book.⁸ The other readers and I will be happy to help you out.

In Chapter 4, *Exploring 2D Graphics*, on the next page, we'll use Android's graphics API to draw the tiles for the Sudoku game.

6. To view the online documentation, open the docs subdirectory of your Android SDK install directory, or point your browser to <http://d.android.com/guide/index.html>.

7. <http://www.planetandroid.com>

8. <http://forums.pragprog.com/forums/152>

Chapter 4

Exploring 2D Graphics

So far, we've covered the basic concepts and philosophy of Android and how to create a simple user interface with a few buttons and a dialog box. You're really starting to get the hang of this Android thing. But something is missing...what is it? Oh yeah, the fun!

Good graphics can add a bit of fun and excitement to any application. Android puts one of the most powerful graphics libraries available on a mobile device at your fingertips. Actually, it puts two of them there: one for two-dimensional graphics and one for three-dimensional graphics.¹

In this chapter, we will cover 2D graphics and apply that knowledge to implement the game part of our Sudoku example. Chapter 10, *3D Graphics in OpenGL*, on page 201 will cover 3D graphics using the OpenGL ES library.

4.1 Learning the Basics

Android provides a complete native two-dimensional graphics library in its `android.graphics` package. With a basic understanding of classes such as `Color` and `Canvas`, you'll be up and drawing in no time.

Color

Android colors are represented with four numbers, one each for alpha, red, green, and blue (ARGB). Each component can have 256 possible values, or 8 bits, so a color is typically packed into a 32-bit integer. For

1. Functionality for four-dimensional graphics was considered for Android, but it was dropped because of a lack of time.

efficiency, Android code uses an integer instead of an instance of the `Color` class.

Red, green, and blue are self-explanatory, but alpha might not be. *Alpha* is a measure of transparency. The lowest value, 0, indicates the color is completely transparent. It doesn't really matter what the values for RGB are, if A is 0. The highest value, 255, indicates the color is completely opaque. Values in the middle are used for translucent, or semitransparent, colors. They let you see some of what is underneath the object being drawn in the foreground.

To create a color, you can use one of the static constants on the `Color` class, like this:

```
int color = Color.BLUE; // solid blue
```

or if you know the alpha, red, green, and blue numbers, you can use one of the static factory methods such as the following:

```
// Translucent purple
color = Color.argb(127, 255, 0, 255);
```

If possible, though, you're usually better off defining all your colors in an XML resource file. This lets you change them easily in one place later:

```
<?xml version="1.0" encoding="utf-8"?>
<resources>
  <color name="mycolor">#7fff00ff</color>
</resources>
```

You can reference colors by name in other XML files, as we did in Chapter 3, or you can use them in Java code like this:

```
color = getResources().getColor(R.color.mycolor);
```

The `getResources()` method returns the `ResourceManager` class for the current activity, and `getColor()` asks the manager to look up a color given a resource ID.

Paint

One of the Android native graphics library's most important classes is the `Paint` class. It holds the style, color, and other information needed to draw any graphics including bitmaps, text, and geometric shapes.

Normally when you paint something on the screen, you want to draw it in a solid color. You set that color with the `Paint.setColor()` method.

For example:

```
cPaint.setColor(Color.LTGRAY);
```

This uses the predefined color value for light gray.

Canvas

The Canvas class represents a surface on which you draw. Initially canvases start off devoid of any content, like blank transparencies for an overhead projector. Methods on the Canvas class let you draw lines, rectangles, circles, or other arbitrary graphics on the surface.

In Android, the display screen is taken up by an Activity, which hosts a View, which in turn hosts a Canvas. You get an opportunity to draw on that canvas by overriding the View.onDraw() method. The only parameter to onDraw() is a canvas on which you can draw.

Here's an example activity called Graphics, which contains a view called GraphicsView:

```
public class Graphics extends Activity {
    @Override
    public void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(new GraphicsView(this));
    }

    static public class GraphicsView extends View {
        public GraphicsView(Context context) {
            super(context);
        }
        @Override
        protected void onDraw(Canvas canvas) {
            // Drawing commands go here
        }
    }
}
```

We're going to put some drawing commands into the onDraw() method in the next section.

Path

The Path class holds a set of vector-drawing commands such as lines, rectangles, and curves. Here's an example that defines a circular path:

```
circle = new Path();
circle.addCircle(150, 150, 100, Direction.CW);
```

Graphics



Figure 4.1: Drawing text around a circle

This defines a circle at position $x=150$, $y=150$, with a radius of 100 pixels. Now that we've defined the path, let's use it to draw the circle's outline plus some text around the inside:

```
private static final String QUOTE = "Now is the time for all " +
    "good men to come to the aid of their country.";
canvas.drawPath(circle, cPaint);
canvas.drawTextOnPath(QUOTE, circle, 0, 20, tPaint);
```

You can see the result in Figure 4.1. Since the circle was drawn in the clockwise direction (`Direction.CW`), the text is also drawn that way.

If you want to get really fancy, Android provides a number of `PathEffect` classes that let you do things such as apply a random permutation to a path, cause all the line segments along a path to be smoothed out with curves or broken up into segments, and create other effects.

Drawable

In Android, a `Drawable` class is used for a visual element like a bitmap or solid color that is intended for display only. You can combine drawables

with other graphics, or you can use them in user interface widgets (for example, as the background for a button or view).

Drawables can take a variety of forms:

- *Bitmap*: A PNG or JPEG image.
- *NinePatch*: A stretchable PNG image, so named because originally it divided the image into nine sections. These are used for the background of resizable bitmap buttons.
- *Shape*: Vector-drawing commands, based on Path. This is sort of a poor man's SVG.
- *Layers*: A container for child drawables that draw on top of each other in a certain z-order.
- *States*: A container that shows one of its child drawables based on its state (a bit mask). One use is to set various selection and focus states for buttons.
- *Levels*: A container that shows only one of its child drawables based on its level (a range of integers). This could be used for a battery or signal strength gauge.
- *Scale*: A container for one child drawable that modifies its size based on the current level. One use might be a zoomable picture viewer.

Drawables are often defined in XML. Here's a common example where a drawable is defined to be a gradient from one color to another (in this case, white to gray). The angle specifies the direction of the gradient (270 degrees means top to bottom). This will be used for the background of a view:

```
<?xml version="1.0" encoding="utf-8"?>
<shape xmlns:android="http://schemas.android.com/apk/res/android">
  <gradient
    android:startColor="#FFFFFF"
    android:endColor="#808080"
    android:angle="270" />
</shape>
```

To use it, we could either refer to it in XML with the `android:background=` attribute or call the `setBackgroundResource()` method in the view's `onCreate()` method like this:

```
setBackgroundResource(R.drawable.background);
```

This gives our `GraphicsView` example a nice gradient background, as shown in Figure 4.2, on the following page.

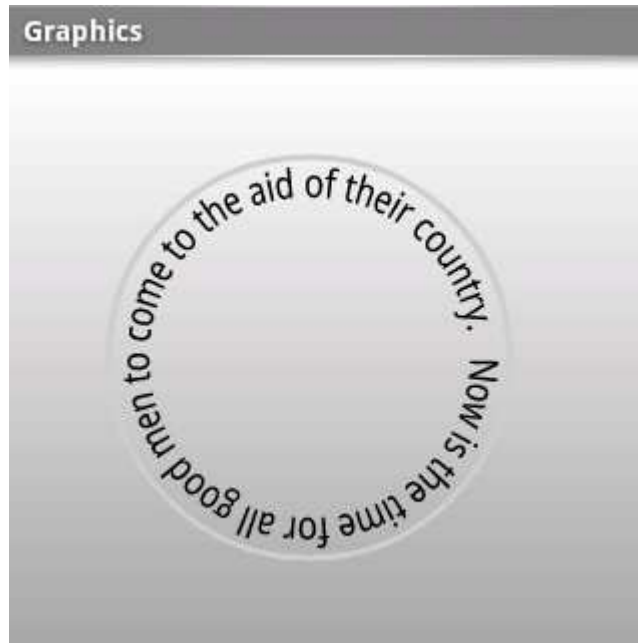


Figure 4.2: Using a gradient background defined in XML

Drawables should be placed in different directories depending on the screen density for which they are designed (see Section 3.4, *Using Alternate Resources*, on page 58).

4.2 Adding Graphics to Sudoku

It's time to apply what we've learned to our Sudoku example. When we left it at the end of Chapter 3, the Sudoku game had an opening screen, an About dialog box, and a way to start a new game. But it was missing one very important part: the game! We'll use the native 2D graphics library to implement that part.

Starting the Game

First we need to fill in the code that starts the game. `startGame()` takes one parameter, the index of the difficulty name selected from the list. Here's the new definition:

[Download](#) `Sudokuv2/src/org/example/sudoku/Sudoku.java`

```
private void startGame(int i) {
```

Sudoku Trivia

A few years after it was published in the United States, Number Place was picked up by the Japanese publisher Nikoli, who gave it the much cooler-sounding name Sudoku (which means “single number” in Japanese). From there it was exported around the world, and the rest is history. Sadly, Garns died in 1989 before getting a chance to see his creation become a worldwide sensation.

```
Log.d(TAG, "clicked on " + i);
Intent intent = new Intent(Sudoku.this, Game.class);
intent.putExtra(Game.KEY_DIFFICULTY, i);
startActivity(intent);
}
```

The game part of Sudoku will be another activity called `Game`, so we create a new intent to kick it off. We place the difficulty number in an `extraData` area provided in the intent, and then we call the `startActivity()` method to launch the new activity.

The `extraData` area is a map of key/value pairs that will be passed along to the intent. The keys are strings, and the values can be any primitive type, array of primitives, `Bundle`, or a subclass of `Serializable` or `Parcelable`.

Defining the Game Class

Here’s the outline of the `Game` activity:

[Download](#) `SudokuV2/src/org/example/sudoku/Game.java`

```
package org.example.sudoku;

import android.app.Activity;
import android.app.Dialog;
import android.os.Bundle;
import android.util.Log;
import android.view.Gravity;
import android.widget.Toast;

public class Game extends Activity {
    private static final String TAG = "Sudoku";

    public static final String KEY_DIFFICULTY =
        "org.example.sudoku.difficulty";
    public static final int DIFFICULTY_EASY = 0;
    public static final int DIFFICULTY_MEDIUM = 1;
```

```

    public static final int DIFFICULTY_HARD = 2;

    private int puzzle[] = new int[9 * 9];

    private PuzzleView puzzleView;

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        Log.d(TAG, "onCreate");

        int diff = getIntent().getIntExtra(KEY_DIFFICULTY,
            DIFFICULTY_EASY);
        puzzle = getPuzzle(diff);
        calculateUsedTiles();

        puzzleView = new PuzzleView(this);
        setContentView(puzzleView);
        puzzleView.requestFocus();
    }
    // ...
}

```

The `onCreate()` method fetches the difficulty number from the intent and selects a puzzle to play. Then it creates an instance of the `PuzzleView` class, setting the `PuzzleView` as the new contents of the view. Since this is a fully customized view, it was easier to do this in code than in XML.

The `calculateUsedTiles()` method, which is defined in Section 4.4, *The Rest of the Story*, on page 97, uses the rules of Sudoku to figure out, for each tile in the nine-by-nine grid, which numbers are not valid for the tile because they appear elsewhere in the horizontal or vertical direction or in the three-by-three subgrid.

This is an activity, so we need to register it in `AndroidManifest.xml`:

[Download](#) `Sudokuv2/AndroidManifest.xml`

```

<activity android:name=".Game"
    android:label="@string/game_title"/>

```

We also need to add a few more string resources to `res/values/strings.xml`:

[Download](#) `Sudokuv2/res/values/strings.xml`

```

<string name="game_title">Game</string>
<string name="no_moves_label">No moves</string>
<string name="keypad_title">Keypad</string>

```

What Size Is It Anyway?

A common mistake made by new Android developers is to use the width and height of a view inside its constructor. When a view's constructor is called, Android doesn't know yet how big the view will be, so the sizes are set to zero. The real sizes are calculated during the layout stage, which occurs after construction but before anything is drawn. You can use the `onSizeChanged()` method to be notified of the values when they are known, or you can use the `getWidth()` and `getHeight()` methods later, such as in the `onDraw()` method.

Defining the PuzzleView Class

Next we need to define the `PuzzleView` class. Instead of using an XML layout, this time let's do it entirely in Java.

Here's the outline:

[Download](#) `SudokuV2/src/org/example/sudoku/PuzzleView.java`

```
package org.example.sudoku;

import android.content.Context;
import android.graphics.Canvas;
import android.graphics.Paint;
import android.graphics.Rect;
import android.graphics.Paint.FontMetrics;
import android.graphics.Paint.Style;
import android.util.Log;
import android.view.KeyEvent;
import android.view.MotionEvent;
import android.view.View;
import android.view.animation.AnimationUtils;

public class PuzzleView extends View {
    private static final String TAG = "Sudoku";
    private final Game game;
    public PuzzleView(Context context) {
        super(context);
        this.game = (Game) context;
        setFocusable(true);
        setFocusableInTouchMode(true);
    }
    // ...
}
```

Other Ways to Do It

When I was writing this example, I tried several different approaches such as using a button for each tile or declaring a grid of `ImageView` classes in XML. After many false starts, I found that the approach of having one view for the entire puzzle and drawing lines and numbers inside that proved to be the fastest and easiest way for this application.

It does have its drawbacks, though, such as the need to draw the selection and explicitly handle keyboard and touch events. When designing your own program, I recommend trying standard widgets and views first and then falling back to custom drawing only if that doesn't work for you.

In the constructor we keep a reference to the `Game` class and set the option to allow user input in the view. Inside `PuzzleView`, we need to implement the `onSizeChanged()` method. This is called after the view is created and Android knows how big everything is.

[Download](#) `Sudoku2/src/org/example/sudoku/PuzzleView.java`

```
private float width;    // width of one tile
private float height;   // height of one tile
private int selX;       // X index of selection
private int selY;       // Y index of selection
private final Rect selRect = new Rect();

@Override
protected void onSizeChanged(int w, int h, int oldw, int oldh) {
    width = w / 9f;
    height = h / 9f;
    getRect(selX, selY, selRect);
    Log.d(TAG, "onSizeChanged: width " + width + ", height "
        + height);
    super.onSizeChanged(w, h, oldw, oldh);
}

private void getRect(int x, int y, Rect rect) {
    rect.set((int) (x * width), (int) (y * height), (int) (x
        * width + width), (int) (y * height + height));
}
```

We use `onSizeChanged()` to calculate the size of each tile on the screen (1/9th of the total view width and height). Note this is a floating-point number, so it's possible that we could end up with a fractional num-

ber of pixels. `selRect` is a rectangle we'll use later to keep track of the selection cursor.

At this point we've created a view for the puzzle, and we know how big it is. The next step is to draw the grid lines that separate the tiles on the board.

Drawing the Board

Android calls a view's `onDraw()` method every time any part of the view needs to be updated. To simplify things, `onDraw()` pretends that you're re-creating the entire screen from scratch. In reality, you may be drawing only a small portion of the view as defined by the canvas's clip rectangle. Android takes care of doing the clipping for you.

Start by defining a few new colors to play with in `res/values/colors.xml`:

[Download](#) `Sudoku2/res/values/colors.xml`

```
<color name="puzzle_background">#ffe6f0ff</color>
<color name="puzzle_hilite">#ffffff</color>
<color name="puzzle_light">#64c6d4ef</color>
<color name="puzzle_dark">#6456648f</color>
<color name="puzzle_foreground">#ff000000</color>
<color name="puzzle_hint_0">#64ff0000</color>
<color name="puzzle_hint_1">#6400ff80</color>
<color name="puzzle_hint_2">#2000ff80</color>
<color name="puzzle_selected">#64ff8000</color>
```

Here's the basic outline for `onDraw()`:

[Download](#) `Sudoku2/src/org/example/sudoku/PuzzleView.java`

```
@Override
protected void onDraw(Canvas canvas) {
    // Draw the background...
    Paint background = new Paint();
    background.setColor(getResources().getColor(
        R.color.puzzle_background));
    canvas.drawRect(0, 0, getWidth(), getHeight(), background);

    // Draw the board...
    // Draw the numbers...
    // Draw the hints...
    // Draw the selection...
}
```

The first parameter is the `Canvas` on which to draw. In this code, we're just drawing a background for the puzzle using the `puzzle_background` color.

Now let's add the code to draw the grid lines for the board:

[Download](#) `Sudoku2/src/org/example/sudoku/PuzzleView.java`

```
// Draw the board...
// Define colors for the grid lines
Paint dark = new Paint();
dark.setColor(getResources().getColor(R.color.puzzle_dark));

Paint hilite = new Paint();
hilite.setColor(getResources().getColor(R.color.puzzle_hilite));

Paint light = new Paint();
light.setColor(getResources().getColor(R.color.puzzle_light));

// Draw the minor grid lines
for (int i = 0; i < 9; i++) {
    canvas.drawLine(0, i * height, getWidth(), i * height,
        light);
    canvas.drawLine(0, i * height + 1, getWidth(), i * height
        + 1, hilite);
    canvas.drawLine(i * width, 0, i * width, getHeight(),
        light);
    canvas.drawLine(i * width + 1, 0, i * width + 1,
        getHeight(), hilite);
}

// Draw the major grid lines
for (int i = 0; i < 9; i++) {
    if (i % 3 != 0)
        continue;
    canvas.drawLine(0, i * height, getWidth(), i * height,
        dark);
    canvas.drawLine(0, i * height + 1, getWidth(), i * height
        + 1, hilite);
    canvas.drawLine(i * width, 0, i * width, getHeight(), dark);
    canvas.drawLine(i * width + 1, 0, i * width + 1,
        getHeight(), hilite);
}
```

The code uses three different colors for the grid lines: a light color between each tile, a dark color between the three-by-three blocks, and a highlight color drawn on the edge of each tile to make them look like they have a little depth. The order in which the lines are drawn is important, since lines drawn later will be drawn over the top of earlier lines. You can see what this will look like in Figure 4.3, on the next page. Next, we need some numbers to go inside those lines.

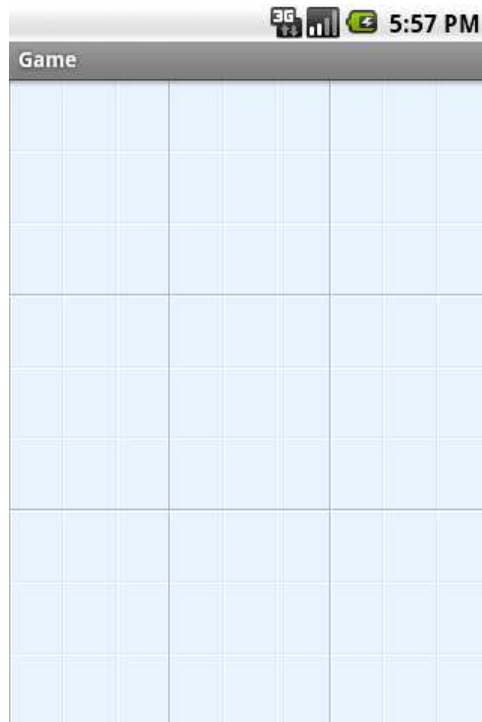


Figure 4.3: Drawing the grid lines with three shades of gray for an embossed effect

Drawing the Numbers

The following code draws the puzzle numbers on top of the tiles. The tricky part here is getting each number positioned and sized so it goes in the exact center of its tile.

[Download](#) `Sudoku2/src/org/example/sudoku/PuzzleView.java`

```
// Draw the numbers...
// Define color and style for numbers
Paint foreground = new Paint(Paint.ANTI_ALIAS_FLAG);
foreground.setColor(getResources().getColor(
    R.color.puzzle_foreground));
foreground.setStyle(Style.FILL);
foreground.setTextSize(height * 0.75f);
foreground.setTextScaleX(width / height);
foreground.setTextAlign(Paint.Align.CENTER);

// Draw the number in the center of the tile
```



Figure 4.4: Centering the numbers inside the tiles

```
FontMetrics fm = foreground.getFontMetrics();
// Centering in X: use alignment (and X at midpoint)
float x = width / 2;
// Centering in Y: measure ascent/descent first
float y = height / 2 - (fm.ascent + fm.descent) / 2;
for (int i = 0; i < 9; i++) {
    for (int j = 0; j < 9; j++) {
        canvas.drawText(this.game.getTileString(i, j), i
            * width + x, j * height + y, foreground);
    }
}
```

We call the `getTileString()` method (defined in Section 4.4, *The Rest of the Story*, on page 97) to find out what numbers to display. To calculate the size of the numbers, we set the font height to three-fourths the height of the tile, and we set the aspect ratio to be the same as the tile's aspect ratio. We can't use absolute pixel or point sizes because we want the program to work at any resolution.

To determine the position of each number, we center it in both the x and y dimensions. The x direction is easy—just divide the tile width by 2. But for the y direction, we have to adjust the starting position downward a little so that the midpoint of the tile will be the midpoint of the number instead of its baseline. We use the graphics library's `FontMetrics` class to tell how much vertical space the letter will take in total, and then we divide that in half to get the adjustment. You can see the results in Figure 4.4, on the previous page.

That takes care of displaying the puzzle's starting numbers (the givens). The next step is to allow the player to enter their guesses for all the blank spaces.

4.3 Handling Input

One difference in Android programming—as opposed to, say, iPhone programming—is that Android phones come in many shapes and sizes and have a variety of input methods. They might have a keyboard, a D-pad, a touch screen, a trackball, or some combination of these.

A good Android program, therefore, needs to be ready to support whatever input hardware is available, just like it needs to be ready to support any screen resolution.

Defining and Updating the Selection

First we're going to implement a little cursor that shows the player which tile is currently selected. The selected tile is the one that will be modified when the player enters a number. This code will draw the selection in `onDraw()`:

```
Download Sudokuv2/src/org/example/sudoku/PuzzleView.java
// Draw the selection...
Log.d(TAG, "selRect=" + selRect);
Paint selected = new Paint();
selected.setColor(getResources().getColor(
    R.color.puzzle_selected));
canvas.drawRect(selRect, selected);
```

We use the selection rectangle calculated earlier in `onSizeChanged()` to draw an alpha-blended color on top of the selected tile.

Next we provide a way to move the selection by overriding the `onKeyDown()` method:

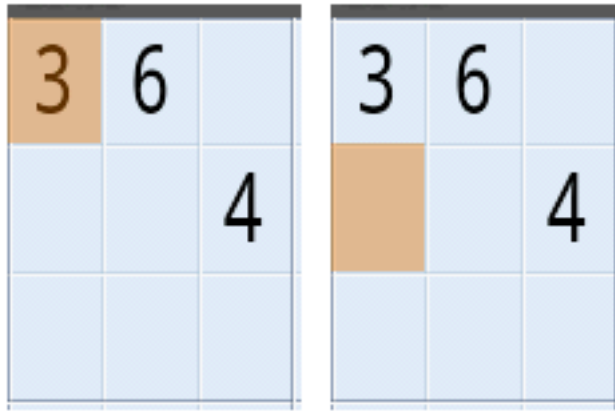


Figure 4.5: Drawing and moving the selection

[Download](#) `Sudoku2/src/org/example/sudoku/PuzzleView.java`

```
@Override
public boolean onKeyDown(int keyCode, KeyEvent event) {
    Log.d(TAG, "onKeyDown: keycode=" + keyCode + ", event="
        + event);
    switch (keyCode) {
        case KeyEvent.KEYCODE_DPAD_UP:
            select(selX, selY - 1);
            break;
        case KeyEvent.KEYCODE_DPAD_DOWN:
            select(selX, selY + 1);
            break;
        case KeyEvent.KEYCODE_DPAD_LEFT:
            select(selX - 1, selY);
            break;
        case KeyEvent.KEYCODE_DPAD_RIGHT:
            select(selX + 1, selY);
            break;
        default:
            return super.onKeyDown(keyCode, event);
    }
    return true;
}
```

If the user has a directional pad (D-pad) and they press the up, down, left, or right button, we call `select()` to move the selection cursor in that direction.

How about a trackball? We could override the `onTrackballEvent()` method, but it turns out that if you don't handle trackball events, Android will translate them into D-pad events automatically. Therefore, we can leave it out for this example.

Inside the `select()` method, we calculate the new `x` and `y` coordinate of the selection and then use `getRect()` again to calculate the new selection rectangle.

Download `Sudoku2/src/org/example/sudoku/PuzzleView.java`

```
private void select(int x, int y) {
    invalidate(selRect);
    selX = Math.min(Math.max(x, 0), 8);
    selY = Math.min(Math.max(y, 0), 8);
    getRect(selX, selY, selRect);
    invalidate(selRect);
}
```

Notice the two calls to `invalidate()`. The first one tells Android that the area covered by the old selection rectangle (on the left of Figure 4.5, on the preceding page) needs to be redrawn. The second `invalidate()` call says that the new selection area (on the right of the figure) needs to be redrawn too. We don't actually draw anything here.

This is an important point: never call any drawing functions except in the `onDraw()` method. Instead, you use the `invalidate()` method to mark rectangles as *dirty*. The window manager will combine all the dirty rectangles at some point in the future and call `onDraw()` again for you. The dirty rectangles become the clip region, so screen updates are optimized to only those areas that change.

Now let's provide a way for the player to enter a new number on the selected tile.

Entering Numbers

To handle keyboard input, we just add a few more cases to the `onKeyDown()` method for the numbers 0 through 9 (0 or space means erase the number).

Download `Sudoku2/src/org/example/sudoku/PuzzleView.java`

```
case KeyEvent.KEYCODE_0:
case KeyEvent.KEYCODE_SPACE: setSelectedTile(0); break;
case KeyEvent.KEYCODE_1:     setSelectedTile(1); break;
case KeyEvent.KEYCODE_2:     setSelectedTile(2); break;
case KeyEvent.KEYCODE_3:     setSelectedTile(3); break;
case KeyEvent.KEYCODE_4:     setSelectedTile(4); break;
```

Optimizing Refreshes

In an earlier version of this example, I invalidated the entire screen whenever the cursor was moved. Thus, on every key press, the whole puzzle had to be redrawn. This caused it to lag noticeably. Switching the code to invalidate only the smallest rectangles that changed made it run much faster.

```
case KeyEvent.KEYCODE_5:      setSelectedTile(5); break;
case KeyEvent.KEYCODE_6:      setSelectedTile(6); break;
case KeyEvent.KEYCODE_7:      setSelectedTile(7); break;
case KeyEvent.KEYCODE_8:      setSelectedTile(8); break;
case KeyEvent.KEYCODE_9:      setSelectedTile(9); break;
case KeyEvent.KEYCODE_ENTER:
case KeyEvent.KEYCODE_DPAD_CENTER:
    game.showKeypadOnError(selX, selY);
    break;
```

To support the D-pad, we check for the Enter or center D-pad button in `onKeyDown()` and have it pop up a keypad that lets the user select which number to place.

For touch, we override the `onTouchEvent()` method and show the same keypad, which will be defined later:

[Download](#) `Sudoku2/src/org/example/sudoku/PuzzleView.java`

```
@Override
public boolean onTouchEvent(MotionEvent event) {
    if (event.getAction() != MotionEvent.ACTION_DOWN)
        return super.onTouchEvent(event);

    select((int) (event.getX() / width),
           (int) (event.getY() / height));
    game.showKeypadOnError(selX, selY);
    Log.d(TAG, "onTouchEvent: x " + selX + ", y " + selY);
    return true;
}
```

Ultimately, all roads will lead back to a call to `setSelectedTile()` to change the number on a tile:

[Download](#) `Sudoku2/src/org/example/sudoku/PuzzleView.java`

```
public void setSelectedTile(int tile) {
    if (game.setTileIfValid(selX, selY, tile)) {
```

```

        invalidate();// may change hints
    } else {
        // Number is not valid for this tile
        Log.d(TAG, "setSelectedTile: invalid: " + tile);
    }
}

```

The `showKeypadOnError()` and `setTileIsValid()` methods will be defined in Section 4.4, *The Rest of the Story*, on page 97.

Note the call to `invalidate()` with no parameters. That marks the whole screen as dirty, which violates my own advice earlier! However, in this case, it's necessary because any new numbers added or removed might change the hints that we are about to implement in the next section.

Adding Hints

How can we help the player out a little without solving the whole puzzle for them? How about if we draw the background of each tile differently depending on how many possible moves it has. Add this to `onDraw()` before drawing the selection:

[Download](#) `SudokuV2/src/org/example/sudoku/PuzzleView.java`

```

// Draw the hints...
// Pick a hint color based on #moves left
Paint hint = new Paint();
int c[] = { getResources().getColor(R.color.puzzle_hint_0),
            getResources().getColor(R.color.puzzle_hint_1),
            getResources().getColor(R.color.puzzle_hint_2), };
Rect r = new Rect();
for (int i = 0; i < 9; i++) {
    for (int j = 0; j < 9; j++) {
        int movesleft = 9 - game.getUsedTiles(i, j).length;
        if (movesleft < c.length) {
            getRect(i, j, r);
            hint.setColor(c[movesleft]);
            canvas.drawRect(r, hint);
        }
    }
}
}

```

We use three states for zero, one, and two possible moves. If there are zero moves, that means the player has done something wrong and needs to backtrack.

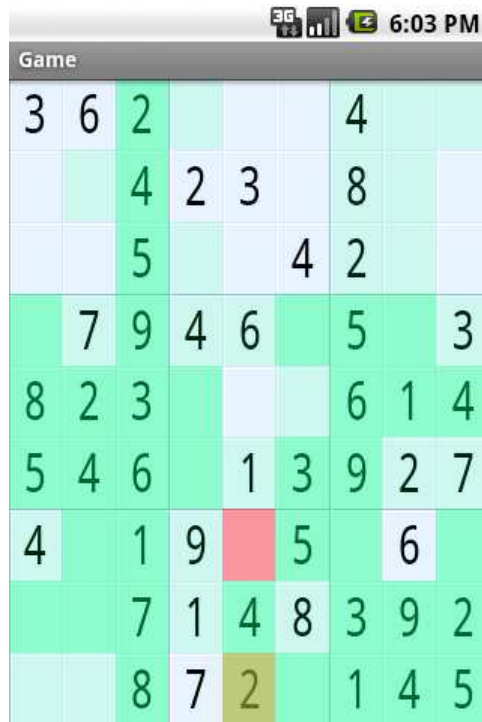


Figure 4.6: Tiles are highlighted based on how many possible values the tile can have.

The result will look like Figure 4.6. Can you spot the mistake(s) made by the player?²

Shaking Things Up

What if the user tries to enter an obviously invalid number, such as a number that already appears in the three-by-three block? Just for fun, let's make the screen wiggle back and forth when they do that. First we add a call to the invalid number case in `setSelectedTile()`.

[Download](#) `Sudoku2/src/org/example/sudoku/PuzzleView.java`

```
Log.d(TAG, "setSelectedTile: invalid: " + tile);
startAnimation(AnimationUtils.loadAnimation(game,
    R.anim.shake));
```

2. The two numbers on the bottom row, middle block, are wrong.

This loads and runs a resource called `R.anim.shake`, defined in `res/anim/shake.xml`, that shakes the screen for 1,000 milliseconds (1 second) by 10 pixels from side to side.

[Download](#) `Sudoku2/res/anim/shake.xml`

```
<?xml version="1.0" encoding="utf-8"?>
<translate
  xmlns:android="http://schemas.android.com/apk/res/android"
  android:fromXDelta="0"
  android:toXDelta="10"
  android:duration="1000"
  android:interpolator="@anim/cycle_7" />
```

The number of times to run the animation and the velocity and acceleration of the animation are controlled by an animation interpolator defined in XML.

[Download](#) `Sudoku2/res/anim/cycle_7.xml`

```
<?xml version="1.0" encoding="utf-8"?>
<cycleInterpolator
  xmlns:android="http://schemas.android.com/apk/res/android"
  android:cycles="7" />
```

This particular one will cause the animation to be repeated seven times.

4.4 The Rest of the Story

Now let's go back and tie up a few loose ends, starting with the Keypad class. These pieces are necessary for the program to compile and operate but have nothing to do with graphics. Feel free to skip ahead to Section 4.5, *Making More Improvements*, on page 106 if you like.

Creating the Keypad

The keypad is handy for phones that don't have keyboards. It displays a grid of the numbers 1 through 9 in an activity that appears on top of the puzzle. The whole purpose of the keypad dialog box is to return a number selected by the player.

Here's the user interface layout from `res/layout/keypad.xml`:

[Download](#) `Sudoku2/res/layout/keypad.xml`

```
<?xml version="1.0" encoding="utf-8"?>
<TableLayout
  xmlns:android="http://schemas.android.com/apk/res/android"
  android:id="@+id/keypad"
  android:orientation="vertical"
  android:layout_width="wrap_content"
  android:layout_height="wrap_content">
```

```

        android:stretchColumns="*">
        <TableRow>
            <Button android:id="@+id/keypad_1"
                android:text="1">
            </Button>
            <Button android:id="@+id/keypad_2"
                android:text="2">
            </Button>
            <Button android:id="@+id/keypad_3"
                android:text="3">
            </Button>
        </TableRow>
        <TableRow>
            <Button android:id="@+id/keypad_4"
                android:text="4">
            </Button>
            <Button android:id="@+id/keypad_5"
                android:text="5">
            </Button>
            <Button android:id="@+id/keypad_6"
                android:text="6">
            </Button>
        </TableRow>
        <TableRow>
            <Button android:id="@+id/keypad_7"
                android:text="7">
            </Button>
            <Button android:id="@+id/keypad_8"
                android:text="8">
            </Button>
            <Button android:id="@+id/keypad_9"
                android:text="9">
            </Button>
        </TableRow>
    </TableRow>
</TableLayout>

```

Next let's define the Keypad class. Here's the outline:

[Download](#) `Sudoku2/src/org/example/sudoku/Keypad.java`

```

package org.example.sudoku;

import android.app.Dialog;
import android.content.Context;
import android.os.Bundle;
import android.view.KeyEvent;
import android.view.View;

public class Keypad extends Dialog {

    protected static final String TAG = "Sudoku";

```

```

private final View keys[] = new View[9];
private View keypad;

private final int useds[];
private final PuzzleView puzzleView;

public Keypad(Context context, int useds[], PuzzleView puzzleView) {
    super(context);
    this.useds = useds;
    this.puzzleView = puzzleView;
}

@Override
protected void onCreate(Bundle savedInstanceState) {
    super.onCreate(savedInstanceState);

    setTitle(R.string.keypad_title);
    setContentView(R.layout.keypad);
    findViews();
    for (int element : useds) {
        if (element != 0)
            keys[element - 1].setVisibility(View.INVISIBLE);
    }
    setListeners();
}

// ...
}

```

If a particular number is not valid (for example, the same number already appears in that row), then we make the number invisible in the grid so the player can't select it (see Figure 4.7, on the following page). The `findViews()` method fetches and saves the views for all the keypad keys and the main keypad window:

[Download](#) `Sudokuv2/src/org/example/sudoku/Keypad.java`

```

private void findViews() {
    keypad = findViewById(R.id.keypad);
    keys[0] = findViewById(R.id.keypad_1);
    keys[1] = findViewById(R.id.keypad_2);
    keys[2] = findViewById(R.id.keypad_3);
    keys[3] = findViewById(R.id.keypad_4);
    keys[4] = findViewById(R.id.keypad_5);
    keys[5] = findViewById(R.id.keypad_6);
    keys[6] = findViewById(R.id.keypad_7);
    keys[7] = findViewById(R.id.keypad_8);
    keys[8] = findViewById(R.id.keypad_9);
}

```



Figure 4.7: Invalid values are hidden in the keypad view.

`setListeners()` loops through all the keypad keys and sets a listener for each one. It also sets a listener for the main keypad window:

[Download](#) `Sudoku2/src/org/example/sudoku/Keypad.java`

```
private void setListeners() {
    for (int i = 0; i < keys.length; i++) {
        final int t = i + 1;
        keys[i].setOnClickListener(new View.OnClickListener() {
            public void onClick(View v) {
                returnResult(t);
            }
        });
    }
    keypad.setOnClickListener(new View.OnClickListener() {
        public void onClick(View v) {
            returnResult(0);
        }
    });
}
```

When the player selects one of the buttons on the keypad, it calls the `returnResult()` method with the number for that button. If the player selects a place that doesn't have a button, then `returnResult()` is called with a zero, indicating the tile should be erased.

`onKeyDown()` is called when the player uses the keyboard to enter a number:

[Download](#) `Sudoku2/src/org/example/sudoku/Keypad.java`

```
@Override
public boolean onKeyDown(int keyCode, KeyEvent event) {
    int tile = 0;
    switch (keyCode) {
        case KeyEvent.KEYCODE_0:
        case KeyEvent.KEYCODE_SPACE: tile = 0; break;
        case KeyEvent.KEYCODE_1:     tile = 1; break;
        case KeyEvent.KEYCODE_2:     tile = 2; break;
        case KeyEvent.KEYCODE_3:     tile = 3; break;
        case KeyEvent.KEYCODE_4:     tile = 4; break;
        case KeyEvent.KEYCODE_5:     tile = 5; break;
        case KeyEvent.KEYCODE_6:     tile = 6; break;
        case KeyEvent.KEYCODE_7:     tile = 7; break;
        case KeyEvent.KEYCODE_8:     tile = 8; break;
        case KeyEvent.KEYCODE_9:     tile = 9; break;
        default:
            return super.onKeyDown(keyCode, event);
    }
    if (isValid(tile)) {
        returnResult(tile);
    }
    return true;
}
```

If the number is valid for the current tile, then it calls `returnResult()`; otherwise, the keystroke is ignored.

The `isValid()` method checks to see whether the given number is valid for the current position:

[Download](#) `Sudoku2/src/org/example/sudoku/Keypad.java`

```
private boolean isValid(int tile) {
    for (int t : useds) {
        if (tile == t)
            return false;
    }
    return true;
}
```

If it appears in the used array, then it's not valid because the same number is already used in the current row, column, or block.

The `returnResult()` method is called to return the number selected to the calling activity:

[Download](#) `Sudoku2/src/org/example/sudoku/Keypad.java`

```
private void returnResult(int tile) {
    puzzleView.setSelectedTile(tile);
    dismiss();
}
```

We call the `PuzzleView.setSelectedTile()` method to change the puzzle's current tile. The `dismiss` call terminates the Keypad dialog box.

Now that we have the activity, let's call it in the `Game` class and retrieve the result:

[Download](#) `Sudoku2/src/org/example/sudoku/Game.java`

```
protected void showKeypadOnError(int x, int y) {
    int tiles[] = getUsedTiles(x, y);
    if (tiles.length == 9) {
        Toast toast = Toast.makeText(this,
            R.string.no_moves_label, Toast.LENGTH_SHORT);
        toast.setGravity(Gravity.CENTER, 0, 0);
        toast.show();
    } else {
        Log.d(TAG, "showKeypad: used=" + toPuzzleString(tiles));
        Dialog v = new Keypad(this, tiles, puzzleView);
        v.show();
    }
}
```

To decide which numbers are possible, we pass the Keypad a string in the `extraData` area containing all the numbers that have already been used.

Implementing the Game Logic

The rest of the code in `Game.java` concerns itself with the logic of the game, in particular with determining which are and aren't valid moves according to the rules. The `setTileIfValid()` method is a key part of that. Given an `x` and `y` position and the new value of a tile, it changes the tile only if the value provided is valid.

[Download](#) `Sudoku2/src/org/example/sudoku/Game.java`

```
protected boolean setTileIfValid(int x, int y, int value) {
    int tiles[] = getUsedTiles(x, y);
    if (value != 0) {
```

```

        for (int tile : tiles) {
            if (tile == value)
                return false;
        }
    }
    setTile(x, y, value);
    calculateUsedTiles();
    return true;
}

```

To detect valid moves, we create an array for every tile in the grid. For each position, it keeps a list of filled-in tiles that are currently visible from that position. If a number appears on the list, then it won't be valid for the current tile. The `getUsedTiles()` method retrieves that list for a given tile position:

[Download](#) `Sudoku2/src/org/example/sudoku/Game.java`

```

private final int used[][][] = new int[9][9][];

protected int[] getUsedTiles(int x, int y) {
    return used[x][y];
}

```

The array of used tiles is somewhat expensive to compute, so we cache the array and recalculate it only when necessary by calling `calculateUsedTiles()`:

[Download](#) `Sudoku2/src/org/example/sudoku/Game.java`

```

private void calculateUsedTiles() {
    for (int x = 0; x < 9; x++) {
        for (int y = 0; y < 9; y++) {
            used[x][y] = calculateUsedTiles(x, y);
            // Log.d(TAG, "used[" + x + "][" + y + "] = "
            // + toString(used[x][y]));
        }
    }
}

```

`calculateUsedTiles()` simply calls `calculateUsedTiles(x, y)` on every position in the nine-by-nine grid:

[Download](#) `Sudoku2/src/org/example/sudoku/Game.java`

```

Line 1 private int[] calculateUsedTiles(int x, int y) {
-     int c[] = new int[9];
-     // horizontal
-     for (int i = 0; i < 9; i++) {
5         if (i == y)
-             continue;
-         int t = getTile(x, i);
-         if (t != 0)

```

```

-         c[t - 1] = t;
10     }
-     // vertical
-     for (int i = 0; i < 9; i++) {
-         if (i == x)
-             continue;
15         int t = getTile(i, y);
-         if (t != 0)
-             c[t - 1] = t;
-     }
-     // same cell block
20     int startx = (x / 3) * 3;
-     int starty = (y / 3) * 3;
-     for (int i = startx; i < startx + 3; i++) {
-         for (int j = starty; j < starty + 3; j++) {
-             if (i == x && j == y)
25                 continue;
-             int t = getTile(i, j);
-             if (t != 0)
-                 c[t - 1] = t;
-         }
30     }
-     // compress
-     int nused = 0;
-     for (int t : c) {
-         if (t != 0)
35             nused++;
-     }
-     int c1[] = new int[nused];
-     nused = 0;
-     for (int t : c) {
40         if (t != 0)
-             c1[nused++] = t;
-     }
-     return c1;
- }

```

We start with an array of nine zeros. On line 4, we check all the tiles on the same horizontal row as the current tile, and if a tile is occupied, we stuff its number into the array.

On line 12, we do the same thing for all the tiles on the same vertical column, and on line 20, we do the same for tiles in the three-by-three block.

The last step, starting at line 32, is to compress the zeros out of the array before we return it. We do this so that `array.length` can be used to quickly tell how many used tiles are visible from the current position.

Miscellaneous

Here are a few other utility functions and variables that round out the implementation. `easyPuzzle`, `mediumPuzzle`, and `hardPuzzle` are our hard-coded Sudoku puzzles for easy, medium, and hard difficulty levels, respectively.

[Download](#) `Sudoku2/src/org/example/sudoku/Game.java`

```
private final String easyPuzzle =
    "36000000000423080000004200" +
    "070460003820000014500013020" +
    "001900000007048300000000045";
private final String mediumPuzzle =
    "650000070000506000014000005" +
    "007009000002314700000700800" +
    "5000006300002010000300000097";
private final String hardPuzzle =
    "009000000080605020501078000" +
    "000000700706040102004000000" +
    "000720903090301080000000600";
```

`getPuzzle()` simply takes a difficulty level and returns a puzzle:

[Download](#) `Sudoku2/src/org/example/sudoku/Game.java`

```
private int[] getPuzzle(int diff) {
    String puz;
    // TODO: Continue last game
    switch (diff) {
        case DIFFICULTY_HARD:
            puz = hardPuzzle;
            break;
        case DIFFICULTY_MEDIUM:
            puz = mediumPuzzle;
            break;
        case DIFFICULTY_EASY:
        default:
            puz = easyPuzzle;
            break;
    }
    return fromPuzzleString(puz);
}
```

Later we'll change `getPuzzle()` to implement a continue function.

`toPuzzleString()` converts a puzzle from an array of integers to a string. `fromPuzzleString()` does the opposite.

[Download](#) `Sudoku2/src/org/example/sudoku/Game.java`

```
static private String toPuzzleString(int[] puz) {
    StringBuilder buf = new StringBuilder();
    for (int element : puz) {
```

```

        buf.append(element);
    }
    return buf.toString();
}

static protected int[] fromPuzzleString(String string) {
    int[] puz = new int[string.length()];
    for (int i = 0; i < puz.length; i++) {
        puz[i] = string.charAt(i) - '0';
    }
    return puz;
}

```

The `getTile()` method takes `x` and `y` positions and returns the number currently occupying that tile. If it's zero, that means the tile is blank.

[Download](#) `Sudoku2/src/org/example/sudoku/Game.java`

```

private int getTile(int x, int y) {
    return puzzle[y * 9 + x];
}

private void setTile(int x, int y, int value) {
    puzzle[y * 9 + x] = value;
}

```

`getTileString()` is used when displaying a tile. It will return either a string with the value of the tile or an empty string if the tile is blank.

[Download](#) `Sudoku2/src/org/example/sudoku/Game.java`

```

protected String getTileString(int x, int y) {
    int v = getTile(x, y);
    if (v == 0)
        return "";
    else
        return String.valueOf(v);
}

```

Once all these pieces are in place, you should have a playable Sudoku game. Give it a try to verify it works. As with any code, though, there is room for improvement.

4.5 Making More Improvements

Although the code presented in this chapter performs acceptably for a Sudoku game, more complex programs will likely need to be more carefully written in order to squeeze the last drop of performance out of the device. In particular, the `onDraw()` method is a very performance-critical piece of code, so it's best to do as little as possible there.

Here are some ideas for speeding up this method:

- If possible, avoid doing any object allocations in the method `onDraw()`.
- Prefetch things such as color constants elsewhere (for example, in the view's constructor).
- Create your `Paint` objects up front, and just use existing instances in `onDraw()`.
- For values used multiple times, such as the width returned by `getWidth()`, retrieve the value at the beginning of the method and then access it from your local copy.

As a further exercise for the reader, I encourage you to think about how you could make the Sudoku game graphically richer. For example, you could add some fireworks when the player solves the puzzle or make the tiles spin around like Vanna White does. A moving background behind the puzzle might be interesting. Let your imagination go wild. If you want to make a top-notch product, touches like this can add pizzazz to an otherwise ordinary offering.

In Chapter 5, *Multimedia*, on the next page, we'll enhance the program with a little mood music, and in Chapter 6, *Storing Local Data*, on page 123, we'll see how to remember the puzzle state and finally implement that Continue button.

4.6 Fast-Forward >>

In this chapter, we just scratched the surface of Android's graphics capabilities. The native 2D library is quite large, so as you're actually writing your programs, be sure to take advantage of the tooltips, auto-completion, and Javadoc provided by the Android Eclipse plug-in. The online documentation for the `android.graphics`³ package goes into much more detail if you need it.

If your program needs more advanced graphics, you may want to look ahead a bit and read Chapter 10, *3D Graphics in OpenGL*, on page 201. There you'll find information on how to use Android's 3D graphics library, which is based on the OpenGL ES standard. Otherwise, turn to the next chapter for an introduction to the wonderful world of Android audio and video.

3. <http://d.android.com/reference/android/graphics/package-summary.html>

Chapter 5

Multimedia

Remember those Apple television ads with the silhouette people dancing wildly to the beat of their iPods? That's the kind of excitement you want your products to generate.¹ Music, sound effects, and video can make your programs more immersive and engaging than text and graphics alone.

This chapter will show you how to add multimedia to your Android application. You may not have your users cavorting in the aisles, but if you do it properly, you can at least put smiles on their faces.

5.1 Playing Audio

It was a dark and stormy night.... There goes the starting shot, and they're off.... The crowd goes wild as State sinks a three-pointer with one second remaining....

Audio cues permeate the environment and set the tempo for our emotions. Think of sound as another way to get into your user's head. Just like you use graphics on the display to convey some information to the user, you can use audio to back that up and reinforce it.

Android supports sound and music output through the `MediaPlayer` class in the `android.media` package.² Let's try it with a simple example that plays sounds when you press a key on the keyboard or D-pad.

1. Of course, normal people older than the age of 8 can't dance like that. Except perhaps that time when my kids put a lizard in my...but I digress.

2. <http://d.android.com/guide/topics/media/index.html>

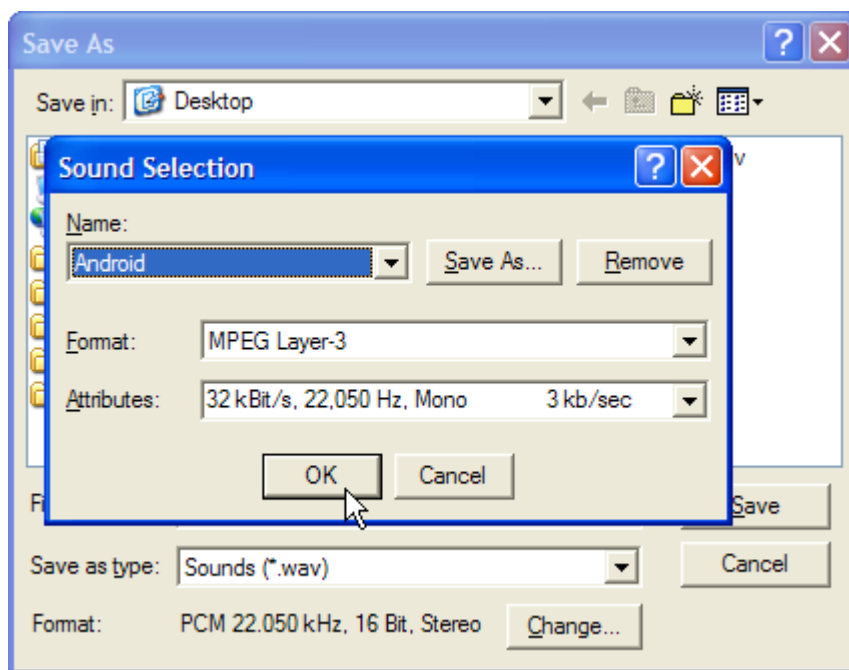


Figure 5.1: Save sound effects in a compressed format that Android can play.

We'll start by creating a “Hello, Android” project, using the following parameters in the New Android Project dialog box:

```
Project name: Audio
Build Target: Android 2.1
Application name: Audio
Package name: org.example.audio
Create Activity: Audio
Min SDK Version: 7
```

Next we'll need a few sounds to play. For this example, I created my own with the Windows Sound Recorder program (Start > Programs > Accessories > Entertainment > Sound Recorder on Windows XP) and an inexpensive headset. After getting the sound levels right, I recorded each sound, selected File > Save As... from the menu, clicked the Change... button, and selected a format Android can recognize (see Figure 5.1). You can find all the sound files and source code for these examples on the book's website.

Copy the sound files into the `res/raw` directory of your project. As you recall from Section 2.4, *Using Resources*, on page 44, simply copying a file into the `res` directory causes the Android Eclipse plug-in to define a Java symbol for you in the `R` class. When you're done, the project should look like Figure 5.2, on the following page.

Now it's time to fill out the `Audio` activity. First we declare a field called `mp` to hold an instance of the `MediaPlayer` class. In this program we're just going to have one `MediaPlayer` active at any given time.

[Download](#) `Audio/src/org/example/audio/Audio.java`

```
package org.example.audio;

import android.app.Activity;
import android.media.MediaPlayer;
import android.os.Bundle;
import android.view.KeyEvent;

public class Audio extends Activity {
    private MediaPlayer mp;

    @Override
    public void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.main);
    }
}
```

Next, we need to intercept the key presses and play the right sounds. We do that by overriding the `Activity.onKeyDown()` method.

[Download](#) `Audio/src/org/example/audio/Audio.java`

```
Line 1  @Override
-      public boolean onKeyDown(int keyCode, KeyEvent event) {
-          int resId;
-          switch (keyCode) {
5         case KeyEvent.KEYCODE_DPAD_UP:
-             resId = R.raw.up;
-             break;
-         case KeyEvent.KEYCODE_DPAD_DOWN:
-             resId = R.raw.down;
10        break;
-         case KeyEvent.KEYCODE_DPAD_LEFT:
-             resId = R.raw.left;
-             break;
-         case KeyEvent.KEYCODE_DPAD_RIGHT:
15        resId = R.raw.right;
-             break;
-         case KeyEvent.KEYCODE_DPAD_CENTER:
-         case KeyEvent.KEYCODE_ENTER:
```

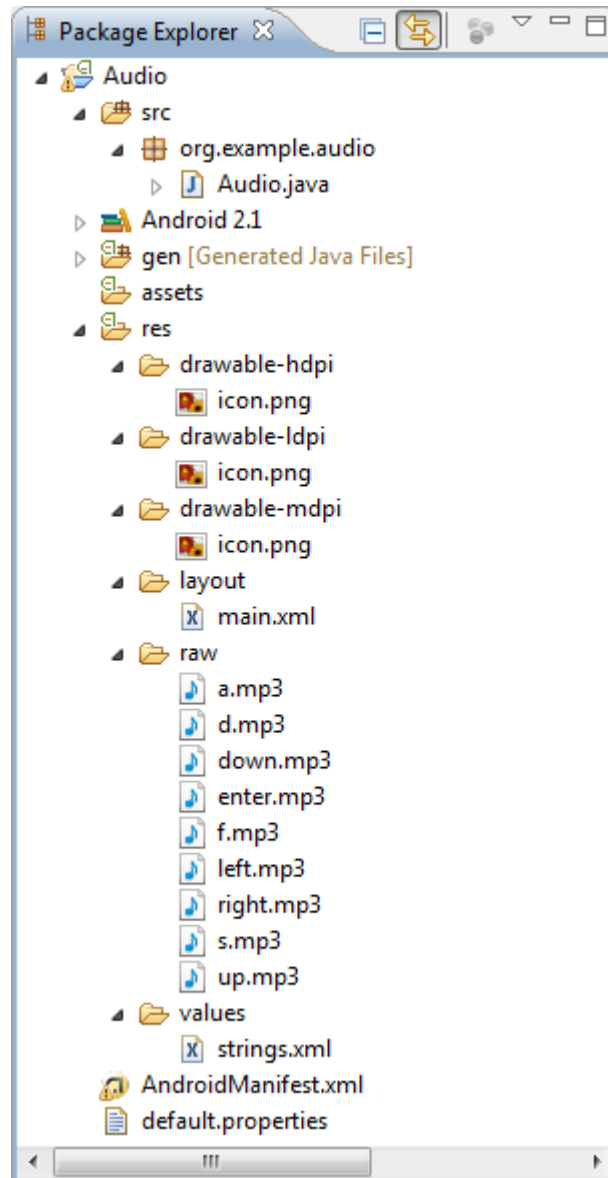


Figure 5.2: Copy audio files into the res/raw directory of your project.



Joe Asks...

What Audio Formats Does Android Support?

Well, there's support on paper, there's support in the emulator, and there's support on the actual devices. On paper, Android supports the following file types (this is subject to change with new releases):

- WAV (PCM uncompressed)
- AAC (Apple iPod format, unprotected)
- MP3 (MPEG-3)
- WMA (Windows media audio)
- AMR (Speech codec)
- OGG (Ogg Vorbis)*
- MIDI (Instruments)

In reality, I've found that only the OGG, WAV, and MP3 formats work well in the emulator, and thus those are the only ones that I can recommend for application development. Android's native audio format appears to be 44.1kHz 16-bit stereo. However, since WAV files at that rate are huge, you should just stick to OGG or MP3 files (mono for voice or stereo for music). OGG files seem to work best for short clips like game sound effects.

Stay away from unusual rates like 8kHz because the resampling artifacts make those rates sound terrible. Use 11kHz, 22kHz, or 44.1kHz sampling rates for the best results. Remember that although the phone may have a tiny speaker, many of your users are going to be plugging in headphones (like an iPod), so you want your audio to be high quality.

*, <http://www.vorbis.com>


```

-         resId = R.raw.enter;
20     break;
-     case KeyEvent.KEYCODE_A:
-         resId = R.raw.a;
-         break;
-     case KeyEvent.KEYCODE_S:
25         resId = R.raw.s;
-         break;
-     case KeyEvent.KEYCODE_D:
-         resId = R.raw.d;
-         break;
30     case KeyEvent.KEYCODE_F:
-         resId = R.raw.f;
-         break;
-     default:
-         return super.onKeyDown(keyCode, event);
35 }
-
-     // Release any resources from previous MediaPlayer
-     if (mp != null) {
-         mp.release();
40     }
-
-     // Create a new MediaPlayer to play this sound
-     mp = MediaPlayer.create(this, resId);
-     mp.start();
45
-     // Indicate this key was handled
-     return true;
- }

```

The first part of the method selects a resource based on which key you pressed. Then on line 38, we call the `release()` method to stop any sounds already playing and free up any resources associated with the old `MediaPlayer`. If you forget to do that, the program will crash (see the sidebar on the following page).

On line 43, we use the `create()` method to create a new `MediaPlayer` using the selected sound resource, and call the `start()` method to begin playing it. The `start()` method is asynchronous, so it returns immediately regardless of how long the sound lasts. If you like, you can use `setOnCompletionListener()` to be notified when the clip is finished.

If you run the program now and then press one of the keys (for example, the Enter key or the center D-pad key), you should hear a sound. If you don't hear anything, check your volume control (don't laugh), or look at the debugging messages in the LogCat view.

When Things Go Wrong

If you do much multimedia programming, you'll soon discover that Android's MediaPlayer can be a fickle beast. The version in newer versions of Android is much improved over its predecessors but it can still crash at the slightest provocation. One reason this happens is that MediaPlayer is mostly a native application with a thin layer of Java on top of it. The native player code is optimized for performance, and it doesn't seem to do much error checking.

Fortunately, Android's strong Linux process protections prevent any harm from being done if a crash occurs. The emulator (or the phone if you're running on a real device) and other applications will continue to run normally. The user would just see the application go away, possibly with a dialog box containing an error message.

During development, though, you can get considerably more diagnostic information to help you determine what went wrong. Messages and tracebacks will be printed to the Android system log, which you can view with the LogCat view in Eclipse or the adb logcat command (see Section 3.10, *Debugging with Log Messages*, on page 74).

Note that audio output may be choppy or delayed in some cases. Try different formats (such as OGG instead of MP3) and lower bit rates. You may also want to investigate using the SoundPool class, which explicitly supports simultaneous streams. It was buggy and poorly documented in the 1.0 release, but as of 1.5 it appears to be stable.

For our next trick, we'll play a movie using only one line of code.

5.2 Playing Video

Video is more than just a bunch of pictures shown one right after another. It's sound as well, and the sound has to be closely synchronized with the images.



Joe Asks...

What Kind of Video Can You Watch on Android?

Here's what is officially supported:

- MP4 (MPEG-4 low bit rate)
- H.263 (3GP)
- H.264 (AVC)

As of Android 1.5, H.263 is the recommended video format because every hardware platform supports it and it's relatively efficient to encode and decode. It is also compatible with other devices such as the iPhone. You can use a program like QuickTime Pro* to convert video from one format to another. Use the lowest resolution and bit rate that you can in order to save space, but don't set it so low that you sacrifice quality.

*, <http://www.apple.com/quicktime/pro>

Android's MediaPlayer class works with video the same way it does with plain audio. The only difference is that you need to create a Surface for the player to use to draw the images. You can use the start() and stop() methods to control playback.

I'm not going to show you another MediaPlayer example, however, because there is a simpler way to embed videos in your application: the VideoView class. To demonstrate it, create a new Android project called Video using these parameters:

Project name: Video
 Build Target: Android 2.1
 Application name: Video
 Package name: org.example.video
 Create Activity: Video
 Min SDK Version: 7

Change the layout (res/layout/main.xml) to this:

[Download](#) Videov1/res/layout/main.xml

```
<?xml version="1.0" encoding="utf-8"?>
<FrameLayout
    xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
```

```

        android:layout_height="fill_parent">
        <VideoView
            android:id="@+id/video"
            android:layout_height="wrap_content"
            android:layout_width="wrap_content"
            android:layout_gravity="center" />
    </FrameLayout>

```

Open Video.java, and change the onCreate() method as follows:

[Download](#) `Videov1/src/org/example/video/Video.java`

```

package org.example.video;

import android.app.Activity;
import android.os.Bundle;
import android.widget.VideoView;

public class Video extends Activity {
    @Override
    public void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);

        // Fill view from resource
        setContentView(R.layout.main);
        VideoView video = (VideoView) findViewById(R.id.video);

        // Load and start the movie
        video.setVideoPath("/data/samplevideo.3gp");
        video.start();
    }
}

```

The setVideoPath() method opens the file, sizes it to its container while preserving the aspect ratio, and begins playing it.

Now you need to upload something to play. To do that, run the following command:

```

C:\> adb push c:\code\samplevideo.3gp /data/samplevideo.3gp
1649 KB/s (369870 bytes in 0.219s)

```

You can find samplevideo.3gp in the download package for this book, or you can create one of your own. The directory used here (/data) is just for illustrative purposes and should not really be used for media files. It will only work on the emulator because that directory is protected on real devices.

Note that Android doesn't seem to care what extension you give the file. You can also upload and download files in Eclipse with the File



Figure 5.3: Embedding a video is easy with `VideoView`.

Explorer view in the Android perspective, but I find the command line to be easier for simple things like this.

There's one more thing: we'd like the video to take over the whole screen including the title bar and status bar. To do that, all you need to do is specify the right theme in `AndroidManifest.xml`:

[Download](#) `Videov1/AndroidManifest.xml`

```
<?xml version="1.0" encoding="utf-8"?>
<manifest xmlns:android="http://schemas.android.com/apk/res/android"
    package="org.example.video"
    android:versionCode="1"
    android:versionName="1.0">
    <application android:icon="@drawable/icon"
        android:label="@string/app_name">
        <activity android:name=".Video"
            android:label="@string/app_name"
            android:theme="@android:style/Theme.NoTitleBar.Fullscreen">
            <intent-filter>
                <action android:name="android.intent.action.MAIN" />
                <category android:name="android.intent.category.LAUNCHER" />
            </intent-filter>
        </activity>
    </application>
</manifest>
```



Joe Asks...

Why Does It Restart the Video When I Rotate the Display?

Android assumes by default that your program knows nothing about screen rotations. To pick up possible resource changes, Android destroys and re-creates your activity from scratch. That means `onCreate()` is called again, which means the video is started again (as this example is currently written).

This behavior will be fine for 90 percent of all applications, so most developers will not have to worry about it. It's even a useful way to test your application life-cycle and state-saving/restoring code (see Section 2.2, *It's Alive!*, on page 39). However, there are a couple of ways to be smarter and optimize the transition.

The simplest way is to implement `onRetainNonConfigurationInstance()` in your activity to save some data that will be kept across the calls to `onDestroy()` and `onCreate()`. When you come back, you use `getLastNonConfigurationInstance()` in the new instance of your activity to recover that information. You can keep anything, even references to your current intent and running threads.

The more complicated way is to use the `android:configChanges=` property in `AndroidManifest.xml` to inform Android which changes you can handle. For example, if you set it to `keyboardHidden|orientation`, then Android will not destroy and re-create your activity when the user flips the keyboard. Instead, it will call `onConfigurationChanged(Configuration)` and assume you know what you're doing.*

*. See <http://d.android.com/reference/android/app/Activity.html#ConfigurationChanges> for more details.

```
</activity>
</application>
<uses-sdk android:minSdkVersion="3" android:targetSdkVersion="7" />
</manifest>
```

Once all that is done, when you run the program, you should see and hear the movie clip (see Figure 5.3, on the previous page). Try rotating the display to verify it works in both portrait and landscape modes. *Voila!* Instant video goodness.

Sudoku Trivia

Dozens of Sudoku variants exist, although none has gained the popularity of the original. One uses a sixteen-by-sixteen grid, with hexadecimal numbers. Another, called Gattai 5 or Samurai Sudoku, uses five nine-by-nine grids that overlap at the corner regions.

Now let's polish up the Sudoku sample with a little mood music.

5.3 Adding Sounds to Sudoku

In this section, we're going to take what we've learned and add background music to the Sudoku game we've been building. One song will play during the opening screen, and another will play during the actual game. This will demonstrate not just how to play music but also some important life-cycle considerations.

To add music to the main screen, we just need to override these two methods in the Sudoku class:

Download [Sudoku\3\src\org\example\sudoku\Sudoku.java](https://github.com/ExampleApp/Sudoku/blob/master/src/org/example/sudoku/Sudoku.java)

```
@Override
protected void onResume() {
    super.onResume();
    Music.play(this, R.raw.main);
}

@Override
protected void onPause() {
    super.onPause();
    Music.stop(this);
}
```

If you recall from Section 2.2, *It's Alive!*, on page 39, the `onResume()` method is called when the activity is ready to begin interacting with the user. This is a good place to start up the music, so we put a `Music.play()` call there. The `Music` class will be defined shortly.

`R.raw.main` refers to `res/raw/main.mp3`. You can find these sound files in the `Sudoku\3` project of the downloadable samples on the book's website.



Joe Asks...

Shouldn't We Use a Background Service for Music?

We haven't said much about the Android Service class, but you may have seen it used in some music-playing examples on the Web. Basically, a Service is a way to start a background process that can run even after your current activity finishes. Services are similar to, but not quite the same as, Linux daemons. If you're writing a general-purpose music player and want the music to continue while you're reading mail or browsing the Web, then, yes, a Service would be appropriate. In most cases, though, you want the music to end when your program ends, so you don't need to use the Service class.

The `onPause()` method is the paired bookend for `onResume()`. Android pauses the current activity prior to resuming a new one, so in Sudoku, when you start a new game, the Sudoku activity will be paused, and then the Game activity will be started. `onPause()` will also be called when the user presses the Back or Home key. These are all places where we want our title music to stop, so we call `Music.stop()` in `onPause()`.

Now let's do something similar for the music on the Game activity:

[Download](#) `Sudokuv3/src/org/example/sudoku/Game.java`

```
@Override
protected void onResume() {
    super.onResume();
    Music.play(this, R.raw.game);
}

@Override
protected void onPause() {
    super.onPause();
    Music.stop(this);
}
```

If you compare this to what we did to the Sudoku class, you'll notice that we're referencing a different sound resource, `R.raw.game` (`res/raw/game.mp3`).

The final piece of the musical puzzle is the Music class, which will manage the MediaPlayer class used to play the current music:

[Download](#) Sudokuv3/src/org/example/sudoku/Music.java

```

Line 1 package org.example.sudoku;
-
- import android.content.Context;
- import android.media.MediaPlayer;
5
- public class Music {
-     private static MediaPlayer mp = null;
-
-     /** Stop old song and start new one */
10     public static void play(Context context, int resource) {
-         stop(context);
-         mp = MediaPlayer.create(context, resource);
-         mp.setLooping(true);
-         mp.start();
15    }
-
-     /** Stop the music */
-     public static void stop(Context context) {
-         if (mp != null) {
20             mp.stop();
-             mp.release();
-             mp = null;
-         }
-     }
25 }
    
```

The play() method first calls the stop() method to halt whatever music is currently playing. Next, it creates a new MediaPlayer instance using MediaPlayer.create(), passing it a context and a resource ID.

After we have a player, we then set an option to make it repeat the music in a loop and then start it playing. The start() method comes back immediately.

The stop() method that begins on line 18 is simple. After a little defensive check to make sure we actually have a MediaPlayer to work with, we call its stop() and release() methods. The MediaPlayer.stop() method, strangely enough, stops the music. The release() method frees system resources associated with the player. Since those are native resources, we can't wait until normal Java garbage collection reclaims them. Leaving out release() is a good way to make your program fail unexpectedly (not that this has ever happened to me, of course; I'm just saying *you* should keep that in mind).

Now comes the fun part—try playing Sudoku with these changes in place. Stress test it in every way you can imagine, such as switching to different activities, pressing the Back button and the Home button from different points in the game, starting the program when it's already running at different points, rotating the display, and so forth. Proper life cycle management is a pain sometimes, but your users will appreciate the effort.

5.4 Fast-Forward >>

In this chapter, we covered playing audio and video clips using the Android SDK. We didn't discuss recording because most programs will not need to do that, but if you happen to be the exception, then look up the `MediaRecorder` class in the online documentation.³

In Chapter 6, *Storing Local Data*, on the following page, you'll learn about some simple ways Android programs can store data between invocations. If you don't need to do that, then you can skip ahead to Chapter 7, *The Connected World*, on page 133 and learn about network access.

3. <http://d.android.com/reference/android/media/MediaRecorder.html>

Storing Local Data

So far, we've concentrated on writing applications that don't need to keep data around when they exit. They start up, run, and go away, leaving no trace that they were ever there. However, most real programs need persistent state, whether it's a simple font size setting, an embarrassing photo from your last office party, or next week's meal plan. Whatever it is, Android lets you permanently store it on your mobile device for later use and protects it from accidental or malicious access by other programs.

Your application can store data using several different techniques depending on the size of the data, its structure, its lifetime, and whether it will be shared with other programs. In this chapter, we'll take a look at three simple methods to keep local data: the preferences API, instance state bundles, and flash memory files. In Chapter 9, *Putting SQL to Work*, on page 181, we'll delve into more advanced techniques using the built-in SQLite database engine.

6.1 Adding Options to Sudoku

In Section 3.7, *Adding a Menu*, on page 68, we used the `onCreateOptionsMenu()` method to add a menu containing one item to the main Sudoku screen. When the user presses the Menu key and selects the Settings... item, the code starts the Prefs activity, which lets the user change the options for the game. Because Prefs extends `PreferenceActivity`, the values for the settings are stored in the program's preferences area, but originally we didn't do anything with them. Now we're going to implement them.

Sudoku Trivia

There are 6,670,903,752,021,072,936,960 possible classic Sudoku solution grids. If you eliminate duplicates that are just rotations, reflections, or relabelings of each other, you're left with "only" 5,472,730,538 solutions.

First let's modify the Prefs class to add a couple of getter methods that retrieve the current values of our two options. Here's the new definition:

[Download](#) `Sudoku4/src/org/example/sudoku/Prefs.java`

```
package org.example.sudoku;

import android.content.Context;
import android.os.Bundle;
import android.preference.PreferenceActivity;
import android.preference.PreferenceManager;

public class Prefs extends PreferenceActivity {
    // Option names and default values
    private static final String OPT_MUSIC = "music";
    private static final boolean OPT_MUSIC_DEF = true;
    private static final String OPT_HINTS = "hints";
    private static final boolean OPT_HINTS_DEF = true;

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        addPreferencesFromResource(R.xml.settings);
    }

    /** Get the current value of the music option */
    public static boolean getMusic(Context context) {
        return PreferenceManager.getDefaultSharedPreferences(context)
            .getBoolean(OPT_MUSIC, OPT_MUSIC_DEF);
    }

    /** Get the current value of the hints option */
    public static boolean getHints(Context context) {
        return PreferenceManager.getDefaultSharedPreferences(context)
            .getBoolean(OPT_HINTS, OPT_HINTS_DEF);
    }
}
```

Be careful that the option keys (music and hints) match the keys used in `res/xml/settings.xml`.

`Music.play()` has to be modified to check for the music preference:

[Download](#) `Sudoku4/src/org/example/sudoku/Music.java`

```
public static void play(Context context, int resource) {
    stop(context);

    // Start music only if not disabled in preferences
    if (Prefs.getMusic(context)) {
        mp = MediaPlayer.create(context, resource);
        mp.setLooping(true);
        mp.start();
    }
}
```

And `PuzzleView.onDraw()` also needs to be modified to check for the hints preference:

[Download](#) `Sudoku4/src/org/example/sudoku/PuzzleView.java`

```
if (Prefs.getHints(getContext())) {
    // Draw the hints...
}
```

If `getHints()` returns true, we draw the highlights for the hints, as shown in Figure 4.6, on page 96. Otherwise, we just skip that part.

Next I'll show you how to use the preferences API to store things other than just options.

6.2 Continuing an Old Game

At any time the player can decide to quit playing our Sudoku game and go do something else. Maybe their boss walked in, or they got a phone call or a notification of an important appointment. Whatever the reason, we want to allow the player to come back later and continue where they left off.

First we need to save the current state of the puzzle somewhere. The preferences API can be used for more than just options; it can store any small stand-alone bits of information that go with your program. In this case, the state of the puzzle can be saved as a string of eighty-one characters, one for each tile.

In the `Game` class, we'll start by defining a couple of constants—one for the puzzle data key and one for a flag to tell us to continue the previous game rather than start a new one.

[Download](#) `Sudoku4/src/org/example/sudoku/Game.java`

```
private static final String PREF_PUZZLE = "puzzle" ;
protected static final int DIFFICULTY_CONTINUE = -1;
```

Next we need to save the current puzzle whenever the game is paused. See Section 2.2, *It's Alive!*, on page 39 for a description of `onPause()` and the other life-cycle methods.

[Download](#) `Sudoku4/src/org/example/sudoku/Game.java`

```
@Override
protected void onPause() {
    super.onPause();
    Log.d(TAG, "onPause");
    Music.stop(this);

    // Save the current puzzle
    getPreferences(MODE_PRIVATE).edit().putString(PREF_PUZZLE,
        toPuzzleString(puzzle)).commit();
}
```

Now the puzzle is saved, but how do we read the saved data? Remember that when the game is started, the `getPuzzle()` method is called, and the difficulty level is passed in. We'll use that for continuing as well.

[Download](#) `Sudoku4/src/org/example/sudoku/Game.java`

```
private int[] getPuzzle(int diff) {
    String puz;
    switch (diff) {
        case DIFFICULTY_CONTINUE:
            puz = getPreferences(MODE_PRIVATE).getString(PREF_PUZZLE,
                easyPuzzle);
            break;
        // ...
    }
    return fromPuzzleString(puz);
}
```

All we need to do is add a check for `DIFFICULTY_CONTINUE`. If that is set, then instead of starting with a fresh puzzle, we read the one we stuffed into the preferences.

Next, we need to make the Continue button on the main screen (see Figure 3.4, on page 58) actually do something. Here is where we set that up.

Download `Sudoku4/src/org/example/sudoku/Sudoku.java`

```
public void onClick(View v) {
    switch (v.getId()) {
        case R.id.continue_button:
            startGame(Game.DIFFICULTY_CONTINUE);
            break;
            // ...
    }
}
```

We added a case in `Sudoku.onClick()` to call `startGame()` when the Continue button is pressed, passing it `DIFFICULTY_CONTINUE`. `startGame()` passes the difficulty to the Game activity, and `Game.onCreate()` calls `Intent.getIntExtra()` to read the difficulty and passes that to `getPuzzle()` (you can see the code for that in Section 4.2, *Starting the Game*, on page 82).

There's one more thing to do: restore from our saved game when our activity goes away and comes back on its own (such as if another activity is started and then the user comes back to the Game activity). This modification to the `Game.onCreate()` method will take care of that:

Download `Sudoku4/src/org/example/sudoku/Game.java`

```
@Override
protected void onCreate(Bundle savedInstanceState) {
    // ...
    // If the activity is restarted, do a continue next time
    getIntent().putExtra(KEY_DIFFICULTY, DIFFICULTY_CONTINUE);
}
```

That pretty much covers it for preferences. Next let's look at saving instance state.

6.3 Remembering the Current Position

If you change the screen orientation while Sudoku is running, you'll notice that it forgets where its cursor is. That's because we use a custom `PuzzleView` view. Normal Android views save their view state automatically, but since we made our own, we don't get that for free.

Unlike persistent state, instance state is not permanent. It lives in a `Bundle` class on Android's application stack. Instance state is intended to be used for small bits of information such as cursor positions.

Here's what we have to do to implement it:

[Download](#) `Sudoku4/src/org/example/sudoku/PuzzleView.java`

```

Line 1  import android.os.Bundle;
-       import android.os.Parcelable;
-
-       public class PuzzleView extends View {
5         private static final String SELX = "selX";
-         private static final String SELY = "selY";
-         private static final String VIEW_STATE = "viewState";
-         private static final int ID = 42;
-
10        public PuzzleView(Context context) {
-            // ...
-            setId(ID);
-        }
-
15        @Override
-        protected Parcelable onSaveInstanceState() {
-            Parcelable p = super.onSaveInstanceState();
-            Log.d(TAG, "onSaveInstanceState");
-            Bundle bundle = new Bundle();
20            bundle.putInt(SELX, selX);
-            bundle.putInt(SELY, selY);
-            bundle.putParcelable(VIEW_STATE, p);
-            return bundle;
-        }
25        @Override
-        protected void onRestoreInstanceState(Parcelable state) {
-            Log.d(TAG, "onRestoreInstanceState");
-            Bundle bundle = (Bundle) state;
-            select(bundle.getInt(SELX), bundle.getInt(SELY));
30            super.onRestoreInstanceState(bundle.getParcelable(VIEW_STATE));
-            return;
-        }
-        // ...
-    }

```

On line 5, we define some constants for keys to save and restore the cursor position. We need to save both our own x and y positions, plus any state needed by the underlying View class.

As part of `Activity.onSaveInstanceState()` processing, Android will walk down the view hierarchy and call `View.onSaveInstanceState()` on every view it finds that has an ID. The same thing happens for `onRestoreInstanceState()`. Normally, this ID would come from XML, but since `PuzzleView` was created in code, we need to set it ourselves. We make up an arbitrary number on line 8 (any value will do as long as it's positive) and then use the `setId()` method to assign it on line 12.

The `onSaveInstanceState()` method is defined on line 16. We call the superclass to get its state, and then we save ours and theirs in a `Bundle`. Failing to call the superclass will result in a runtime error.

Later, `onRestoreInstanceState()` (line 26) will be called to tease out the information we saved. We get our own `x` and `y` positions from the `Bundle`, and then we call the superclass to let it get whatever it needs. After making these changes, the cursor will be remembered by `PuzzleView`, just like any other Android view.

Next let's look at keeping data in plain old files.

6.4 Accessing the Internal File System

Android runs Linux under the covers, so there's a real file system mounted in there with a root directory and everything. The files are stored on nonvolatile flash memory built into the device, so they are not lost when the phone is turned off.

All of the usual Java file I/O routines from the `java.io` package are available for your program to use, with the caveat that your process has limited permissions so it can't mess up any other application's data. In fact, the main thing it can access is a package private directory created at install time (`/data/data/packagename`).

A few helper methods are provided on the `Context` class (and thus on the `Activity` class extended by each of your activities) to let you read and write data there. Here are the ones you're most likely to need:

<code>deleteFile()</code>	Delete a private file. Returns true if it worked, false otherwise.
<code>fileList()</code>	Return a list of all files in the application's private area in a <code>String</code> array.
<code>openFileInput()</code>	Open a private file for reading. Returns a <code>java.io.FileInputStream</code> .
<code>openFileOutput()</code>	Open a private file for writing. Returns a <code>java.io.FileOutputStream</code> .

However, since this internal memory is limited, I recommend you keep the size of any data you put there low, say a megabyte or two at the most, and carefully handle I/O errors when writing in case the space runs out.

Luckily, internal memory isn't the only storage that you have to work with.

All in the Family

If you recall from Section 2.5, *Safe and Secure*, on page 45, each application normally gets its own user ID at install time. That user ID is the only one that is allowed to read and write from the application's private directory. However, if two applications are signed* by the same digital certificate, then Android assumes they are from the same developer and gives them the same user ID.

On the one hand, that allows them to share all sorts of data with each other if they so choose. But on the other, it also means they'll need to take special care to stay out of each other's way.

*, <http://d.android.com/guide/topics/security/security.html#signing>

6.5 Accessing SD Cards

Some Android devices will include a slot for additional flash memory to be plugged in, typically a Secure Digital (SD) card. These memory cards, if present, are much larger than the built-in memory, and thus they're ideal for storing multimegabyte music and video files. They cannot be used for code, and every application can read and write files there.

In Section 5.2, *Playing Video*, on page 114, we uploaded a sample video file to the /data directory of the emulated device. This is the wrong place for it, since we're not supposed to put large files on the internal file system. So, now I'm going to show you a better way.

The first step is to create and format a virtual SD card that we can "plug in" to the emulator. Luckily we've already done this—if you recall, in Section 1.3, *Creating an AVD*, on page 27 when we created the "em21" virtual device, we gave it a 64MB virtual SD card as well. You can make it any size you like, but if you make it too small, it may cause the emulator to crash; if you make it too big, you'll just waste space on your computer's disk drive.

Next, let's copy the sample video to the SD card:

```
C:\> adb push c:\code\samplevideo.3gp /sdcard/samplevideo.3gp
1468 KB/s (369870 bytes in 0.246s)
```

Then we need to modify the `onCreate()` method of the `Video` class to play the movie from the SD card instead of the `/data` directory:

```
Download Videov2/src/org/example/video/Video.java
// Load and start the movie
video.setVideoPath("/sdcard/samplevideo.3gp");
video.start();
```

Now try to run the program. The video should play normally.

Note: Starting with Android 1.6 you will need to request the `WRITE_EXTERNAL_STORAGE` permission in your manifest file if you want to write to the SD card from your application. Reading from the card doesn't require any special permissions.

6.6 Fast-Forward >>

In this chapter, we covered a couple of basic ways to store local data on the Android platform. That should be enough to get you started, but for structured data such as phone lists and recipes, you'll need something more advanced. See Chapter 9, *Putting SQL to Work*, on page 181 for directions on how to use Android's built-in SQLite database and how to share information between applications using content providers.

This brings us to the end of Part II. With the help of the Sudoku example, you've learned all the basics of Android programming, including user interfaces, 2D graphics, audio, video, and simple data storage.

Now it's time to leave Sudoku behind and move beyond the basics.

Part III

Beyond the Basics

Chapter 7

The Connected World

Over the next few chapters, we'll cover more advanced topics such as network access and location-based services. You can write many useful applications without these features, but going beyond the basic features of Android will really help you add value to your programs, giving them much more functionality with a minimum of effort.

What do you use your mobile phone for? Aside from making calls, more and more people are using their phones as mobile Internet devices. Analysts predict that in a few years mobile phones will surpass desktop computers as the number-one way to connect to the Internet.¹ This point has already been reached in some parts of the world.²

Android phones are well equipped for the new connected world of the mobile Internet. First, Android provides a full-featured web browser based on the WebKit open source project.³ This is the same engine you will find in Google Chrome, the Apple iPhone, and the Safari desktop browser but with a twist. Android lets you use the browser as a component right inside your application.

Second, Android gives your programs access to standard network services like TCP/IP sockets. This lets you consume web services from Google, Yahoo, Amazon, and many other sources on the Internet.

1. <http://archive.mobilecomputingnews.com/2010/0205.html>

2. <http://www.comscore.com/press/release.asp?press=1742>

3. <http://webkit.org>



Figure 7.1: Opening a browser using an Android intent

In this chapter, you'll learn how to take advantage of all these features and more through four example programs:

- **BrowserIntent:** Demonstrates opening an external web browser using an Android intent
- **BrowserView:** Shows you how to embed a browser directly into your application
- **LocalBrowser:** Explains how JavaScript in an embedded WebView and Java code in your Android program can talk to each other
- **Translate:** Uses data binding, threading, and web services for an amusing purpose

7.1 Browsing by Intent

The simplest thing you can do with Android's networking API is to open a browser on a web page of your choice. You might want to do this to provide a link to your home page from your program or to access some server-based application such as an ordering system. In Android all it takes is three lines of code.

To demonstrate, let's write a new example called **BrowserIntent**, which will have an edit field where you can enter a URL and a **Go** button you press to open the browser on that URL (see Figure 7.1). Start by creating a new "Hello, Android" project with the following values in the New Project wizard:

```
Project name: BrowserIntent
Build Target: Android 2.1
Application name: BrowserIntent
Package name: org.example.browserintent
```

Create Activity: `BrowserIntent`
 Min SDK Version: 7

Once you have a the basic program, change the layout file (`res/layout/main.xml`) so it looks like this:

[Download](#) `BrowserIntent/res/layout/main.xml`

```
<?xml version="1.0" encoding="utf-8"?>
<LinearLayout
    xmlns:android="http://schemas.android.com/apk/res/android"
    android:orientation="horizontal"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent">
    <EditText
        android:id="@+id/url_field"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        android:layout_weight="1.0"
        android:lines="1"
        android:inputType="textUri"
        android:imeOptions="actionGo" />
    <Button
        android:id="@+id/go_button"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        android:text="@string/go_button" />
</LinearLayout>
```

This defines our two controls, an `EditText` control and a `Button`.

On `EditText`, we set `android:layout_weight="1.0"` to make the text area fill up all the horizontal space to the left of the button, and we also set `android:lines="1"` to limit the height of the control to one vertical line. Note that this has no effect on the amount of text the user can enter here, just the way it is displayed.

Android 1.5 introduced support for soft keyboards and other alternate input methods. The options for `android:inputType="textUri"` and `android:imeOptions="actionGo"` are hints for how the soft keyboard should appear. They tell Android to replace the standard keyboard with one that has convenient buttons for “.com” and “/” to enter web addresses and a “Go” button that opens the web page.⁴

4. See <http://d.android.com/reference/android/widget/TextView.html> and <http://android-developers.blogspot.com/2009/04/updating-applications-for-on-screen.html> for more information on input options.

As always, human-readable text should be put in a resource file, `res/values/strings.xml`:

[Download](#) `BrowserIntent/res/values/strings.xml`

```
<?xml version="1.0" encoding="utf-8"?>
<resources>
    <string name="app_name">BrowserIntent</string>
    <string name="go_button">Go</string>
</resources>
```

Next we need to fill in the `onCreate()` method in the `BrowserIntent` class. This is where we'll build the user interface and hook up all the behavior. If you don't feel like typing all this in, the complete source code is available online at the books's website.⁵

[Download](#) `BrowserIntent/src/org/example/browserintent/BrowserIntent.java`

```
Line 1 package org.example.browserintent;
-
- import android.app.Activity;
- import android.content.Intent;
5 import android.net.Uri;
- import android.os.Bundle;
- import android.view.KeyEvent;
- import android.view.View;
- import android.view.View.OnClickListener;
10 import android.view.View.OnKeyListener;
- import android.widget.Button;
- import android.widget.EditText;
-
- public class BrowserIntent extends Activity {
15     private EditText urlText;
-     private Button goButton;
-
-     @Override
-     public void onCreate(Bundle savedInstanceState) {
20         super.onCreate(savedInstanceState);
-         setContentView(R.layout.main);
-
-         // Get a handle to all user interface elements
-         urlText = (EditText) findViewById(R.id.url_field);
25         goButton = (Button) findViewById(R.id.go_button);
-
-         // Setup event handlers
-         goButton.setOnClickListener(new OnClickListener() {
-             public void onClick(View view) {
```

5. <http://pragprog.com/titles/eband3>


```

30         openBrowser();
-     }
- }
- });
- urlText.setOnKeyListener(new OnKeyListener() {
-     public boolean onKey(View view, int keyCode, KeyEvent event) {
35         if (keyCode == KeyEvent.KEYCODE_ENTER) {
-             openBrowser();
-             return true;
-         }
-         return false;
40     }
- }
- });
- }
- }

```

Inside `onCreate()`, we call `setContentView()` on line 21 to load the view from its definition in the layout resource, and then we call `findViewById()` on line 24 to get a handle to our two user interface controls.

Line 28 tells Android to run some code when the user selects the Go button, either by touching it or by navigating to it and pressing the center D-pad button. When that happens, we call the `openBrowser()` method, which will be defined in a moment.

As a convenience, if the user types an address and hits the Enter key (if their phone has one), we want the browser to open just like they had clicked Go. To do this, we define a listener starting on line 33 that will be called every time the user types a keystroke into the edit field. If it's the enter key, then we call the `openBrowser()` method to open the browser; otherwise, we return false to let the text control handle the key normally.

Now comes the part you've been waiting for: the `openBrowser()` method. As promised, it's three lines long:

[Download](#) `BrowserIntent/src/org/example/browserintent/BrowserIntent.java`

```

/** Open a browser on the URL specified in the text box */
private void openBrowser() {
    Uri uri = Uri.parse(urlText.getText().toString());
    Intent intent = new Intent(Intent.ACTION_VIEW, uri);
    startActivity(intent);
}

```

The first line retrieves the address of the web page as a string (for example, “`http://www.android.com`”) and converts it to a uniform resource identifier (URI). The next line creates a new `Intent` class with an action of `ACTION_VIEW`, passing it the `Uri` class just created as the object we



Figure 7.2: Viewing a web page with the default browser

want to view. Finally, we call the `startActivity()` method to request that this action be performed.

When the Browser activity starts, it will create its own view (see Figure 7.2), and your program will be paused. If the user presses the Back key at that point, the browser window will go away, and your application will continue. But what if you want to see some of your user interface and a web page at the same time? Android allows you to do that by using the `WebView` class.

7.2 Web with a View

On your desktop computer, a web browser is a large, complicated, memory-gobbling program with all sorts of features like bookmarks, plug-ins, Flash animations, tabs, scroll bars, printing, and so forth.

When I was working on the Eclipse project and someone suggested replacing some common text views with embedded web browsers, I thought they were crazy. Wouldn't it make more sense, I argued, to simply enhance the text viewer to do italics or tables or whatever it was that was missing?

It turns out they weren't crazy because:

- A web browser can be (relatively) lean and mean if you strip out everything but the basic rendering engine.

- If you enhance a text view to add more and more things that a browser engine can do, you end up with either an overly complicated, bloated text viewer or an underpowered browser.

Android provides a wrapper around the WebKit browser engine called `WebView` that you can use to get the real power of a browser with as little as 1MB of overhead. Although 1MB is still significant on an embedded device, there are many cases where using a `WebView` is appropriate.

`WebView` works pretty much like any other Android view except that it has a few extra methods specific to the browser. I'm going to show you how it works by doing an embedded version of the previous example. This one will be called `BrowserView` instead of `BrowserIntent`, since it uses an embedded View instead of an Intent.

Start by creating a new “Hello, Android” project using these settings:

```
Project name: BrowserView
Build Target: Android 2.1
Application name: BrowserView
Package name: org.example.browserview
Create Activity: BrowserView
Min SDK Version: 7
```

The layout file for `BrowserView` is similar to the one in `BrowserIntent`, except we've added a `WebView` at the bottom:

[Download](#) BrowserView/res/layout/main.xml

```
<?xml version="1.0" encoding="utf-8"?>
<LinearLayout
    xmlns:android="http://schemas.android.com/apk/res/android"
    android:orientation="vertical"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent">
    <LinearLayout
        android:orientation="horizontal"
        android:layout_width="fill_parent"
        android:layout_height="wrap_content">
        <EditText
            android:id="@+id/url_field"
            android:layout_width="wrap_content"
            android:layout_height="wrap_content"
            android:layout_weight="1.0"
            android:lines="1"
            android:inputType="textUri"
            android:imeOptions="actionGo" />
        <Button
            android:id="@+id/go_button"
            android:layout_width="wrap_content"
            android:layout_height="wrap_content"
```

```

        android:text="@string/go_button" />
    </LinearLayout>
    <WebView
        android:id="@+id/web_view"
        android:layout_width="fill_parent"
        android:layout_height="wrap_content"
        android:layout_weight="1.0" />
</LinearLayout>

```

We use two `LinearLayout` controls to make everything appear in the right place. The outermost control divides the screen into top and bottom regions; the top has the text area and button, and the bottom has the `WebView`. The innermost `LinearLayout` is the same as before; it just makes the text area go on the left and the button on the right.

The `onCreate()` method for `BrowserView` is exactly the same as before, except that now there is one extra view to look up:

[Download](#) `BrowserView/src/org/example/browserview/BrowserView.java`

```

import android.webkit.WebView;
// ...

public class BrowserView extends Activity {
    private WebView webView;
    // ...
    @Override
    public void onCreate(Bundle savedInstanceState) {
        // ...
        webView = (WebView) findViewById(R.id.web_view);
        // ...
    }
}

```

The `openBrowser()` method, however, is different:

[Download](#) `BrowserView/src/org/example/browserview/BrowserView.java`

```

/** Open a browser on the URL specified in the text box */
private void openBrowser() {
    webView.getSettings().setJavaScriptEnabled(true);
    webView.loadUrl(urlText.getText().toString());
}

```

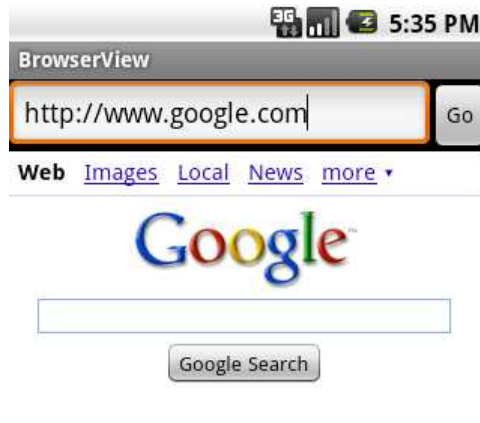


Figure 7.3: Embedding a browser using WebView

The `loadUrl()` method causes the browser engine to begin loading and displaying a web page at the given address. It returns immediately even though the actual loading may take some time (if it finishes at all).

Don't forget to update the string resources:

[Download](#) `BrowserView/res/values/strings.xml`

```
<?xml version="1.0" encoding="utf-8"?>
<resources>
    <string name="app_name">BrowserView</string>
    <string name="go_button">Go</string>
</resources>
```

We need to make one more change to the program. Add this line to `AndroidManifest.xml` before the `<application>` tag:

[Download](#) `BrowserView/AndroidManifest.xml`

```
<uses-permission android:name="android.permission.INTERNET" />
```

If you leave this out, Android will not give your application access to the Internet, and you'll get a "Web page not available" error.

Try running the program now, and enter a valid web address starting with "http://"; when you press Return or select the Go button, the web page should appear (see Figure 7.3).

WebView has dozens of other methods you can use to control what is being displayed or get notifications on state changes.



Joe Asks...

Why Didn't `BrowserIntent` Need `<uses-permission>`?

The previous example, `BrowserIntent`, simply fired off an intent to request that some other application view the web page. That other application (the browser) is the one that needs to ask for Internet permissions in its own `AndroidManifest.xml`.

You can find a complete list in the online documentation for `WebView`, but here are the methods you are most likely to need:

- `addJavascriptInterface()`: Allows a Java object to be accessed from JavaScript (more on this one in the next section)
- `createSnapshot()`: Creates a screenshot of the current page
- `getSettings()`: Returns a `WebSettings` object used to control the settings
- `loadData()`: Loads the given string data into the browser
- `loadDataWithBaseURL()`: Loads the given data using a base URL
- `loadUrl()`: Loads a web page from the given URL
- `setDownloadListener()`: Registers callbacks for download events, such as when the user downloads a .zip or .apk file
- `setWebChromeClient()`: Registers callbacks for events that need to be done outside the `WebView` rectangle, such as updating the title or progress bar or opening a JavaScript dialog box
- `setWebViewClient()`: Lets the application set hooks in the browser to intercept events such as resource loads, key presses, and authorization requests
- `stopLoading()`: Stops the current page from loading

One of the most powerful things you can do with the `WebView` control is to talk back and forth between it and the Android application that contains it. Let's take a closer look at this feature now.

7.3 From JavaScript to Java and Back

Your Android device can do a number of cool things such as store local data, draw graphics, play music, make calls, and determine its location.



Joe Asks...

Is Allowing JavaScript to Call Java Dangerous?

Whenever you allow a web page to access local resources or call functions outside the browser sandbox, you need to consider the security implications very carefully. For example, you wouldn't want to create a method to allow JavaScript to read data from any arbitrary path name because that might expose some private data to a malicious site that knew about your method and your filenames.

Here are a few things to keep in mind. First, don't rely on security by obscurity. Enforce limits on the pages that can use your methods and on the things those methods can do. And remember the golden rule of security: *don't rule things out; rule them in*. In other words, don't try to check for all the bad things that someone can ask you to do (for example, invalid characters in a query). You're bound to miss something. Instead, disallow everything, and pass only the good things you know are safe.

Wouldn't it be nice if you could access that functionality from a web page? With an embedded WebView control, you can.

The key is the `addJavascriptInterface()` method in the `WebView` class. You can use it to extend the Document Object Model (DOM) inside the embedded browser and to define a new object that JavaScript code can access. When the JavaScript code invokes methods on that object, it will actually be invoking methods in your Android program.

You can call JavaScript methods from your Android program too. All you have to do is call the `loadUrl()` method, passing it a URL of the form **javascript:code-to-execute**. Instead of going to a new page, the browser will execute the given JavaScript expression inside the current page. You can call a method, change JavaScript variables, modify the browser document—anything you need.

To demonstrate calls between JavaScript in the `WebView` and Java in the Android program, let us now build a program that is half HTML/JavaScript and half Android (see Figure 7.4, on the next page). The top part of the application window is a `WebView` control, and the bottom

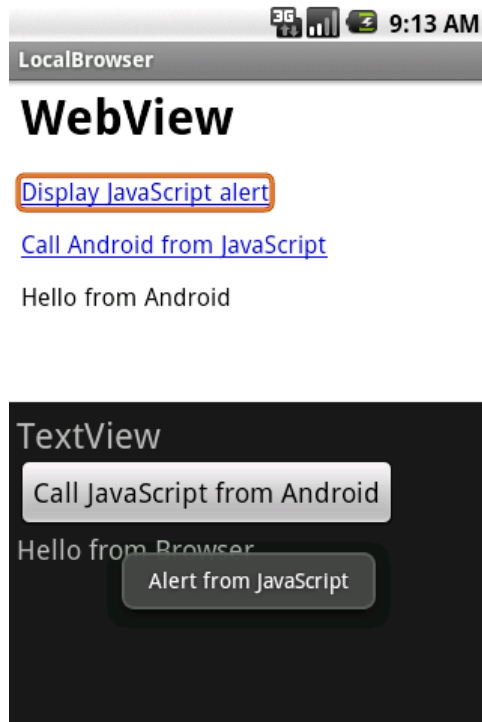


Figure 7.4: Communicating between Android and an embedded Web-View

part is a `TextView` and `Button` from the Android user interface. When you click the buttons and links, it makes calls between the two environments.

Start by creating a “Hello, Android” program using these parameters:

Project name: LocalBrowser
 Build Target: Android 2.1
 Application name: LocalBrowser
 Package name: org.example.localbrowser
 Create Activity: LocalBrowser
 Min SDK Version: 7

The user interface for this program will be split into two parts. The first part is defined in the Android layout file, `res/layout/main.xml`:

[Download](#) LocalBrowser/res/layout/main.xml

```
<?xml version="1.0" encoding="utf-8"?>
```



```

<LinearLayout
  xmlns:android="http://schemas.android.com/apk/res/android"
  android:orientation="vertical"
  android:layout_width="fill_parent"
  android:layout_height="fill_parent">
  <WebView
    android:id="@+id/web_view"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent"
    android:layout_weight="1.0" />
  <LinearLayout
    android:orientation="vertical"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent"
    android:layout_weight="1.0"
    android:padding="5sp">
    <TextView
      android:layout_width="fill_parent"
      android:layout_height="wrap_content"
      android:textSize="24sp"
      android:text="@string/textview" />
    <Button
      android:id="@+id/button"
      android:text="@string/call_javascript_from_android"
      android:layout_width="wrap_content"
      android:layout_height="wrap_content"
      android:textSize="18sp" />
    <TextView
      android:id="@+id/text_view"
      android:layout_width="fill_parent"
      android:layout_height="wrap_content"
      android:textSize="18sp" />
  </LinearLayout>
</LinearLayout>

```

The second part is the index.html file that will be loaded into the WebView. This file goes in the assets directory, not the res directory, because it's not a compiled resource. Anything in the assets directory is copied verbatim onto local storage when your program is installed. The directory is intended to be used for local copies of HTML, images, and scripts that the browser can view without being connected to the network.

[Download](#) LocalBrowser/assets/index.html

```

Line 1 <html>
- <head>
- <script language="JavaScript">
-   function callJS(arg) {
5     document.getElementById('replaceme').innerHTML = arg;
-   }
- </script>

```

```

- </head>
- <body>
10 <h1>WebView</h1>
- <p>
- <a href="#" onclick="window.alert('Alert from JavaScript')">
-   Display JavaScript alert</a>
- </p>
15 <p>
- <a href="#" onclick="window.android.callAndroid('Hello from Browser')">
-   Call Android from JavaScript</a>
- </p>
- <p id="replaceme">
20 </p>
- </body>
- </html>

```

Line 4 of `index.html` defines the `callJS()` function that our Android program will be calling later. It takes a string argument and inserts it at the *replaceme* tag, which is at line 19.

In Figure 7.4, on page 144, you see two HTML links that are defined starting at line 12. The first one just calls a standard `window.alert()` function to open a window displaying a short message. The second link, at line 16, calls the `callAndroid()` method on the `window.android` object. If you loaded this page into a normal web browser, `window.android` would be undefined. But since we're embedding a browser into an Android application, we can define the object ourselves so the page can use it.

Next we turn to the Android code in the `LocalBrowser` class. Here's the basic outline, including all the imports we'll need later:

Download `LocalBrowser/src/org/example/localbrowser/LocalBrowser.java`

```

Line 1 package org.example.localbrowser;
-
- import android.app.Activity;
- import android.os.Bundle;
5 import android.os.Handler;
- import android.util.Log;
- import android.view.View;
- import android.view.View.OnClickListener;
- import android.webkit.JsResult;
10 import android.webkit.WebChromeClient;
- import android.webkit.WebView;
- import android.widget.Button;
- import android.widget.TextView;
- import android.widget.Toast;
15

```

```

- public class LocalBrowser extends Activity {
-     private static final String TAG = "LocalBrowser";
-     private final Handler handler = new Handler();
-     private WebView webView;
20     private TextView textView;
-     private Button button;
-
-     @Override
-     public void onCreate(Bundle savedInstanceState) {
25         super.onCreate(savedInstanceState);
-         setContentView(R.layout.main);
-
-         // Find the Android controls on the screen
-         webView = (WebView) findViewById(R.id.web_view);
-         textView = (TextView) findViewById(R.id.text_view);
30         button = (Button) findViewById(R.id.button);
-         // Rest of onCreate follows...
-     }
- }

```

Note the initialization of a Handler object at line 18. JavaScript calls come in on a special thread dedicated to the browser, but Android user interface calls can be made only from the main (GUI) thread. We'll use the Handler class to make the transition.

To call Android Java code from JavaScript, you need to define a plain old Java object with one or more methods, like this:

```

Download LocalBrowser/src/org/example/localbrowser/LocalBrowser.java
/** Object exposed to JavaScript */
private class AndroidBridge {
    public void callAndroid(final String arg) { // must be final
        handler.post(new Runnable() {
            public void run() {
                Log.d(TAG, "callAndroid(" + arg + ")");
                textView.setText(arg);
            }
        });
    }
}

```

When JavaScript calls the callAndroid() method, the application creates a new Runnable object and post it on the running queue of the main thread using Handler.post(). As soon as the main thread gets a chance, it will invoke the run() method, which will call setText() to change the text on the TextView object. Now it's time to tie everything together in the onCreate() method. First we turn on JavaScript (it's off by default) and register our bridge to JavaScript:

Download LocalBrowser/src/org/example/localbrowser/LocalBrowser.java

```
// Turn on JavaScript in the embedded browser
webView.getSettings().setJavaScriptEnabled(true);

// Expose a Java object to JavaScript in the browser
webView.addJavascriptInterface(new AndroidBridge(),
    "android");
```

Then we create an anonymous WebChromeClient object and register it with the setWebChromeClient() method.

Download LocalBrowser/src/org/example/localbrowser/LocalBrowser.java

```
// Set up a function to be called when JavaScript tries
// to open an alert window
webView.setWebChromeClient(new WebChromeClient() {
    @Override
    public boolean onJsAlert(final WebView view,
        final String url, final String message,
        JsResult result) {
        Log.d(TAG, "onJsAlert(" + view + ", " + url + ", "
            + message + ", " + result + ")");
        Toast.makeText(LocalBrowser.this, message, 3000).show();
        result.confirm();
        return true; // I handled it
    }
});
```

The term *chrome* here refers to all the trimmings around a browser window. If this were a full-blown browser client, we'd need to handle navigation, bookmarks, menus, and so forth. In this case, all we want to do is change what happens with JavaScript code when the browser tries to open a JavaScript alert (using `window.alert()`). Inside `onJsAlert()` we use the Android `Toast` class to create a message window that will appear for a short amount of time (in this case, 3000 milliseconds, or 3 seconds).

Once we finish configuring the `WebView`, we can use `loadUrl()` to load the local web page:

Download LocalBrowser/src/org/example/localbrowser/LocalBrowser.java

```
// Load the web page from a local asset
webView.loadUrl("file:///android_asset/index.html");
```

URLs of the form `file:///android_asset/filename` (note the three forward slashes) have a special meaning to Android's browser engine. As you might have guessed, they refer to files in the `assets` directory. In this case, we're loading the `index.html` file defined earlier.

Here is the `res/values/strings.xml` file for the `LocalBrowser` example:

Download LocalBrowser/res/values/strings.xml

```
<?xml version="1.0" encoding="utf-8"?>
<resources>
    <string name="app_name">LocalBrowser</string>
    <string name="textview">TextView</string>
    <string name="call_javascript_from_android">
        Call JavaScript from Android
    </string>
</resources>
```

The last thing we have to do is wire up the button at the bottom of the screen so it will make a JavaScript call (a call from Java to JavaScript).

Download LocalBrowser/src/org/example/localbrowser/LocalBrowser.java

```
// This function will be called when the user presses the
// button on the Android side
button.setOnClickListener(new OnClickListener() {
    public void onClick(View view) {
        Log.d(TAG, "onClick(" + view + ")");
        webView.loadUrl("javascript:callJS('Hello from Android')");
    }
});
```

To do that, we set a listener for button clicks using `setOnClickListener()`. When the button is pressed, `onClick()` is called, which turns around and calls `WebView.loadUrl()`, passing it a JavaScript expression to evaluate in the browser. The expression is a call to the `callJS()` function defined in `index.html`.

Run the program now, and try it. When you click “Display JavaScript alert,” an Android message window will appear. When you click “Call Android from JavaScript,” the string “Hello from Browser” will be displayed in an Android text control. And finally, when you press the “Call JavaScript from Android” button, the string “Hello from Android” is sent to the browser and inserted in the HTML where it will be displayed at the end of the web page.

Sometimes you don’t need to display a web page, but you just need to access some kind of web service or other server-side resource. In the next section, I’ll show you how to do this.

7.4 Using Web Services

Android provides a full set of Java-standard networking APIs, such as the `java.net.HttpURLConnection` package, that you can use in your programs. The tricky part is to make the calls asynchronously so that your program’s user interface will be responsive at all times.

Consider what would happen if you just make a blocking network call in your main (GUI) thread. Until that call returns (and it might never return), your application cannot respond to any user interface events such as keystrokes or button presses. It will appear hung to the user. Obviously, that's something you'll have to avoid.

The `java.util.concurrent` package is perfect for this kind of work. First created by Doug Lea as a stand-alone library and later incorporated into Java 5, this package supports concurrent programming at a higher level than the regular Java Thread class. The `ExecutorService` class manages one or more threads for you, and all you have to do is submit tasks (instances of `Runnable` or `Callable`) to the executor to have them run. An instance of the `Future` class is returned, which is a reference to some as-yet-unknown future value that will be returned by your task (if any). You can limit the number of threads that are created, and you can interrupt running tasks if necessary.

To illustrate these concepts, let's create a fun little program that calls the Google Translation API.⁶ Have you ever laughed at strange translations to and from foreign languages, especially computer-generated translations? This program will let the user enter a phrase in one language, ask Google to translate to a second language, and then ask Google to translate it back into the first language. Ideally, you'd end up with the same words you started with, but this is not always the case, as you can see in Figure 7.5, on the next page.

To use this program, simply select the starting and target languages, and then start typing a phrase. As you type, the program will use the Google Translation web service to translate your text into and out of the target language.

To create this application, start with a “Hello, Android” application using these parameters:

```
Project name: Translate
Build Target: Android 2.1
Application name: Translate
Package name: org.example.translate
Create Activity: Translate
Min SDK Version: 7
```

6. <http://code.google.com/apis/ajaxlanguage>

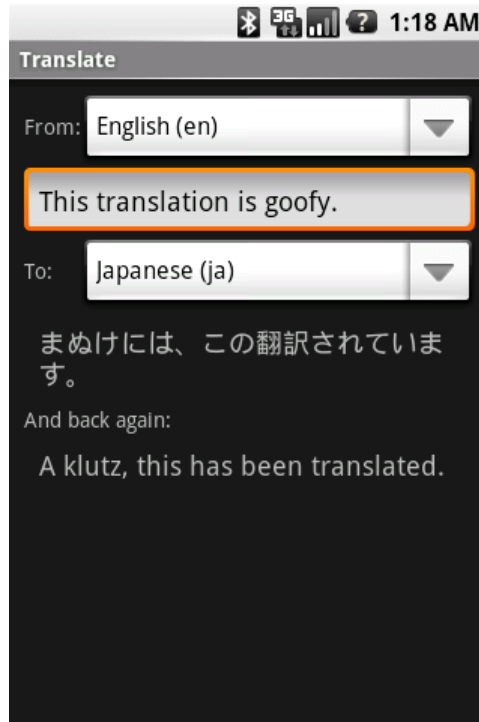


Figure 7.5: Machine translation is still a work in progress.

Lost in Translation

When I first thought of this example, I imagined that it would be easy to get some hilarious results. Unfortunately (or fortunately, depending on your point of view), the Google service does a pretty good job with most languages. If you find any especially funny cases where the translator really flubs up, please post them on the discussion forum at the book's website (<http://pragprog.com/titles/eband3>) for others to enjoy.

Since this example will access the Internet to make a web service call, we will need to tell Android to grant us permission. Add this line to `AndroidManifest.xml` before the `<application>` XML tag:

[Download](#) [Translate/AndroidManifest.xml](#)

```
<uses-permission android:name="android.permission.INTERNET" />
```

The layout for this example is a little more complicated than usual, so we'll use the `TableLayout` view. `TableLayout` lets you arrange your views into rows and columns, taking care of alignment and stretching the columns to fit the content. It's similar to using `<table>` and `<tr>` tags in HTML.

[Download](#) [Translate/res/layout/main.xml](#)

```
<?xml version="1.0" encoding="utf-8"?>
<ScrollView
    xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent">
    <TableLayout
        android:layout_width="fill_parent"
        android:layout_height="fill_parent"
        android:stretchColumns="1"
        android:padding="10dip">
        <TableRow>
            <TextView android:text="@string/from_text" />
            <Spinner android:id="@+id/from_language" />
        </TableRow>
        <EditText
            android:id="@+id/original_text"
            android:hint="@string/original_hint"
            android:padding="10dip"
            android:textSize="18sp" />
        <TableRow>
            <TextView android:text="@string/to_text" />
            <Spinner android:id="@+id/to_language" />
        </TableRow>
        <TextView
            android:id="@+id/translated_text"
            android:padding="10dip"
            android:textSize="18sp" />
        <TextView android:text="@string/back_text" />
        <TextView
            android:id="@+id/retranslated_text"
            android:padding="10dip"
            android:textSize="18sp" />
    </TableLayout>
```


</ScrollView>

In this example, we have six rows, each row containing one or two columns. Note that if there is only one view in a row, you don't have to use a TableRow to contain it. Also, it's not necessary to use `android:layout_width=` and `android:layout_height=` on every view like you have to with `LinearLayout`.

The Spinner class is a new one we haven't seen before. It's similar to a combo box in other user interface toolkits. The user selects the spinner (for example, by touching it), and a list of possible values appears for them to pick. In this example, we're going to use this control for selecting from a list of languages.

The actual list is stored as an Android resource in the file `res/values/arrays.xml`:

[Download](#) [Translate](#) `res/values/arrays.xml`

```
<?xml version="1.0" encoding="utf-8"?>
<resources>
  <array name="languages">
    <item>Bulgarian (bg)</item>
    <item>Chinese Simplified (zh-CN)</item>
    <item>Chinese Traditional (zh-TW)</item>
    <item>Catalan (ca)</item>
    <item>Croatian (hr)</item>
    <item>Czech (cs)</item>
    <item>Danish (da)</item>
    <item>Dutch (nl)</item>
    <item>English (en)</item>
    <item>Filipino (tl)</item>
    <item>Finnish (fi)</item>
    <item>French (fr)</item>
    <item>German (de)</item>
    <item>Greek (el)</item>
    <item>Indonesian (id)</item>
    <item>Italian (it)</item>
    <item>Japanese (ja)</item>
    <item>Korean (ko)</item>
    <item>Latvian (lv)</item>
    <item>Lithuanian (lt)</item>
    <item>Norwegian (no)</item>
    <item>Polish (pl)</item>
    <item>Portuguese (pt-PT)</item>
    <item>Romanian (ro)</item>
    <item>Russian (ru)</item>
    <item>Spanish (es)</item>
    <item>Serbian (sr)</item>
    <item>Slovak (sk)</item>
```

```

        <item>Slovenian (sl)</item>
        <item>Swedish (sv)</item>
        <item>Ukrainian (uk)</item>
    </array>
</resources>

```

This defines a list called `languages` that contains most of the languages recognized by the Google Translation API. Note that each value has a long name (for example, *Spanish*) and a short name (for example, *es*). We'll use the short name when passing the language to the translator.

Now let's start modifying the `Translate` class. Here's the basic outline:

[Download](#) `Translate/src/org/example/translate/Translate.java`

```

Line 1 package org.example.translate;
-
- import java.util.concurrent.ExecutorService;
- import java.util.concurrent.Executors;
5 import java.util.concurrent.Future;
- import java.util.concurrent.RejectedExecutionException;
-
- import android.app.Activity;
- import android.os.Bundle;
10 import android.os.Handler;
- import android.textEditable;
- import android.text.TextWatcher;
- import android.view.View;
- import android.widget.AdapterView;
15 import android.widget.AdapterView;
- import android.widget.AdapterView;
- import android.widget.AdapterView;
- import android.widget.AdapterView;
- import android.widget.AdapterView;
20 import android.widget.AdapterView;
- public class Translate extends Activity {
-     private Spinner fromSpinner;
-     private Spinner toSpinner;
-     private EditText origText;
25 private TextView transText;
- private TextView retransText;
-
-     private TextWatcher textWatcher;
-     private OnItemSelectedListener itemListener;
30
-     private Handler guiThread;
-     private ExecutorService transThread;
-     private Runnable updateTask;
-     private Future transPending;

```

```

35  - @Override
-   - public void onCreate(Bundle savedInstanceState) {
-       -     super.onCreate(savedInstanceState);
-
40     -     setContentView(R.layout.main);
-       -     initThreading();
-       -     findViews();
-       -     setAdapters();
-       -     setListeners();
45  -   }
- }

```

After declaring a few variables, we define the `onCreate()` method starting at line 37 to initialize the threading and user interface. Don't worry, we'll fill out all those other methods it calls as we go.

The `findViews()` method, called from line 42, just gets a handle to all the user interface elements defined in the layout file:

[Download](#) `Translate/src/org/example/translate/Translate.java`

```

private void findViews() {
    fromSpinner = (Spinner) findViewById(R.id.from_language);
    toSpinner = (Spinner) findViewById(R.id.to_language);
    origText = (EditText) findViewById(R.id.original_text);
    transText = (TextView) findViewById(R.id.translated_text);
    retransText = (TextView) findViewById(R.id.retranslated_text);
}

```

The `setAdapters()` method, called from `onCreate()` on line 43, defines a data source for the spinners:

[Download](#) `Translate/src/org/example/translate/Translate.java`

```

private void setAdapters() {
    // Spinner list comes from a resource,
    // Spinner user interface uses standard layouts
    ArrayAdapter<CharSequence> adapter = ArrayAdapter.createFromResource(
        this, R.array.languages,
        android.R.layout.simple_spinner_item);
    adapter.setDropDownViewResource(
        android.R.layout.simple_spinner_dropdown_item);
    fromSpinner.setAdapter(adapter);
    toSpinner.setAdapter(adapter);

    // Automatically select two spinner items
    fromSpinner.setSelection(8); // English (en)
    toSpinner.setSelection(11); // French (fr)
}

```

In Android, an `Adapter` is a class that binds a data source (in this case, the languages array defined in `arrays.xml`) to a user interface control (in



Joe Asks...

Is All This Delay and Threading Stuff Really Necessary?

One reason you need to do it this way is to avoid making too many calls to the external web service. Imagine what happens as the user enters the word *scissors*. The program sees the word typed in a character at a time, first *s*, then *c*, then *i*, and so on, possibly with backspaces because nobody can remember how to spell *scissors*. Do you really want to make a web service request for every character? Not really. Besides putting unnecessary load on the server, it would be wasteful in terms of power. Each request requires the device's radio to transmit and receive several data packets, which uses up a bit of battery power. You want to wait until the user finishes typing before sending the request, but how do you tell they are done?

The algorithm used here is that as soon as the user types a letter, a delayed request is started. If they don't type another letter before the one-second delay is up, then the request goes through. Otherwise, the first request is removed from the request queue before it goes out. If the request is already in progress, we try to interrupt it. The same goes for language changes, except we use a smaller delay. The good news is that now that I've done it once for you, you can use the same pattern in your own asynchronous programs.

this case, a spinner). We use the standard layouts provided by Android for individual items in the list and for the drop-down box you see when you select the spinner.

Next we set up the user interface handlers in the `setListeners()` routine (called from line 44 of `onCreate()`):

[Download](#) [Translate/src/org/example/translate/Translate.java](https://github.com/GoogleCloudPlatform/android-translation/blob/master/src/org/example/translate/Translate.java)

```
private void setListeners() {
    // Define event listeners
    textWatcher = new TextWatcher() {
        public void beforeTextChanged(CharSequence s, int start,
            int count, int after) {
            /* Do nothing */
        }
        public void onTextChanged(CharSequence s, int start,
            int before, int count) {
```

```

        queueUpdate(1000 /* milliseconds */);
    }
    public void afterTextChanged(Editable s) {
        /* Do nothing */
    }
};
itemListener = new OnItemSelectedListener() {
    public void onItemSelected(AdapterView parent, View v,
        int position, long id) {
        queueUpdate(200 /* milliseconds */);
    }
    public void onNothingSelected(AdapterView parent) {
        /* Do nothing */
    }
};

// Set listeners on graphical user interface widgets
origText.addTextChangedListener(textWatcher);
fromSpinner.setOnItemSelectedListener(itemListener);
toSpinner.setOnItemSelectedListener(itemListener);
}

```

We define two listeners: one that is called when the text to translate is changed and one that is called when the language is changed. `queueUpdate()` puts a delayed update request on the main thread's to-do list using a `Handler`. We arbitrarily use a 1,000-millisecond delay for text changes and a 200-millisecond delay for language changes.

The update request is defined inside the `initThreading()` method:

[Download](#) `Translate/src/org/example/translate/Translate.java`

```

Line 1 private void initThreading() {
-     guiThread = new Handler();
-     transThread = Executors.newSingleThreadExecutor();
-
5     // This task does a translation and updates the screen
-     updateTask = new Runnable() {
-         public void run() {
-             // Get text to translate
-             String original = origText.getText().toString().trim();
10
-             // Cancel previous translation if there was one
-             if (transPending != null)
-                 transPending.cancel(true);
-
15             // Take care of the easy case
-             if (original.length() == 0) {
-                 transText.setText(R.string.empty);
-                 retransText.setText(R.string.empty);
-             } else {

```

```

20         // Let user know we're doing something
        transText.setText(R.string.translating);
        retransText.setText(R.string.translating);
        -
        -
        // Begin translation now but don't wait for it
25     try {
        TranslateTask translateTask = new TranslateTask(
            Translate.this, // reference to activity
            original, // original text
            getLang(fromSpinner), // from language
30            getLang(toSpinner) // to language
        );
        transPending = transThread.submit(translateTask);
        -
        -
    } catch (RejectedExecutionException e) {
        // Unable to start new task
35        transText.setText(R.string.translation_error);
        retransText.setText(R.string.translation_error);
        -
        -
    }
    -
    -
    }
40 };
    -
    }

```

We have two threads: the main Android thread used for the user interface and a translate thread that we'll create for running the actual translation job. We represent the first one with an Android Handler and the second with Java's `ExecutorService`.

Line 6 defines the update task, which will be scheduled by the `queueUpdate()` method. When it gets to run, it first fetches the current text to translate and then prepares to send a translation job to the translate thread. It cancels any translation that is already in progress (on line 13), takes care of the case where there is no text to translate (line 17), and fills in the two text controls where translated text will appear with the string "Translating..." (line 21). That text will be replaced later by the actual translated text.

Finally, on line 26, we create an instance of `TranslateTask`, giving it a reference to the `Translate` activity so it can call back to change the text, a string containing the original text, and the short names of the two languages selected in the spinners. Line 32 submits the new task to the translation thread, returning a reference to the `Future` return value. In this case, we don't really have a return value since `TranslateTask` changes the GUI directly, but we use the `Future` reference back on line 13 to cancel the translation if necessary.

To finish up the `Translate` class, here are a few utility functions used in other places:

Download [Translate/src/org/example/translate/Translate.java](https://src.org/example/translate/Translate.java)

```

/** Extract the language code from the current spinner item */
private String getLang(Spinner spinner) {
    String result = spinner.getSelectedItem().toString();
    int lparen = result.indexOf('(');
    int rparen = result.indexOf(')');
    result = result.substring(lparen + 1, rparen);
    return result;
}

/** Request an update to start after a short delay */
private void queueUpdate(long delayMillis) {
    // Cancel previous update if it hasn't started yet
    guiThread.removeCallbacks(updateTask);
    // Start an update if nothing happens after a few milliseconds
    guiThread.postDelayed(updateTask, delayMillis);
}

/** Modify text on the screen (called from another thread) */
public void setTranslated(String text) {
    guiSetText(transText, text);
}

/** Modify text on the screen (called from another thread) */
public void setRetranslated(String text) {
    guiSetText(retransText, text);
}

/** All changes to the GUI must be done in the GUI thread */
private void guiSetText(final TextView view, final String text) {
    guiThread.post(new Runnable() {
        public void run() {
            view.setText(text);
        }
    });
}

```

The `getLang()` method figures out which item is currently selected in a spinner, gets the string for that item, and parses out the short language code needed by the Translation API.

`queueUpdate()` puts an update request on the main thread's request queue but tells it to wait a little while before actually running it. If there was already a request on the queue, it's removed.

The `setTranslated()` and `setRetranslated()` methods will be used by `TranslateTask` to update the user interface when translated results come back from the web service. They both call a private function called `guiSetText()`.

`guiSetText()` uses the `Handler.post()` method to ask the main GUI thread to update the text on a `TextView` control. This extra step is necessary because you can't call user interface functions from non-user-interface threads, and `guiSetText()` will be called by the translate thread.

Here is the `res/values/strings.xml` file for the Translate example:

[Download](#) `Translate/res/values/strings.xml`

```
<?xml version="1.0" encoding="utf-8"?>
<resources>
    <string name="app_name">Translate</string>
    <string name="from_text">From:</string>
    <string name="to_text">To:</string>
    <string name="back_text">And back again:</string>
    <string name="original_hint">Enter text to translate</string>
    <string name="empty"></string>
    <string name="translating">Translating...</string>
    <string name="translation_error">(Translation error)</string>
    <string name="translation_interrupted">(Translation
        interrupted)</string>
</resources>
```

Finally, here's the definition of the `TranslateTask` class:

[Download](#) `Translate/src/org/example/translate/TranslateTask.java`

```
package org.example.translate;

import java.io.BufferedReader;
import java.io.IOException;
import java.io.InputStreamReader;
import java.net.HttpURLConnection;
import java.net.URL;
import java.net.URLEncoder;

import org.json.JSONException;
import org.json.JSONObject;

import android.util.Log;

public class TranslateTask implements Runnable {
    private static final String TAG = "TranslateTask";
    private final Translate translate;
    private final String original, from, to;

    TranslateTask(Translate translate, String original, String from,
        String to) {
        this.translate = translate;
        this.original = original;
        this.from = from;
        this.to = to;
    }
}
```



```

}

public void run() {
    // Translate the original text to the target language
    String trans = doTranslate(original, from, to);
    translate.setTranslated(trans);

    // Then translate what we got back to the first language.
    // Ideally it would be identical but it usually isn't.
    String retrans = doTranslate(trans, to, from); // swapped
    translate.setRetranslated(retrans);
}

/**
 * Call the Google Translation API to translate a string from one
 * language to another. For more info on the API see:
 * http://code.google.com/apis/ajaxlanguage
 */
private String doTranslate(String original, String from,
    String to) {
    String result = translate.getResources().getString(
        R.string.translation_error);
    HttpURLConnection con = null;
    Log.d(TAG, "doTranslate(" + original + ", " + from + ", "
        + to + ")");

    try {
        // Check if task has been interrupted
        if (Thread.interrupted())
            throw new InterruptedException();

        // Build RESTful query for Google API
        String q = URLEncoder.encode(original, "UTF-8");
        URL url = new URL(
            "http://ajax.googleapis.com/ajax/services/language/translate"
            + "?v=1.0" + "&q=" + q + "&langpair=" + from
            + "%7C" + to);
        con = (HttpURLConnection) url.openConnection();
        con.setReadTimeout(10000 /* milliseconds */);
        con.setConnectTimeout(15000 /* milliseconds */);
        con.setRequestMethod("GET");
        con.addRequestProperty("Referer",
            "http://www.pragprog.com/titles/eband3/hello-android");
        con.setDoInput(true);

        // Start the query
        con.connect();

        // Check if task has been interrupted
        if (Thread.interrupted())
            throw new InterruptedException();
    }
}

```

```

// Read results from the query
BufferedReader reader = new BufferedReader(
    new InputStreamReader(con.getInputStream(), "UTF-8"));
String payload = reader.readLine();
reader.close();

// Parse to get translated text
JSONObject jsonObject = new JSONObject(payload);
result = jsonObject.getJSONObject("responseData")
    .getString("translatedText")
    .replace("&#39;", "'")
    .replace("&", "&");

// Check if task has been interrupted
if (Thread.interrupted())
    throw new InterruptedException();

} catch (IOException e) {
    Log.e(TAG, "IOException", e);
} catch (JSONException e) {
    Log.e(TAG, "JSONException", e);
} catch (InterruptedException e) {
    Log.d(TAG, "InterruptedException", e);
    result = translate.getResources().getString(
        R.string.translation_interrupted);
} finally {
    if (con != null) {
        con.disconnect();
    }
}

// All done
Log.d(TAG, "    -> returned " + result);
return result;
}
}

```

This is a nice example of calling a RESTful web service using `URLConnection`, parsing results in JavaScript Object Notation (JSON) format, and handling all sorts of network errors and requests for interruptions. I'm not going to explain it in detail here because it contains nothing Android specific except for a few debugging messages.

7.5 Fast-Forward >>

In this chapter, we covered a lot of ground, from opening a simple web page to using an asynchronous web service. HTML/JavaScript pro-

gramming is beyond the scope of this book, but there are several good references available. If you're going to do much concurrent programming with classes such as `ExecutorService`, I recommend *Java Concurrency in Practice* [Goe06] by Brian Goetz.

The next chapter will explore a new level of interactivity through location and sensor services. If you're anxious to learn more about data sources and data binding, you can skip ahead to Chapter 9, *Putting SQL to Work*, on page 181.

Locating and Sensing

The Android platform uses many different technologies. Some of them are new, and some have been seen before in other settings. What's unique about Android is how these technologies work together. In this chapter, we'll consider the following:

- Location awareness, through inexpensive GPS devices
- Handheld accelerometers, such as those found on the Nintendo Wii remote
- Mashups, often combining maps with other information

Several popular Android programs use these concepts to create a more compelling and relevant experience for the user. For example, the Locale application¹ can adapt the settings on your phone based on where you are. Are you always forgetting to set your ringer to vibrate when you're at work or the movies? Locale can take care of that using the Android Location API described here.

8.1 Location, Location, Location

Right now there are 31 satellites zipping around the world with nothing better to do than help you find your way to the grocery store. The Global Positioning System (GPS), originally developed by the military but then converted to civilian use, beams highly precise time signals to Earth-based receivers such as the one in your Android phone. With good reception and a little math, the GPS chip can figure out your position to within 50 feet.²

1. <http://www.androidlocale.com>

2. You don't have to know how GPS works to use it, but if you're curious, see <http://adventure.howstuffworks.com/gps.htm>.



Joe Asks...

Does GPS Let Anyone Snoop on My Location?

No. GPS receivers are just that—receivers. The GPS chip, and thus any program running in your Android device, knows where it is. But unless one of those programs deliberately transmits that information, nobody can use it to find you.

In addition to GPS, Android also supports calculating your position using information from nearby cell phone towers, and if you're connected to a wifi hotspot, it can use that too. Keep in mind that all these location providers are unreliable to some extent. When you walk inside a building, for example, GPS signals can't reach you.

To demonstrate Android's location services, let's write a test program that simply displays your current position and keeps updating it on the screen as you move around. You can see the program in Figure 8.1, on the next page.

Where Am I?

Start by creating a "Hello, Android" application using these parameters in the New Project wizard:

```
Project name: LocationTest
Build Target: Android 2.1
Application name: LocationTest
Package name: org.example.locationtest
Create Activity: LocationTest
Min SDK Version: 7
```

Access to location information is protected by Android permissions. To gain access, you'll need to add these lines in the `AndroidManifest.xml` file before the `<application>` tag:

[Download](#) LocationTest/AndroidManifest.xml

```
<uses-permission
    android:name="android.permission.ACCESS_COARSE_LOCATION" />
<uses-permission
    android:name="android.permission.ACCESS_FINE_LOCATION" />
```

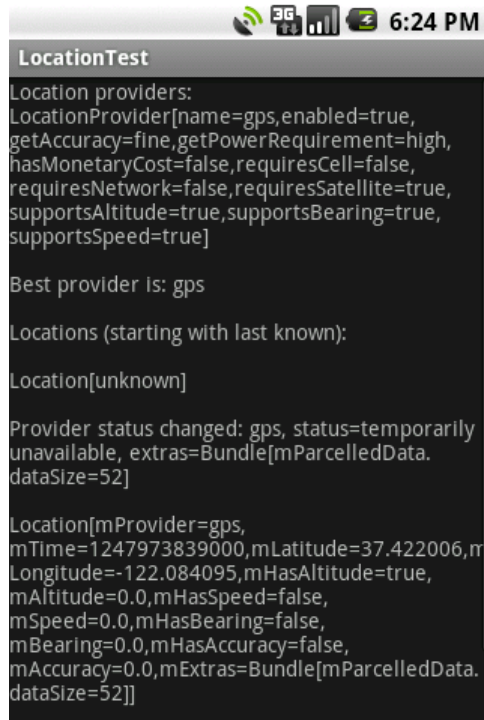


Figure 8.1: Testing the LocationManager

In this example, both fine-grained location providers such as GPS and course-grained location providers such as cell tower triangulation will be supported.

For the user interface, we're going to print all the location data into a big scrolling `TextView`, which is defined in `res/layout/main.xml`:

[Download](#) LocationTest/res/layout/main.xml

```
<?xml version="1.0" encoding="utf-8"?>
<ScrollView
    xmlns:android="http://schemas.android.com/apk/res/android"
    android:orientation="vertical"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent">
    <TextView
        android:id="@+id/output"
        android:layout_width="fill_parent"
        android:layout_height="wrap_content" />
</ScrollView>
```

With the preliminaries out of the way, we can start coding. Here's the outline of the `LocationTest` class and the `onCreate()` method. (Ignore the reference to `LocationListener` on line 15 for now; we'll come back to it later.)

[Download](#) LocationTest/src/org/example/locationtest/LocationTest.java

```
Line 1 package org.example.locationtest;
-
-
- import java.util.List;
-
-
5 import android.app.Activity;
- import android.location.Criteria;
- import android.location.Location;
- import android.location.LocationListener;
- import android.location.LocationManager;
10 import android.location.LocationProvider;
- import android.os.Bundle;
- import android.widget.TextView;
-
-
- public class LocationTest extends Activity implements
15     LocationListener {
-     private LocationManager mgr;
-     private TextView output;
-     private String best;
-
-
20     @Override
-     public void onCreate(Bundle savedInstanceState) {
-         super.onCreate(savedInstanceState);
-         setContentView(R.layout.main);
-
-
25     mgr = (LocationManager) getSystemService(LOCATION_SERVICE);
-     output = (TextView) findViewById(R.id.output);
-
-
-     log("Location providers:");
-     dumpProviders();
```

```

30
-     Criteria criteria = new Criteria();
-     best = mgr.getBestProvider(criteria, true);
-     log("\nBest provider is: " + best);
-
35     log("\nLocations (starting with last known:");
-     Location location = mgr.getLastKnownLocation(best);
-     dumpLocation(location);
- }
- }

```

The starting point for Android location services is the `getSystemService()` call on line 25. It returns a `LocationManager` class that we save into a field for later use.

On line 29, we call our `dumpProviders()` method to print a list of all the location providers in the system.

Next we need to pick one of the possible providers to use. I've seen some examples that simply pick the first available one, but I recommend using the `getBestProvider()` method, as shown here. Android will pick the best provider according to a `Criteria` that you provide (see line 31). If you have any restrictions on cost, power, accuracy, and so on, this is where you put them. In this example, there are no restrictions.

Depending on the provider, it may take some time for the device to figure out your current location. This could be a few seconds, a minute, or more. However, Android remembers the last position it returned, so we can query and print that immediately on line 36. This location could be out of date—for example, if the device was turned off and moved—but it's usually better than nothing.

Knowing where we were is only half the fun. Where are we going next?

Updating the Location

To have Android notify you about location changes, call the `requestLocationUpdates()` method on the `LocationManager` object. To save battery power, we want updates only when the program is in the foreground. Therefore, we need to hook into the Android activity life-cycle methods by overriding `onResume()` and `onPause()`:

[Download](#) `LocationTest/src/org/example/locationtest/LocationTest.java`

```

@Override
protected void onResume() {
    super.onResume();
    // Start updates (doc recommends delay >= 60000 ms)

```



```

    mgr.requestLocationUpdates(best, 15000, 1, this);
}

@Override
protected void onPause() {
    super.onPause();
    // Stop updates to save power while app paused
    mgr.removeUpdates(this);
}

```

When the application resumes, we call `requestLocationUpdates()` to start the update process. It takes four parameters: the provider name, a delay (so you don't get updates too often), a minimum distance (changes less than this are ignored), and a `LocationListener` object.

When the application pauses, we call `removeUpdates()` to stop getting updates. The location provider will be powered down if it's not needed for a while.

Now you know why `LocationTest` implements `LocationListener`, so we could just pass a reference to the activity instead of making a new listener object. That will save us about 1KB of memory at runtime.

Here's the definition of the four methods required by that interface:

Download `LocationTest/src/org/example/locationtest/LocationTest.java`

```

public void onLocationChanged(Location location) {
    dumpLocation(location);
}

public void onProviderDisabled(String provider) {
    log("\nProvider disabled: " + provider);
}

public void onProviderEnabled(String provider) {
    log("\nProvider enabled: " + provider);
}

public void onStatusChanged(String provider, int status,
    Bundle extras) {
    log("\nProvider status changed: " + provider + ", status="
        + S[status] + ", extras=" + extras);
}

```

The most important method in the bunch is `onLocationChanged()`.

As the name suggests, it's called every time the provider notices that the device's location has changed. The `onProviderDisabled()`, `onProviderEn-`

abled(), and onStatusChanged() methods can be used to switch to other providers in case your first choice becomes unavailable.

The code for the remaining methods of LocationTest—log(), dumpProviders(), and dumpLocation()—is not very interesting, so I won't bore you with it here. You can find it all in the downloadable samples on the book's website.

Emulation Notes

If you run the LocationTest example on a real device, it will show your current position as you walk around. On the emulator, it uses a fake GPS provider that always returns the same position unless you change it. Let's do that now.

In Eclipse you can change your simulated location using the Emulator Control view (Window > Show View > Other... > Android > Emulator Control). Scroll down to the bottom, and you'll find a place to enter the longitude and latitude manually. When you click the Send button, Eclipse will send the new position to the emulated device, and you'll see it displayed in any programs that are watching for it.

You can also run the Dalvik Debug Monitor Service (DDMS) program outside of Eclipse and send fake position changes in that way. In addition to manual, position-at-a-time updates, you can use a recorded path read from an external file. See the DDMS documentation for more information.³

With Android location providers, you can find out where you are in a broad, global sense. If you want more local information such as tilt and temperature, you have to use a different API. That's the subject of the next section.

8.2 Set Sensors to Maximum

Let's say you're writing a racing game so you need to give the player a way to steer their car on the screen. One way would be to use buttons, like driving games on a Sony Playstation or the Nintendo DS. Press right to steer right, press left to steer left, and hold down another button for the gas. It works, but it's not very natural.

3. <http://d.android.com/guide/developing/tools/ddms.html>

Have you ever watched somebody play one of those games? Unconsciously, they sway from side to side when making a hairpin curve, jerk the controller when bumping into another car, lean forward when speeding up, and pull back when putting on the brakes. Wouldn't it be cool if those motions actually had some effect on the game play? Now they can.

Engaging Sensors

The Android SDK supports many different types of sensor devices:

- `TYPE_ACCELEROMETER`: Measures acceleration in the x, y, and z axes
- `TYPE_LIGHT`: Tells you how bright your surrounding area is
- `TYPE_MAGNETIC_FIELD`: Returns magnetic attraction in the x, y, and z axes
- `TYPE_ORIENTATION`: Measures the yaw, pitch, and roll of the device
- `TYPE_PRESSURE`: Senses the current atmospheric pressure
- `TYPE_PROXIMITY`: Provides the distance between the sensor and some object
- `TYPE_TEMPERATURE`: Measures the temperature of the surrounding area

Not all devices will offer all this functionality, of course.⁴

The `SensorTest` example, available on the book's web site, demonstrates using the Sensor API. Android's `SensorManager` class is similar to `LocationManager`, except the updates will come much more quickly, perhaps hundreds per second. To get access to the sensors, you first call the `getSystemService()` method like this:

Download `SensorTest/src/org/example/sensortest/SensorTest.java`

```
private SensorManager mgr;
// ...
mgr = (SensorManager) getSystemService(SENSOR_SERVICE);
```

Then you call the `registerListener()` in your `onResume()` method to start getting updates and `unregisterListener()` in your `onPause()` method to stop getting them.

4. Unfortunately, Android 1.5 removed support for the `TRICORDER` sensor that turned your device into a fully functional Star Trek Tricorder. Darn it, Jim—I'm a programmer, not an *ovum paschalis*.

Interpreting Sensor Readings

The sensor service will call your `onSensorChanged()` method every time a value changes. It should look something like this:

[Download](#) `SensorTest/src/org/example/sensortest/SensorTest.java`

```
public void onSensorChanged(SensorEvent event) {  
    for (int i = 0; i < event.values.length; i++) {  
        // ...  
    }  
}
```

All the sensors return an array of floating-point values. The size of the array depends on the particular sensor; for example, `TYPE_TEMPERATURE` returns only one value, the temperature in degrees Celsius. You may not even need to use all the numbers returned. For instance, if you just need a compass heading, you can use the first number returned from the `TYPE_ORIENTATION` sensor.

Turning the sensor readings (especially from the accelerometer) into meaningful information is something of a black art. Here are a few tips to keep in mind:

- Accelerometer readings are extremely jittery. You'll need to smooth out the data using some kind of weighted averaging, but you have to be careful not to smooth it too much, or your interface will feel laggy and soft.
- Sensor numbers will come in at random times. You may get several in a row, then have a short pause, and then receive a bunch more. Don't assume a nice even rate.
- Try to get ahead of the user by predicting what they're going to do next. Let's say the last three readings show the start of a roll to the right, with each one a little faster than the last. You can guess with some degree of accuracy what the next reading is going to be and start reacting based on your prediction.

The most challenging use of sensors is an action game that requires a one-to-one connection between how the player moves the device and what happens on the screen. Unfortunately, the emulator isn't going to be much use for this kind of thing.

Emulation Notes

According to Google, it is not possible to test the sensors using the emulator at all. Most computers don't have a light sensor, a GPS chip, or a compass built into them. Sure enough, if you run the `SensorTest` program in the emulator, it will display no results at all. However, a project called `OpenIntents`⁵ provides an alternate sensor's API that you can call just for testing purposes.

The way it works is that you connect the emulator to another application running on your desktop computer called the `Sensor Simulator`. The simulator shows a picture of a virtual phone and lets you move it around on the screen with the mouse (see Figure 8.2, on the following page), and then it feeds those movements to your Android program running on the emulator. If your development computer actually does have sensors of its own (like the Apple MacBook) or you can connect to a Wii remote with Bluetooth, the `Sensor Simulator` can use that as a data source.

5. <http://www.openintents.org>

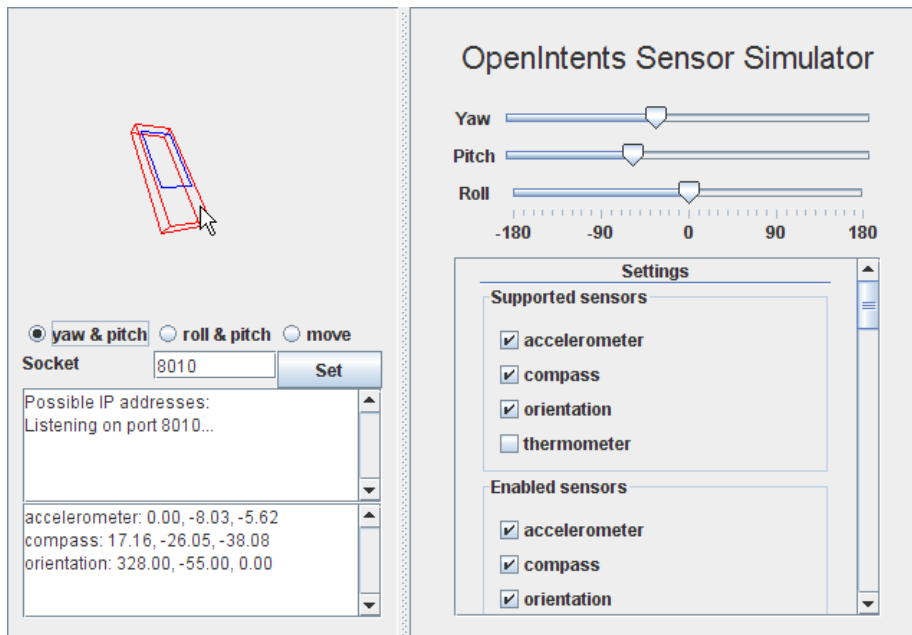


Figure 8.2: Faking out the sensors with the Sensor Simulator

The downside is that you have to modify your source code to make it work. See the OpenIntents website for more information if you want to try it. My recommendation is to forget about sensor emulation and get your hands on a real device. Keep tweaking your algorithms until it feels right.

Now that you know the low-level calls to get your location and query the sensors for numbers such as your compass heading, for certain applications you can forget all that and just use the Google Maps API.

8.3 Bird's-Eye View

One of the first “killer apps” for Ajax was Google Maps.⁶ Using JavaScript and the XMLHttpRequest object, Google engineers created a draggable, zoomable, silky-smooth map viewer that ran in any modern web browser without a plug-in. The idea was quickly copied by other vendors such as Microsoft and Yahoo, but the Google version is arguably still the best.

6. <http://maps.google.com>



Figure 8.3: Embedded map showing your current location

You can use these web-based maps in Android, perhaps with an embedded `WebView` control as discussed in Section 7.2, *Web with a View*, on page 138. But the architecture of your application would be overly convoluted. That's why Google created the `MapView` control.

Embedding a `MapView`

A `MapView` can be embedded directly in your Android application with just a few lines of code. Most of the functionality of Google Maps, plus hooks for adding your own touches, is provided (see Figure 8.3).

The `MapView` class can also tie into your location and sensor providers. It can show your current location on the map and even display a compass showing what direction you're heading. Let's create a sample program to demonstrate a few of its capabilities.

First create a “Hello, Android” application using these values in the wizard:

Project name: MyMap
 Build Target: Google APIs (Platform: 2.1)
 Application name: MyMap
 Package name: org.example.mymap
 Create Activity: MyMap
 Min SDK Version: 7

Note that we’re using the “Google APIs” build target instead of the “Android 2.1” target. That’s because the Google Maps APIs are not part of the normal Android distribution. Edit the layout file, and replace it with a MapView that takes over the whole screen:

[Download](#) MyMap/res/layout/main.xml

```
<?xml version="1.0" encoding="utf-8"?>
<LinearLayout
    xmlns:android="http://schemas.android.com/apk/res/android"
    android:id="@+id/frame"
    android:orientation="vertical"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent">
    <com.google.android.maps.MapView
        android:id="@+id/map"
        android:apiKey="MapAPIKey"
        android:layout_width="fill_parent"
        android:layout_height="fill_parent"
        android:clickable="true" />
</LinearLayout>
```

Substitute *MapAPIKey* with a Google Maps API key that you get from Google.⁷ Note that we have to use the fully qualified name (com.google.android.maps.MapView) because MapView is not a standard Android class. We also need to stick a `<uses-library>` tag in the `<application>` element of AndroidManifest.xml:

[Download](#) MyMap/AndroidManifest.xml

```
<?xml version="1.0" encoding="utf-8"?>
<manifest xmlns:android="http://schemas.android.com/apk/res/android"
    package="org.example.mymap"
    android:versionCode="1"
    android:versionName="1.0">
    <uses-permission
        android:name="android.permission.ACCESS_COARSE_LOCATION" />
    <uses-permission
        android:name="android.permission.ACCESS_FINE_LOCATION" />
    <uses-permission
```

7. <http://code.google.com/android/maps-api-signup.html>


```

        android:name="android.permission.INTERNET" />
<application android:icon="@drawable/icon"
    android:label="@string/app_name">
    <activity android:name=".MyMap"
        android:label="@string/app_name">
        <intent-filter>
            <action android:name="android.intent.action.MAIN" />
            <category android:name="android.intent.category.LAUNCHER" />
        </intent-filter>
    </activity>
    <uses-library android:name="com.google.android.maps" />
</application>
<uses-sdk android:minSdkVersion="3" android:targetSdkVersion="7" />
</manifest>

```

If you leave out the `<uses-library>` tag, you will get a `ClassNotFoundException` at runtime.

In addition to the fine- and coarse-grained location providers, the `MapView` class needs Internet access so that it can call Google's servers to get the map image tiles. These will be cached in your application directory automatically.

Here's the outline of the `MyMap` class:

[Download](#) `MyMap/src/org/example/mymap/MyMap.java`

```

package org.example.mymap;

import android.os.Bundle;

import com.google.android.maps.MapActivity;
import com.google.android.maps.MapController;
import com.google.android.maps.MapView;
import com.google.android.maps.MyLocationOverlay;

public class MyMap extends MapActivity {
    private MapView map;
    private MapController controller;

    @Override
    public void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.main);
        initMapView();
        initMyLocation();
    }
    @Override
    protected boolean isRouteDisplayed() {
        // Required by MapActivity
        return false;
    }
}

```



Joe Asks...

Why Is MapView in the `com.google.android.maps` Package and Not `android.maps`?

Any code in the `android.*` packages is part of the Android core. It's open source and available on every Android device. By contrast, maps are proprietary to Google and to the data providers that Google paid for the geological information and imagery. Google provides the API free of charge as long as you agree to certain conditions.* If you're not happy with the restrictions, you can roll your own views and find your own data sources, but it's not going to be easy or cheap.

*, <http://code.google.com/apis/maps/terms.html>

The most important part is that your activity has to extend `MapActivity`. The `MapActivity` class spins up the background threads, connects to the Internet for tile data, handles caching, does animations, takes care of the life cycle, and much more. All you need to do is properly set it up and let it go.

Getting Ready

The first thing we need to do is call `findViewById()` to get access to the `MapView` and its container. We can do that in the `initMapView()` method:

Download [MyMap/src/org/example/mymap/MyMap.java](#)

```
private void initMapView() {
    map = (MapView) findViewById(R.id.map);
    controller = map.getController();
    map.setSatellite(true);
    map.setBuiltInZoomControls(true);
}
```

The `getController()` method returns a `MapController` that we'll use to position and zoom the map. `setSatellite()` switches the map into satellite mode, and `setBuiltInZoomControls()`⁸ turns on the standard zoom controls. The `MapView` class will take care of making the controls visible when the user pans the map and fading them out slowly when panning stops.

8. Introduced in Android 1.5.

The last step is to tell the `MapView` to follow your position in the `initMyLocation()` method:

[Download](#) `MyMap/src/org/example/mymap/MyMap.java`

```
private void initMyLocation() {
    final MyLocationOverlay overlay = new MyLocationOverlay(this, map);
    overlay.enableMyLocation();
    //overlay.enableCompass(); // does not work in emulator
    overlay.runOnFirstFix(new Runnable() {
        public void run() {
            // Zoom in to current location
            controller.setZoom(8);
            controller.animateTo(overlay.getMyLocation());
        }
    });
    map.getOverlays().add(overlay);
}
```

Android provides a `MyLocationOverlay` class that does most of the heavy lifting. An overlay is just something that is drawn on top of the map, which in this case is a pulsing dot showing your current location. You call `enableMyLocation()` to tell the overlay to start listening to location updates and `enableCompass()` to tell it to start listening to updates from the compass.

The `runOnFirstFix()` method tells the overlay what to do the first time it gets a position reading from the location provider. In this case, we set the zoom level and then start an animation that moves the map from wherever it's pointing now to where you are located.

If you run the program now, you should see something like Figure 8.3, on page 175. Touch and drag the screen to move around the map, and use the zoom buttons to get a closer look. When you walk around carrying the phone, the dot on the map should follow you.

Emulation Notes

The first time you run the `MyMap` program on the emulator you may get an Android AVD Error. Follow the directions in Section 1.3, *Creating an AVD*, on page 27 to create a new AVD for the “Google APIs (Google Inc.) - API Level 7” build target called “em21google.”

On the emulator, you'll initially see a zoomed-out map of the world and no dot for your current location. As before, use the Emulator Control view in Eclipse (or in the stand-alone DDMS program) to feed fake GPS data to the sample application.

When running in the emulator, the compass inset will not be shown because the compass sensor is not emulated.

8.4 Fast-Forward >>

This chapter introduced you to the exciting new world of location- and environmental-aware mobile computing. These technologies, in combination with trends such as the adoption of broadband mobile Internet and the exponential growth of computing power and storage, are going to revolutionize the way we interact with computers and with each other.

Another way to perceive the world is by looking and listening. Android provides the Camera class⁹ for taking photographs using the built-in camera (if there is one), but you can also use it to do other things like make a bar-code reader. The MediaRecorder class¹⁰ allows you to record and store audio clips. These are beyond the scope of this book, but if you need them for your program, consult the online documentation.

Speaking of storage, the next chapter will show you how to use SQL to store structured information (for example, a travel log of locations, photographs, and notes) locally on your mobile phone. If that's not your area of interest, you can skip ahead to Chapter 10, *3D Graphics in OpenGL*, on page 201 and learn how to unlock Android's hidden 3D graphics potential.

9. <http://d.android.com/reference/android/hardware/Camera.html>

10. <http://d.android.com/reference/android/media/MediaRecorder.html>

Putting SQL to Work

In Chapter 6, *Storing Local Data*, on page 123, we explored keeping data around in Preferences and in plain files. That works fine when the amount of data is small or when the data is all one type (such as a picture or an audio file). However, there is a better way to store large amounts of structured data: a relational database.

For the past 30 years, databases have been a staple of enterprise application development, but until recently they were too expensive and unwieldy for smaller-scale use. That is changing with small embedded engines such as the one included with the Android platform.

This chapter will show you how to use Android's embedded database engine, SQLite. You'll also learn how to use Android's data binding to connect your data sources to your user interface. Finally, you'll look at the `ContentProvider` class, which allows two applications to share the same data.

9.1 Introducing SQLite

SQLite¹ is a tiny yet powerful database engine created by Dr. Richard Hipp in 2000. It is arguably the most widely deployed SQL database engine in the world. Besides Android, SQLite can be found in the Apple iPhone, Symbian phones, Mozilla Firefox, Skype, PHP, Adobe AIR, Mac OS X, Solaris, and many other places.

1. <http://www.sqlite.org>

SQLite License

The SQLite source code contains no license because it is in the public domain. Instead of a license, the source offers you this blessing:

May you do good and not evil.

May you find forgiveness for yourself and forgive others.

May you share freely, never taking more than you give.

There are three reasons why it is so popular:

- It's free. The authors have placed it in the public domain and don't charge for its use.
- It's small. The current version is about 150KB, well within the memory budget of an Android phone.
- It requires no setup or administration. There is no server, no config file, and no need for a database administrator.

A SQLite database is just a file. You can take that file, move it around, and even copy it to another system (for example, from your phone to your workstation), and it will work fine. Android stores the file in the `/data/data/packagename/databases` directory (see Figure 9.1, on the next page). You can use the `adb` command or the File Explorer view in Eclipse (Window > Show View > Other... > Android > File Explorer) to view, move, or delete it.

Instead of calling Java I/O routines to access this file from your program, you run Structured Query Language (SQL) statements. Through its helper classes and convenience methods, Android hides some of the syntax from you, but you still need to know a bit of SQL to use it.

9.2 SQL 101

If you've used Oracle, SQL Server, MySQL, DB2, or other database engines, then SQL should be old hat to you. You can skip this section and go to Section 9.3, *Hello, Database*, on page 184. For the rest of you, here's a quick refresher.

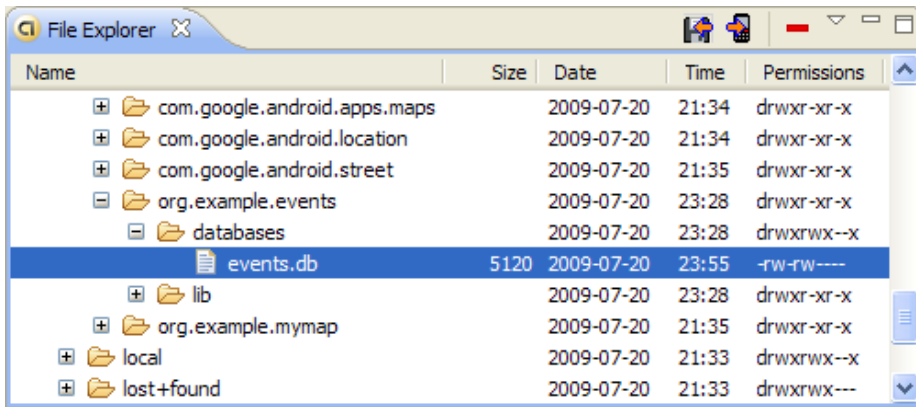


Figure 9.1: SQLite stores an entire database in one file.

To use a SQL database, you submit SQL statements and get back results. There are three main types of SQL statements: DDL, Modification, and Query.

DDL Statements

A database file can have any number of tables. A table consists of rows, and each row has a certain number of columns. Each column of the table has a name and a data type (text string, number, and so forth). You define these tables and column names by first running Data Definition Language (DDL) statements. Here's a statement that creates a table with three columns:

[Download](#) SQLite/create.sql

```
create table mytable (
  _id integer primary key autoincrement,
  name text,
  phone text );
```

One of the columns is designated as the **PRIMARY KEY**, a number that uniquely identifies the row. **AUTOINCREMENT** means that the database will add 1 to the key for every record to make sure it's unique. By convention, the first column is always called `_id`. The `_id` column isn't strictly required for SQLite, but later when we want to use an Android ContentProvider, we'll need it.

Note that, unlike most databases, in SQLite the column types are just hints. If you try to store a string in an integer column, or vice versa, it will just work with no complaints. The SQLite authors consider this to be a feature, not a bug.

Modification Statements

SQL provides a number of statements that let you insert, delete, and update records in the database. For example, to add a few phone numbers, you could use this:

[Download](#) SQLite/insert.sql

```
insert into mytable values(null, 'Steven King', '555-1212');
insert into mytable values(null, 'John Smith', '555-2345');
insert into mytable values(null, 'Fred Smitheizen', '555-4321');
```

The values are specified in the same order you used in the **CREATE TABLE** statement. We specify **NULL** for `_id` because SQLite will figure that value out for us.

Query Statements

Once data has been loaded into a table, you run queries against the table using a **SELECT** statement. For example, if you wanted to get the third entry, you could do this:

[Download](#) SQLite/selectid.sql

```
select * from mytable where(_id=3);
```

It's more likely you'd want to do a look up a person's phone number by name. Here's how you'd find all the records containing "Smith" in the name:

[Download](#) SQLite/selectwhere.sql

```
select name, phone from mytable where(name like "%smith%");
```

Keep in mind that SQL is case insensitive. Keywords, column names, and even search strings can be specified in either uppercase or lowercase.

Now you know just enough about SQL to be dangerous. Let's see how to put that knowledge to work in a simple program.

9.3 Hello, Database

To demonstrate SQLite, let's create a little application called Events that stores records in a database and displays them later. We're going

to start simple and build up from there. Open a new “Hello, Android” program using these values in the project wizard:

```
Project name: Events
Build Target: Android 2.1
Application name: Events
Package name: org.example.events
Create Activity: Events
Min SDK Version: 7
```

As always, you can download the complete source code from the book’s website.

We need somewhere to hold a few constants describing the database, so let’s create a Constants interface:

[Download](#) Events\src\org\example\events\Constants.java

```
package org.example.events;

import android.provider.BaseColumns;

public interface Constants extends BaseColumns {
    public static final String TABLE_NAME = "events";

    // Columns in the Events database
    public static final String TIME = "time";
    public static final String TITLE = "title";
}
```

Each event will be stored as a row in the events table. Each row will have an `_id`, time, and title column. `_id` is the primary key, declared in the `BaseColumns` interface that we extend. time and title will be used for a time stamp and event title, respectively.

Using SQLiteOpenHelper

Next we create a helper class called `EventsData` to represent the database itself. This class extends the Android `SQLiteOpenHelper` class, which manages database creation and versions. All you need to do is provide a constructor and override two methods.

[Download](#) Events\src\org\example\events\EventsData.java

```
Line 1 package org.example.events;
-
- import static android.provider.BaseColumns._ID;
- import static org.example.events.Constants.TABLE_NAME;
5 import static org.example.events.Constants.TIME;
- import static org.example.events.Constants.TITLE;
- import android.content.Context;
- import android.database.sqlite.SQLiteDatabase;
```

```

- import android.database.sqlite.SQLiteOpenHelper;
10
- public class EventsData extends SQLiteOpenHelper {
-     private static final String DATABASE_NAME = "events.db";
-     private static final int DATABASE_VERSION = 1;
-
15     /** Create a helper object for the Events database */
-     public EventsData(Context ctx) {
-         super(ctx, DATABASE_NAME, null, DATABASE_VERSION);
-     }
-
20     @Override
-     public void onCreate(SQLiteDatabase db) {
-         db.execSQL("CREATE TABLE " + TABLE_NAME + " (" + _ID
-             + " INTEGER PRIMARY KEY AUTOINCREMENT, " + TIME
-             + " INTEGER, " + TITLE + " TEXT NOT NULL);");
25     }
-
-     @Override
-     public void onUpgrade(SQLiteDatabase db, int oldVersion,
-         int newVersion) {
30         db.execSQL("DROP TABLE IF EXISTS " + TABLE_NAME);
-         onCreate(db);
-     }
- }

```

The constructor starts on line 16. `DATABASE_NAME` is the actual filename of the database we'll be using (`events.db`), and `DATABASE_VERSION` is just a number we make up. If this were a real program, you would increase the version number whenever you had to make significant changes to the database design (for example, to add a new column).

The first time you try to access a database, `SQLiteOpenHelper` will notice it doesn't exist and call the `onCreate()` method to create it. On line 21, we override that and run a **CREATE TABLE** SQL statement. This will create the events table and the `events.db` database file that contains it.

When Android detects you're referencing an old database (based on the version number), it will call the `onUpgrade()` method (line 28). In this example, we just delete the old table, but you could do something smarter here if you like. For example, you could run an **ALTER TABLE** SQL command to add a column to an existing database.

Defining the Main Program

Our first attempt at the Events program will use a local `SQLite` database to store the events, and it will show them as a string inside a `TextView`.



Joe Asks...

Why Is Constants an Interface?

It's a Java thing. I don't know about you, but I dislike having to repeat the class name every time I use a constant. For example, I want to just type `TIME` and not `Constants.TIME`. Traditionally, the way to do that in Java is use interfaces. Classes can inherit from the `Constants` interface and then leave out the interface name when referencing any fields. If you look at the `BaseColumns` interface, you'll see the Android programmers used the same trick.

Starting with Java 5, however, there's a better way: static imports. That's the method I'll use in `EventsData` and other classes in this chapter. Since `Constants` is an interface, you can use it the old way or the new way as you prefer.

Unfortunately, as of this writing, Eclipse's support for static imports is a little spotty, so if you use static imports in your own programs, Eclipse may not insert the import statements for you automatically. Here's a little trick for Eclipse users: type a wildcard static import after the package statement (for example, `import static org.example.events.Constants.*;`) to make things compile. Later, you can use `Source > Organize Imports` to expand the wildcard and sort the import statements. Let's hope this will be more intuitive in future versions of Eclipse.

Define the layout file (`layout/main.xml`) as follows:

[Download](#) Eventsv1/res/layout/main.xml

```
<?xml version="1.0" encoding="utf-8"?>
<ScrollView
    xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent">
    <TextView
        android:id="@+id/text"
        android:layout_width="fill_parent"
        android:layout_height="wrap_content" />
</ScrollView>
```

This declares the `TextView` with an imaginative ID of `text` (`R.id.text` in code) and wraps it with a `ScrollView` in case there are too many events to fit on the screen. You can see how it looks in Figure 9.2, on the next page.

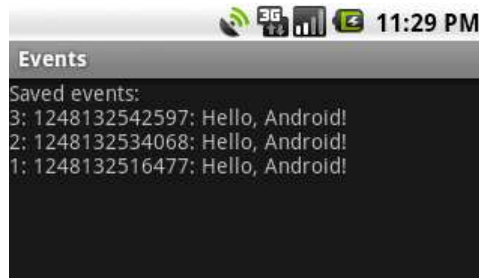


Figure 9.2: The first version displays database records in a TextView.

The main program is the `onCreate()` method in the Events activity. Here's the outline:

[Download](#) Eventsv1/src/org/example/events/Events.java

```

Line 1 package org.example.events;
-
- import static android.provider.BaseColumns._ID;
- import static org.example.events.Constants.TABLE_NAME;
5 import static org.example.events.Constants.TIME;
- import static org.example.events.Constants.TITLE;
- import android.app.Activity;
- import android.content.ContentValues;
- import android.database.Cursor;
10 import android.database.sqlite.SQLiteDatabase;
- import android.os.Bundle;
- import android.widget.TextView;
-
- public class Events extends Activity {
15     private EventsData events;
-
-     @Override
-     public void onCreate(Bundle savedInstanceState) {
-         super.onCreate(savedInstanceState);
20         setContentView(R.layout.main);
-         events = new EventsData(this);
-         try {
-             addEvent("Hello, Android!");
-             Cursor cursor = getEvents();
25             showEvents(cursor);
-         } finally {
-             events.close();
-         }
-     }
30 }

```

On line 20 of `onCreate()`, we set the layout for this view. Then we create an instance of the `EventsData` class on line 21 and start a **try** block. If you look ahead to line 27, you can see we close the database inside the **finally** block. So even if an error occurs in the middle, the database will still be closed.

The events table wouldn't be very interesting if there weren't any events, so on line 23 we call the `addEvent()` method to add an event to it. Every time you run this program, you'll get a new event. You could add menus or gestures or keystrokes to generate other events if you like, but I'll leave that as an exercise to the reader.

On line 24, we call the `getEvents()` method to get the list of events, and finally on line 25, we call the `showEvents()` method to display the list to the user.

Pretty easy, eh? Now let's define those new methods we just used.

Adding a Row

The `addEvent()` method cuts a new record in the database using the string provided as the event title.

[Download](#) `Eventsv1/src/org/example/events/Events.java`

```
private void addEvent(String string) {
    // Insert a new record into the Events data source.
    // You would do something similar for delete and update.
    SQLiteDatabase db = events.getWritableDatabase();
    ContentValues values = new ContentValues();
    values.put(TIME, System.currentTimeMillis());
    values.put(TITLE, string);
    db.insertOrThrow(TABLE_NAME, null, values);
}
```

Since we need to modify the data, we call `getWritableDatabase()` to get a read/write handle to the events database. The database handle is cached, so you can call this method as many times as you like.

Next we fill in a `ContentValues` object with the current time and the event title and pass that to the `insertOrThrow()` method to do the actual **INSERT** SQL statement. You don't need to pass in the record ID because `SQLite` will make one up and return it from the method call.

As the name implies, `insertOrThrow()` can throw an exception (of type `SQLException`) if it fails. It doesn't have to be declared with a **throws** keyword because it's a `RuntimeException` and not a checked exception. However, if you want to, you can still handle it in a **try/catch** block like any

other exception. If you don't handle it and there is an error, the program will terminate, and a traceback will be dumped to the Android log.

By default, as soon as you do the insert, the database is updated. If you need to batch up or delay modifications for some reason, consult the SQLite website for more details.

Running a Query

The `getEvents()` method does the database query to get a list of events:

[Download](#) Eventsv1/src/org/example/events/Events.java

```
private static String[] FROM = { _ID, TIME, TITLE, };
private static String ORDER_BY = TIME + " DESC";
private Cursor getEvents() {
    // Perform a managed query. The Activity will handle closing
    // and re-querying the cursor when needed.
    SQLiteDatabase db = events.getReadableDatabase();
    Cursor cursor = db.query(TABLE_NAME, FROM, null, null, null,
        null, ORDER_BY);
    startManagingCursor(cursor);
    return cursor;
}
```

We don't need to modify the database for a query, so we call `getReadableDatabase()` to get a read-only handle. Then we call `query()` to perform the actual **SELECT** SQL statement. `FROM` is an array of the columns we want, and `ORDER_BY` tells SQLite to return the results in order from newest to oldest.

Although we don't use them in this example, the `query()` method has parameters to specify a **WHERE** clause, a **GROUP BY** clause, and a **HAVING** clause. Actually, `query()` is just a convenience for the programmer. If you prefer, you could build up the **SELECT** statement yourself in a string and use the `rawQuery()` method to execute it. Either way, the return value is a `Cursor` object that represents the result set.

A `Cursor` is similar to a Java `Iterator` or a JDBC `ResultSet`. You call methods on it to get information about the current row, and then you call another method to move to the next row. We'll see how to use it when we display the results in a moment.

The final step is to call `startManagingCursor()`, which tells the activity to take care of managing the cursor's life cycle based on the activity's life cycle. For example, when the activity is paused, it will automatically deactivate the cursor and then requery it when the activity is restarted. When the activity terminates, all managed cursors will be closed.

Displaying the Query Results

The last method we need to define is `showEvents()`. This function takes a `Cursor` as input and formats the output so the user can read it.

[Download](#) `Eventsv1/src/org/example/events/Events.java`

```

Line 1 private void showEvents(Cursor cursor) {
-   // Stuff them all into a big string
-   StringBuilder builder = new StringBuilder(
-       "Saved events:\n");
5   while (cursor.moveToNext()) {
-       // Could use getColumnIndexOrThrow() to get indexes
-       long id = cursor.getLong(0);
-       long time = cursor.getLong(1);
-       String title = cursor.getString(2);
10  builder.append(id).append(": ");
-       builder.append(time).append(": ");
-       builder.append(title).append("\n");
-   }
-   // Display on the screen
15  TextView text = (TextView) findViewById(R.id.text);
-       text.setText(builder);
-   }

```

In this version of `Events`, we're just going to create a big string (see line 3) to hold all the events items, separated by newlines. This is not the recommended way to do things, but it'll work for now.

Line 5 calls the `Cursor.moveToNext()` method to advance to the next row in the data set. When you first get a `Cursor`, it is positioned before the first record, so calling `moveToNext()` gets you to the first record. We keep looping until `moveToNext()` returns false, which indicates there are no more rows.

Inside the loop (line 7), we call `getLong()` and `getString()` to fetch data from the columns of interest, and then we append the values to the string (line 10). There is another method on `Cursor`, `getColumnIndexOrThrow()`, that we could have used to get the column index numbers (the values 0, 1, and 2 passed to `getLong()` and `getString()`). However, it's a little slow, so if you need it, you should call it outside the loop and remember the indexes yourself.

Once all the rows have been processed, we look up the `TextView` from `layout/main.xml` and stuff the big string into it (line 15).

If you run the example now, you should see something like Figure 9.2, on page 188. Congratulations on your first Android database program! There is plenty of room for improvement, though.

What would happen if there were thousands or millions of events in the list? The program would be very slow and might run out of memory trying to build a string to hold them all. What if you wanted to let the user select one event and do something with it? If everything is in a string, you can't do that. Luckily, Android provides a better way: data binding.

9.4 Data Binding

Data binding allows you to connect your model (data) to your view with just a few lines of code. To demonstrate data binding, we'll modify the Events example to use a `ListView` that is bound to the result of a database query. First, we need to make the `Events` class extend `ListActivity` instead of `Activity`:

[Download](#) Eventsv2/src/org/example/events/Events.java

```
import android.app.ListActivity;
// ...
public class Events extends ListActivity {
    // ...
}
```

Next, we need to change how the events are displayed in the `Events.showEvents()` method:

[Download](#) Eventsv2/src/org/example/events/Events.java

```
import android.widget.SimpleCursorAdapter;
// ...
private static int[] TO = { R.id.rowid, R.id.time, R.id.title, };
private void showEvents(Cursor cursor) {
    // Set up data binding
    SimpleCursorAdapter adapter = new SimpleCursorAdapter(this,
        R.layout.item, cursor, FROM, TO);
    setListAdapter(adapter);
}
```

Notice this code is much smaller than before (two lines vs. ten). The first line creates a `SimpleCursorAdapter` for the `Cursor`, and the second line tells the `ListActivity` to use the new adapter. The adapter acts as a go-between, connecting the view with its data source.

If you recall, we first used an adapter in the *Translate* sample program (see `Translate.setAdapters()` in Section 7.4, *Using Web Services*, on page 149). In that example, we used an `ArrayAdapter` because the data source was an array defined in XML. For this one, we use a `SimpleCursorAdapter` because the data source is a `Cursor` object that came from a database query.

The constructor for SimpleCursorAdapter takes five parameters:

- *context*: A reference to the current Activity
- *layout*: A resource that defines the views for a single list item
- *cursor*: The data set cursor
- *from*: The list of column names where the data is coming from
- *to*: The list of views where the data is going to

The layout for a list item is defined in layout/item.xml. Note the definitions for the row ID, time, and title views that are referenced in the TO array.

[Download](#) Eventsv2/res/layout/item.xml

```
<?xml version="1.0" encoding="utf-8"?>
<RelativeLayout
    xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent"
    android:orientation="horizontal"
    android:padding="10sp">
    <TextView
        android:id="@+id/rowid"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content" />
    <TextView
        android:id="@+id/rowidcolon"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        android:text=": "
        android:layout_toRightOf="@id/rowid" />
    <TextView
        android:id="@+id/time"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        android:layout_toRightOf="@id/rowidcolon" />
    <TextView
        android:id="@+id/timecolon"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        android:text=": "
        android:layout_toRightOf="@id/time" />
    <TextView
        android:id="@+id/title"
        android:layout_width="fill_parent"
        android:layout_height="wrap_content"
        android:ellipsize="end"
        android:singleLine="true"
        android:textStyle="italic"
        android:layout_toRightOf="@id/timecolon" />
</RelativeLayout>
```

This looks more complicated than it is. All we're doing is putting the ID, time, and title on one line with colons in between the fields. I added a little padding and formatting to make it look nice.

Finally, we need to change the layout for the activity itself in `layout/main.xml`. Here's the new version:

[Download](#) Eventsv2/res/layout/main.xml

```
<?xml version="1.0" encoding="utf-8"?>
<LinearLayout
    xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent">
    <!-- Note built-in ids for 'list' and 'empty' -->
    <ListView
        android:id="@android:id/list"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"/>
    <TextView
        android:id="@android:id/empty"
        android:layout_width="wrap_content"
        android:layout_height="wrap_content"
        android:text="@string/empty" />
</LinearLayout>
```

Because the activity extends `ListActivity`, Android looks for two special IDs in the layout file. If the list has items in it, the `android:id/list` view will be displayed; otherwise, the `android:id/empty` view will be displayed. So if there are no items, instead of a blank screen the user will see the message “No events!”

Here are the string resources we need:

[Download](#) Eventsv2/res/values/strings.xml

```
<?xml version="1.0" encoding="utf-8"?>
<resources>
    <string name="app_name">Events</string>
    <string name="empty">No events!</string>
</resources>
```

For the final result, see Figure 9.3, on the following page. As an exercise for the reader, think about how you could enhance this application now that you have a real list to play with. For example, when the user selects an event, you could open a detail viewer, mail the event to technical support, or perhaps delete the selected event and all the ones below it from the database.

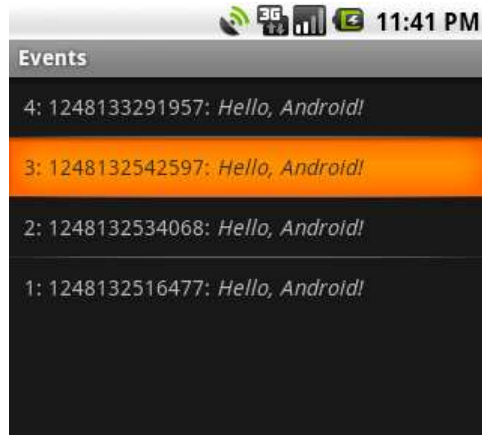


Figure 9.3: This version uses a ListActivity and data binding.

There's still one little problem with this example. No other application can add things to the events database or even look at them! For that, we'll need to use an Android ContentProvider.

9.5 Using a ContentProvider

In the Android security model (see the discussion above in Section 2.5, *Safe and Secure*, on page 45), files written by one application cannot be read from or written to by any other application. Each program has its own Linux user ID and data directory (`/data/data/packagename`) and its own protected memory space. Android programs can communicate with each other in two ways:

- *Inter-Process Communication (IPC)*: One process declares an arbitrary API using the Android Interface Definition Language (AIDL) and the `IBinder` interface. Parameters are marshaled safely and efficiently between processes when the API is called. This advanced technique is used for remote procedure calls to a background Service thread.²

2. IPC, services, and binders are beyond the scope of this book. For more information, see <http://d.android.com/guide/developing/tools/aidl.html>, <http://d.android.com/reference/android/app/Service.html>, and <http://d.android.com/reference/android/os/IBinder.html>.

- *ContentProvider*: Processes register themselves to the system as providers of certain kinds of data. When that information is requested, they are called by Android through a fixed API to query or modify the content in whatever way they see fit. This is the technique we're going to use for the Events sample.

Any piece of information managed by a *ContentProvider* is addressed through a URI that looks like this:

`content://authority/path/id`

where:

- `content://` is the standard required prefix.
- *authority* is the name of the provider. Using your fully qualified package name is recommended to prevent name collisions.
- *path* is a virtual directory within the provider that identifies the kind of data being requested.
- *id* is the primary key of a specific record being requested. To request all records of a particular type, omit this and the trailing slash.

Android comes with several providers already built in, including the following:³

- `content://browser`
- `content://contacts`
- `content://media`
- `content://settings`

To demonstrate using a *ContentProvider*, let's convert the Events example to use one. For our Events provider, these will be valid URIs:

```
content://org.example.events/events/3 -- single event with _id=3
content://org.example.events/events -- all events
```

First we need to add a two more constants to `Constants.java`:

[Download](#) `Eventsv3/src/org/example/events/Constants.java`

```
import android.net.Uri;
// ...
public static final String AUTHORITY = "org.example.events";
public static final Uri CONTENT_URI = Uri.parse("content://"
    + AUTHORITY + "/" + TABLE_NAME);
```

3. For an up-to-date list, see <http://d.android.com/reference/android/provider/package-summary.html>.

Instead of using the strings here, use the documented constants such as `Browser.BOOKMARKS_URI`. Note that access to some providers requires additional permissions to be requested in your manifest file.

The layout files (main.xml and item.xml) don't need to be changed, so the next step is to make a few minor changes to the Events class.

Changing the Main Program

The main program (the Events.onCreate() method) actually gets a little simpler because there is no database object to keep track of:

[Download](#) Eventsv3/src/org/example/events/Events.java

```
@Override
public void onCreate(Bundle savedInstanceState) {
    super.onCreate(savedInstanceState);
    setContentView(R.layout.main);
    addEvent("Hello, Android!");
    Cursor cursor = getEvents();
    showEvents(cursor);
}
```

We don't need the **try/finally** block, and we can remove references to EventData.

Adding a Row

Two lines change in addEvent(). Here's the new version:

[Download](#) Eventsv3/src/org/example/events/Events.java

```
import static org.example.events.Constants.CONTENT_URI;
private void addEvent(String string) {
    // Insert a new record into the Events data source.
    // You would do something similar for delete and update.
    ContentValues values = new ContentValues();
    values.put(TIME, System.currentTimeMillis());
    values.put(TITLE, string);
    getContentResolver().insert(CONTENT_URI, values);
}
```

The call to getWritableDatabase() is gone, and the call to insertOrThrow() is replaced by getContentResolver().insert(). Instead of a database handle, we use a content URI.

Running a Query

The getEvents() method is also simplified when using a ContentProvider:

[Download](#) Eventsv3/src/org/example/events/Events.java

```
private Cursor getEvents() {
    // Perform a managed query. The Activity will handle closing
    // and re-querying the cursor when needed.
    return managedQuery(CONTENT_URI, FROM, null, null, ORDER_BY);
}
```

Here we use the `Activity.managedQuery()` method, passing it the content URI, the list of columns we're interested in, and the order they should be sorted in.

By removing all references to the database, we've decoupled the Events client from the Events data provider. The client is simpler, but now we have to implement a new piece we didn't have before.

9.6 Implementing a ContentProvider

A `ContentProvider` is a high-level object like an `Activity` that needs to be declared to the system. So, the first step when making one is to add it to your `AndroidManifest.xml` file before the `<activity>` tag (as a child of `<application>`):

[Download](#) Eventsv3/AndroidManifest.xml

```
<provider android:name=".EventsProvider"
          android:authorities="org.example.events" />
```

`android:name` is the class name (appended to the manifest's package name), and `android:authorities` is the string used in the content URI.

Next we create the `EventsProvider` class, which must extend `ContentProvider`. Here's the basic outline:

[Download](#) Eventsv3/src/org/example/events/EventsProvider.java

```
package org.example.events;

import static android.provider.BaseColumns._ID;
import static org.example.events.Constants.AUTHORITY;
import static org.example.events.Constants.CONTENT_URI;
import static org.example.events.Constants.TABLE_NAME;
import android.content.ContentProvider;
import android.content.ContentUris;
import android.content.ContentValues;
import android.content.UriMatcher;
import android.database.Cursor;
import android.database.sqlite.SQLiteDatabase;
import android.net.Uri;
import android.text.TextUtils;

public class EventsProvider extends ContentProvider {
    private static final int EVENTS = 1;
    private static final int EVENTS_ID = 2;

    /** The MIME type of a directory of events */
    private static final String CONTENT_TYPE
        = "vnd.android.cursor.dir/vnd.example.event";
```

```

/** The MIME type of a single event */
private static final String CONTENT_ITEM_TYPE
    = "vnd.android.cursor.item/vnd.example.event";

private EventsData events;
private UriMatcher uriMatcher;
// ...
}

```

By convention we use `vnd.example` instead of `org.example` in the MIME type.⁴ `EventsProvider` handles two types of data:

- `EVENTS` (MIME type `CONTENT_TYPE`): A directory or list of events
- `EVENTS_ID` (MIME type `CONTENT_ITEM_TYPE`): A single event

In terms of the URI, the difference is that the first type does not specify an ID, but the second type does. We use Android's `UriMatcher` class to parse the URI and tell us which one the client specified. And we reuse the `EventsData` class from earlier in the chapter to manage the real database inside the provider.

In the interest of space, I'm not going to show the rest of the class here, but you can download the whole thing from the book website. All three versions of the Events example can be found in the source code .zip file.

The final version of the Events sample looks exactly like the previous version on the outside (see Figure 9.3, on page 195). On the inside, however, you now have the framework for an event store that can be used by other applications in the system, even ones written by other developers.

9.7 Fast-Forward >>

In this chapter, we learned how to store data in an Android SQL database. If you want to do more with SQL, you'll need to learn about more statements and expressions than the ones we covered here. A book such as *SQL Pocket Guide* [Gen06] by Jonathan Gennick or *The Definitive Guide to SQLite* [Owe06] by Mike Owens would be a good investment, but keep in mind that the SQL syntax and functions vary slightly from database to database.

4. Multipurpose Internet Mail Extensions (MIME) is an Internet standard for describing the type of any kind of content.

Another option for data storage on Android is db4o.⁵ This library is larger than SQLite and uses a different license (GNU Public License), but it's free and may be easier for you to use, especially if you don't know SQL.

The SimpleCursorAdapter introduced in this chapter can be customized to show more than just text. For example, you could display rating stars or sparklines or other views based on data in the Cursor. Look for ViewBinder in the SimpleCursorAdapter documentation for more information.⁶

And now for something completely different...the next chapter will cover 3D graphics with OpenGL.

5. <http://www.db4o.com/android>

6. <http://d.android.com/reference/android/widget/SimpleCursorAdapter.html>

3D Graphics in OpenGL

Two-dimensional graphics are great for most programs, but sometimes you need an extra level of depth, interactivity, or realism that isn't possible in 2D. For these times, Android provides a three-dimensional graphics library based on the OpenGL ES standard. In this chapter, we'll explore 3D concepts and build up a sample program that uses OpenGL.

10.1 Understanding 3D Graphics

The world is three-dimensional, yet we routinely view it in two dimensions. When you watch television or look at a picture in a book, the 3D images are flattened out, or *projected*, onto a 2D surface (the TV panel or book page).

Try this simple experiment: cover one eye and look out the window. What do you see? Light from the sun bounces off objects outside, passes through the window, and travels to your eye so you can perceive it. In graphics terms, the scene outside is projected onto the window (or *viewport*). If someone replaced your window with a high-quality photograph, it would look the same until you moved.

Based on how close your eye is to the window and how big the window is, you can see a limited amount of the world outside. This is called your *field of view*. If you draw a line from your eye to the four corners of the window and beyond, you would get the pyramid in Figure 10.1, on the next page. This is called the *view frustum* (Latin for a “piece broken off”). For performance reasons, the frustum is usually bounded by near and far clipping planes as well. You can see everything inside the frustum but nothing outside of it.

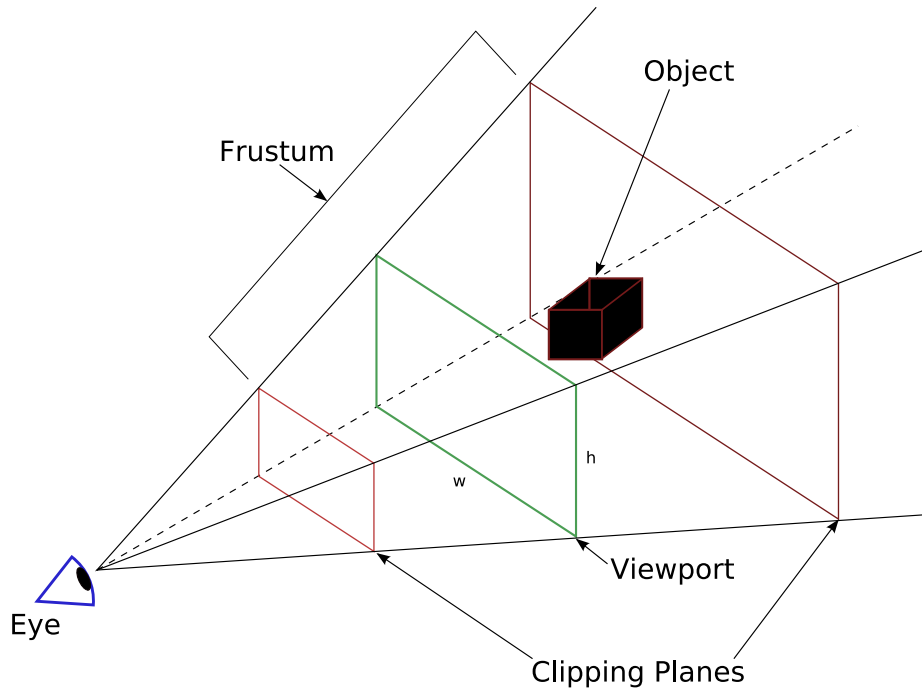


Figure 10.1: Viewing a three-dimensional scene

In 3D computer graphics, your computer screen acts as the viewport. Your job is to fool the user into thinking it's a window into another world just on the other side of the glass. The OpenGL graphics library is the API you use to accomplish that.

10.2 Introducing OpenGL

OpenGL¹ was developed by Silicon Graphics in 1992. It provides a unified interface for programmers to take advantage of hardware from any manufacturer. At its core, OpenGL implements familiar concepts such as viewports and lighting and tries to hide most of the hardware layer from the developer.

Because it was designed for workstations, OpenGL is too large to fit on a mobile device. So, Android implements a subset of OpenGL called

1. <http://www.opengl.org>

Thank You, John Carmack

OpenGL has proven to be very successful, but it almost wasn't. In 1995, Microsoft introduced a competitor called Direct3D. Owing to Microsoft's dominant market position and significant R&D investments, for a while it looked like Direct3D was going to take over as a de facto industry standard for gaming. However, one man, John Carmack, cofounder of id Software, refused to comply. His wildly popular Doom and Quake games almost single-handedly forced hardware manufacturers to keep their OpenGL device drivers up-to-date on the PC. Today's Linux, Mac OS X, and mobile device users can thank John and id Software for helping to keep the OpenGL standard relevant.

OpenGL for Embedded Systems (OpenGL ES).² This standard was created by the Khronos Group, an industry consortium of companies such as Intel, AMD, Nvidia, Nokia, Samsung, and Sony. The same library (with minor differences) is now available on major mobile platforms including Android, Symbian, and iPhone.

Every language has its own language bindings for OpenGL ES, and Java is no exception. Java's language binding was defined by a Java Specification Request (JSR) 239.³ Android implements this standard as closely as possible, so you can refer to a variety of books and documentation on JSR 239 and OpenGL ES for a full description of all its classes and methods.

Now let's take a look at how to create a simple OpenGL program in Android.

10.3 Building an OpenGL Program

Begin by creating a new "Hello, Android" project as in Section 1.2, *Creating Your First Program*, on page 26, but this time supply the following parameters in the New Android Project dialog box:

Project name: OpenGL
 Build Target: Android 2.1
 Application name: OpenGL
 Package name: org.example.opengl

2. <http://www.khronos.org/opengles>

3. <http://jcp.org/en/jsr/detail?id=239>



Joe Asks...

Will Every Phone Have 3D?

Yes and no. Some low-end devices running Android may not actually have 3D hardware. However, the OpenGL programming interface will still be there. All the 3D functions will be emulated in software. Your program will still run, but it will be much slower than a hardware-accelerated device. For this reason, it's a good idea to provide options for users to turn off certain details and special effects that take time to draw but aren't absolutely necessary for the program. That way, if the user is running your program on a slower device, they can disable some of your eye candy to get better performance.

Create Activity: OpenGL

Min SDK Version: 7

This will create OpenGL.java to contain your main activity. Edit this, and change it to refer to a custom view named GLView, as shown next.

[Download](#) OpenGL/src/org/example/opengl/OpenGL.java

```
package org.example.opengl;

import android.app.Activity;
import android.os.Bundle;

public class OpenGL extends Activity {
    GLView view;
    @Override
    public void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        view = new GLView(this);
        setContentView(view);
    }

    @Override
    protected void onPause() {
        super.onPause();
        view.onPause();
    }

    @Override
    protected void onResume() {
        super.onResume();
    }
}
```

```

        view.onResume();
    }
}

```

We override the `onPause()` and `onResume()` methods so they can call the methods of the same name in the view.

We won't need the layout resource (`res/layout/main.xml`), so you can delete it. Now let's define our custom view class:

[Download](#) `OpenGL/src/org/example/opengl/GLView.java`

```

package org.example.opengl;

import android.content.Context;
import android.opengl.GLSurfaceView;

class GLView extends GLSurfaceView {
    private final GLRenderer renderer;

    GLView(Context context) {
        super(context);

        // Uncomment this to turn on error-checking and logging
        //setDebugFlags(DEBUG_CHECK_GL_ERROR | DEBUG_LOG_GL_CALLS);

        renderer = new GLRenderer(context);
        setRenderer(renderer);
    }
}

```

`GLSurfaceView` is a new class introduced in Android 1.5 that greatly simplifies using OpenGL in Android. It provides the glue to connect OpenGL ES to the View system and Activity life cycle. It takes care of picking the appropriate frame buffer pixel format and it manages a separate rendering thread to enable smooth animation. All `GLView` needs to do is extend `GLSurfaceView` and define a renderer for the view.

In the next section, we'll fill the screen with a solid color.

10.4 Rendering the Scene

As we saw in Section 4.2, *Drawing the Board*, on page 87, the Android 2D library calls the `onDraw()` method of your view whenever it needs to redraw a section of the screen. OpenGL is a bit different.

In OpenGL ES on Android, drawing is separated out into a rendering class which is responsible for initializing and drawing the entire screen. Let's define that now.

Here's the outline for the GLRenderer class:

[Download](#) OpenGL/src/org/example/opengl/GLRendererer.java

```
package org.example.opengl;

import javax.microedition.khronos.egl.EGLConfig;
import javax.microedition.khronos.opengles.GL10;

import android.content.Context;
import android.opengl.GLSurfaceView;
import android.opengl.GLU;
import android.util.Log;

class GLRenderer implements GLSurfaceView.Renderer {
    private static final String TAG = "GLRenderer";
    private final Context context;

    GLRenderer(Context context) {
        this.context = context;
    }

    public void onSurfaceCreated(GL10 gl, EGLConfig config) {
        // ...
    }

    public void onSurfaceChanged(GL10 gl, int width, int height) {
        // ...
    }

    public void onDrawFrame(GL10 gl) {
        // ...
    }
}
```

GLRenderer implements the GLSurfaceView.Renderer interface, which has three methods. Let's start with the onSurfaceCreated() method, which is called when the OpenGL Surface (kind of like a Canvas in regular 2D) is created or re-created:

[Download](#) OpenGL/src/org/example/opengl/GLRendererer.java

```
Line 1 public void onSurfaceCreated(GL10 gl, EGLConfig config) {
2     // Set up any OpenGL options we need
3     gl.glEnable(GL10.GL_DEPTH_TEST);
4     gl.glDepthFunc(GL10.GL_LEQUAL);
5     gl.glEnableClientState(GL10.GL_VERTEX_ARRAY);
6
7     // Optional: disable dither to boost performance
8     // gl.glDisable(GL10.GL_DITHER);
9 }
```

On line 3, we set a couple of OpenGL options. OpenGL has dozens of options that can be enabled or disabled with `glEnable()` and `glDisable()`. The most commonly used ones include the following:

Option	Description
<code>GL_BLEND</code>	Blend the incoming color values with the values already in the color buffer.
<code>GL_CULL_FACE</code>	Ignore polygons based on their winding (clockwise or counterclockwise) in window coordinates. This is a cheap way to eliminate back faces.
<code>GL_DEPTH_TEST</code>	Do depth comparisons, and update the depth buffer. Pixels farther away than those already drawn will be ignored.
<code>GL_LIGHT<i>i</i></code>	Include light number <i>i</i> when figuring out an object's brightness and color.
<code>GL_LIGHTING</code>	Turn on lighting and material calculations.
<code>GL_LINE_SMOOTH</code>	Draw antialiased lines (lines without jaggies).
<code>GL_MULTISAMPLE</code>	Perform multisampling for antialiasing and other effects.
<code>GL_POINT_SMOOTH</code>	Draw antialiased points.
<code>GL_TEXTURE_2D</code>	Use textures to draw surfaces.

All options are off by default except for `GL_DITHER` and `GL_MULTISAMPLE`. Note that everything you enable has some cost in performance.

Next let's fill out the `onSurfaceChanged()` method. This method is called once after the `Surface` is created and then again whenever the size of the `Surface` changes:

[Download](#) `OpenGL/src/org/example/opengl/GLRenderer.java`

```

Line 1 public void onSurfaceChanged(GL10 gl, int width, int height) {
      2     // Define the view frustum
      3     gl.glViewport(0, 0, width, height);
      4     gl.glMatrixMode(GL10.GL_PROJECTION);
      5     gl.glLoadIdentity();
      6     float ratio = (float) width / height;
      7     GLU.gluPerspective(gl, 45.0f, ratio, 1, 100f);
      8 }

```

Here we configure our view frustum and set a few OpenGL options. Note the call to the `GLU.gluPerspective()` helper function on line 7. The last two arguments are the distance from the eye to the near and far clipping planes (see Figure 10.1, on page 202).

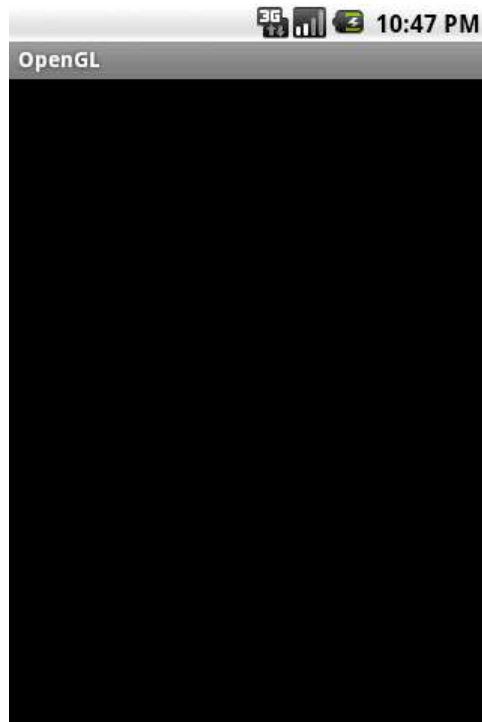


Figure 10.2: That was a lot of trouble to get a black screen.

It's time to draw something. The `onDrawFrame()` method is called over and over in the rendering thread created by the `GLSurfaceView` class.

[Download](#) `OpenGL/src/org/example/opengl/GLRenderer.java`

```
public void onDrawFrame(GL10 gl) {
    // Clear the screen to black
    gl.glClear(GL10.GL_COLOR_BUFFER_BIT
        | GL10.GL_DEPTH_BUFFER_BIT);

    // Position model so we can see it
    gl.glMatrixMode(GL10.GL_MODELVIEW);
    gl.glLoadIdentity();
    gl.glTranslatef(0, 0, -3.0f);

    // Other drawing commands go here...
}
```

To start with, we set the screen to black. We clear both the color and depth buffers. Always remember to clear both, or you'll get some very

Version 1.what?

OpenGL ES 1.0 is based on full OpenGL version 1.3, and ES 1.1 is based on OpenGL 1.5. JSR 239 has two versions: the original 1.0 and a maintenance release version 1.0.1. There are also some OpenGL ES extensions that I won't get into. Android implements JSR 239 1.0.1, and OpenGL ES implements 1.0. In the future, it's expected that Android will support OpenGL ES 1.1 and beyond.

Don't let all the 1.x versions worry you. These standards have evolved over a period of several years. By now, they are fairly stable and well thought out.

strange results left over from the depth information for the previous frame. We also set the starting position for the rest of the drawing commands which will be completed in the next section.

If you run the program now, you get Figure 10.2, on the previous page. If you're thinking that it's silly to draw the same black screen over and over again in a loop, you're right. This will make more sense later when we talk about animation, so just bear with me for now.

Let's move on and draw something a little more interesting. But first we need to define exactly what we're drawing (the model).

10.5 Building a Model

Depending on the complexity of the objects you want to draw, you will typically create them using a graphical design tool and import them into your program. For the purposes of this example, we'll just define a simple model in code: a cube.

[Download](#) OpenGL/src/org/example/opengl/GLCube.java

```
Line 1 package org.example.opengl;
-
- import java.nio.ByteBuffer;
- import java.nio.ByteOrder;
5 import java.nio.IntBuffer;
-
- import javax.microedition.khronos.opengles.GL10;
-
- import android.content.Context;
```

```

10  import android.graphics.Bitmap;
   - import android.graphics.BitmapFactory;
   - import android.opengl.GLUtils;
   -
   - class GLCube {
15      private final IntBuffer mVertexBuffer;
      public GLCube() {
   -         int one = 65536;
   -         int half = one / 2;
   -         int vertices[] = {
20             // FRONT
   -             -half, -half, half, half, -half, half,
   -             -half, half, half, half, half, half,
   -             // BACK
   -             -half, -half, -half, -half, half, -half,
25             half, -half, -half, half, half, -half,
   -             // LEFT
   -             -half, -half, half, -half, half, half,
   -             -half, -half, -half, -half, half, -half,
   -             // RIGHT
30             half, -half, -half, half, half, -half,
   -             half, -half, half, half, half, half,
   -             // TOP
   -             -half, half, half, half, half, half,
   -             -half, half, -half, half, half, -half,
35             // BOTTOM
   -             -half, -half, half, -half, -half, -half,
   -             half, -half, half, half, -half, -half, };
   -
   -         // Buffers to be passed to gl*Pointer() functions must be
40         // direct, i.e., they must be placed on the native heap
   -         // where the garbage collector cannot move them.
   -         //
   -         // Buffers with multi-byte data types (e.g., short, int,
   -         // float) must have their byte order set to native order
45         ByteBuffer vbb = ByteBuffer.allocateDirect(vertices.length * 4);
   -         vbb.order(ByteOrder.nativeOrder());
   -         mVertexBuffer = vbb.asIntBuffer();
   -         mVertexBuffer.put(vertices);
   -         mVertexBuffer.position(0);
50     }
   -
   -     public void draw(GL10 gl) {
   -         gl.glVertexPointer(3, GL10.GL_FIXED, 0, mVertexBuffer);
   -
   -         gl.glColor4f(1, 1, 1, 1);
55         gl.glNormal3f(0, 0, 1);
   -         gl.glDrawArrays(GL10.GL_TRIANGLE_STRIP, 0, 4);
   -         gl.glNormal3f(0, 0, -1);
   -         gl.glDrawArrays(GL10.GL_TRIANGLE_STRIP, 4, 4);
60     }

```

Fixed vs. Floating Point

OpenGL ES provides fixed-point (integer) and floating-point interfaces for all its methods. The fixed-point methods end with the letter *x*, and the floating-point ones end with the letter *f*. For example, you can use either `glColor4x()` and `glColor4f()` to set the four components of a color.

A fixed-point number is scaled by 2^{32} , or 65,536. So, 32,768 in fixed point is equivalent to 0.5f. Put another way, the integral part uses the most significant two bytes of a four-byte int, while the fractional part uses the least significant two bytes. This is quite different from the way the native Android 2D library uses integers, so be careful.

In a simple example like this one, it doesn't matter whether you use fixed-point or floating-point arithmetic, so I use them interchangeably as convenient. Keep in mind, though, that some Android devices will not have floating-point hardware, so fixed point may be significantly faster. My advice is to code it first using floating point, because it's easier to program, and then optimize the slow parts using fixed point later if necessary.

```
-      gl.glColor4f(1, 1, 1, 1);
-      gl.glNormal3f(-1, 0, 0);
-      gl.glDrawArrays(GL10.GL_TRIANGLE_STRIP, 8, 4);
-      gl.glNormal3f(1, 0, 0);
65      gl.glDrawArrays(GL10.GL_TRIANGLE_STRIP, 12, 4);
-
-      gl.glColor4f(1, 1, 1, 1);
-      gl.glNormal3f(0, 1, 0);
-      gl.glDrawArrays(GL10.GL_TRIANGLE_STRIP, 16, 4);
70      gl.glNormal3f(0, -1, 0);
-      gl.glDrawArrays(GL10.GL_TRIANGLE_STRIP, 20, 4);
-  }
- }
```

The vertices array on line 19 defines the corners of the cube in fixed-point model coordinates (see the “Fixed vs. Floating Point” sidebar). Each face of a cube is a square, which consists of two triangles. We use a common OpenGL drawing mode called *triangle strips*. In this mode, we specify two starting points, and then after that every subsequent point defines a triangle with the previous two points. It's a quick way to get a lot of geometry pumped out to the graphics hardware in a hurry.

Note that each point has three coordinates (x, y, and z). The x and y axes point to the right and up, respectively, and the z axis points out of the screen toward the eye point.

In the draw method (line 52), we use the vertex buffer created in the constructor and draw six different runs of triangles (for the six sides of the cube). In a real program, you would want to combine the calls into one or two strips, because the fewer number of OpenGL calls you make, the faster your program will go.

Now let's use our new class in GLRenderer:

[Download](#) `OpenGL/src/org/example/opengl/GLRenderer.java`

```
private final GLCube cube = new GLCube();
public void onDrawFrame(GL10 gl) {
    // ...
    // Draw the model
    cube.draw(gl);
}
```

Now if you run the program, you'll see the exciting image in Figure 10.3, on the following page. Well, it's more exciting than black.

10.6 Lights, Camera, ...

In real life you have light sources such as the sun, headlights, torches, or glowing lava pools. OpenGL lets you define up to eight light sources in your scene. There are two parts to lighting—a light and something to shine it on. Let's start with the light.

All 3D graphics libraries support three types of lighting:

- *Ambient*: A general glow that the light contributes to the entire scene, even to objects facing away from the light. It's important to have a little ambient light so you can pick out details even in the shadows.
- *Diffuse*: Soft directional lighting, as you might get from a fluorescent panel. Most of the light contributed to your scene will typically come from diffuse sources.
- *Specular*: Shiny light, usually from bright point sources. Combined with shiny materials, this gives you highlights (glints) that add realism.

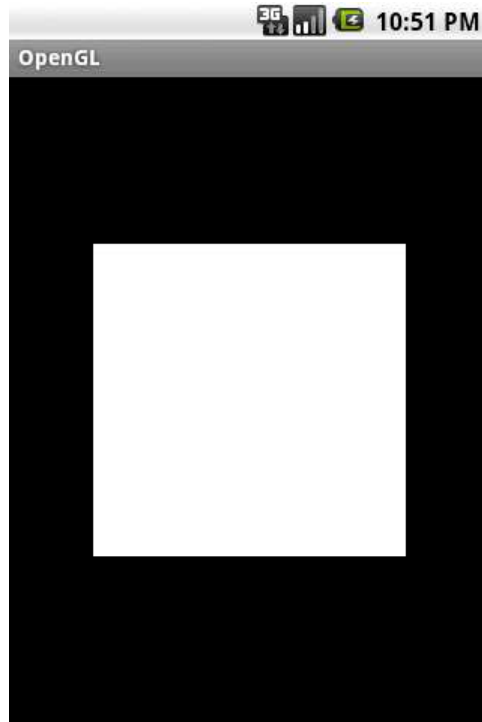


Figure 10.3: Drawing an unshaded cube

A single light source can contribute all three types of light. These values go into a lighting equation that determines the color and brightness of each pixel on the screen.

The lighting is defined in the `GLRenderer.onSurfaceCreated()` method:

[Download](#) `OpenGL/src/org/example/opengl/GLRenderer.java`

```
float lightAmbient[] = new float[] { 0.2f, 0.2f, 0.2f, 1 };
float lightDiffuse[] = new float[] { 1, 1, 1, 1 };
float[] lightPos = new float[] { 1, 1, 1, 1 };
gl.glEnable(GL10.GL_LIGHTING);
gl.glEnable(GL10.GL_LIGHT0);
gl.glLightfv(GL10.GL_LIGHT0, GL10.GL_AMBIENT, lightAmbient, 0);
gl.glLightfv(GL10.GL_LIGHT0, GL10.GL_DIFFUSE, lightDiffuse, 0);
gl.glLightfv(GL10.GL_LIGHT0, GL10.GL_POSITION, lightPos, 0);
```

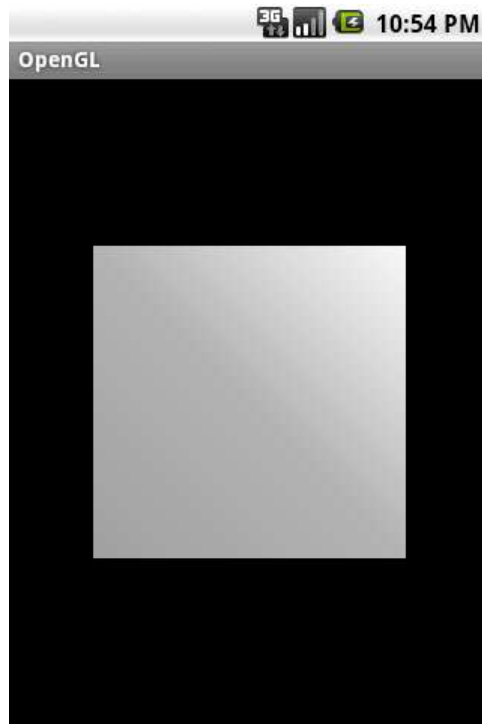


Figure 10.4: Lighting the scene

In our code we define one light source at position (1, 1, 1). It's a white omnidirectional light that has a bright diffuse component and a dim ambient component. In this example, we're not using specular lighting.

Next, we need to tell OpenGL about the materials our cube is made of. Light reflects differently off different materials, such as metal, plastic, or paper. To simulate this in OpenGL, add this code in `onSurfaceCreated()` to define how the material reacts with the three types of light: ambient, diffuse, and specular:

[Download](#) `OpenGL/src/org/example/opengl/GLRenderer.java`

```
float matAmbient[] = new float[] { 1, 1, 1, 1 };
float matDiffuse[] = new float[] { 1, 1, 1, 1 };
gl.glMaterialfv(GL10.GL_FRONT_AND_BACK, GL10.GL_AMBIENT,
    matAmbient, 0);
gl.glMaterialfv(GL10.GL_FRONT_AND_BACK, GL10.GL_DIFFUSE,
    matDiffuse, 0);
```

The object will appear to have a dull finish, as if it were made out of paper (see Figure 10.4, on the previous page). The top-right corner of the cube is closer to the light, so it appears brighter.

10.7 Action!

Up to now the cube has just been sitting there without moving. That's pretty boring, so let's make it move. To do that, we need to make a couple of changes to our `onSurfaceCreated()` and `onDrawFrame()` methods in `GLRenderer`.

[Download](#) `OpenGL/src/org/example/opengl/GLRenderer.java`

```
private long startTime;
private long fpsStartTime;
private long numFrames;
public void onSurfaceCreated(GL10 gl, EGLConfig config) {
    // ...
    startTime = System.currentTimeMillis();
    fpsStartTime = startTime;
    numFrames = 0;
}
public void onDrawFrame(GL10 gl) {
    // ...
    // Set rotation angle based on the time
    long elapsed = System.currentTimeMillis() - startTime;
    gl.glRotatef(elapsed * (30f / 1000f), 0, 1, 0);
    gl.glRotatef(elapsed * (15f / 1000f), 1, 0, 0);

    // Draw the model
    cube.draw(gl);
}
```

This code rotates the cube a little bit every time through the main loop. Specifically, every second it rotates 30 degrees around the x axis and 15 degrees around the y axis. The result will be a nice, smooth, spinning cube (see Figure 10.5, on the following page).

10.8 Applying Texture

Although the scene is starting to look more interesting, nobody would mistake it for real life. Everyday objects have textures, like the rough surface of a brick wall or the gravel on a garden path. Do you own a laminated table? A wood laminate is just a photograph of wood grain that is glued on the surface of a less expensive material like plastic or particle board.

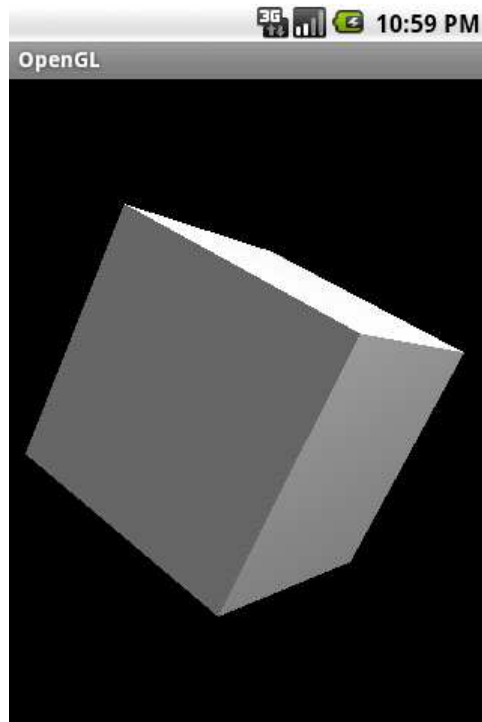


Figure 10.5: Rotating the cube

Time-Based Animation

The first version of this example kept track of the current rotation angle and simply incremented it each time through the loop. Can you think of a reason why that was a bad idea?

Since Android can run on a variety of different devices, you can't predict how long it will take to draw a single frame. It might take half a second or 1/100th of a second. If you moved an object a fixed amount every frame, then on slow devices the object would move too slowly, and on fast devices it would move too fast. By tying the amount of movement to how much time has elapsed, you can achieve predictable movement on any device. Faster hardware will draw the animation more smoothly, but objects will get from A to B in the same amount of time.

We're going to do the same thing to our cube using a picture. Unfortunately, the code to do this is fairly long. Don't worry if you don't understand it all right away.

[Download](#) `OpenGL/src/org/example/opengl/GLCube.java`

```
private final IntBuffer mTextureBuffer;

public GLCube() {
    int texCoords[] = {
        // FRONT
        0, one, one, one, 0, 0, one, 0,
        // BACK
        one, one, one, 0, 0, one, 0, 0,
        // LEFT
        one, one, one, 0, 0, one, 0, 0,
        // RIGHT
        one, one, one, 0, 0, one, 0, 0,
        // TOP
        one, 0, 0, 0, one, one, 0, one,
        // BOTTOM
        0, 0, 0, one, one, 0, one, one, };
    // ...
    ByteBuffer tbb = ByteBuffer.allocateDirect(texCoords.length * 4);
    tbb.order(ByteOrder.nativeOrder());
    mTextureBuffer = tbb.asIntBuffer();
    mTextureBuffer.put(texCoords);
    mTextureBuffer.position(0);
}

static void loadTexture(GL10 gl, Context context, int resource) {
    Bitmap bmp = BitmapFactory.decodeResource(
        context.getResources(), resource);
    GLUtils.texImage2D(GL10.GL_TEXTURE_2D, 0, bmp, 0);
    gl.glTexParameterx(GL10.GL_TEXTURE_2D,
        GL10.GL_TEXTURE_MIN_FILTER, GL10.GL_LINEAR);
    gl.glTexParameterx(GL10.GL_TEXTURE_2D,
        GL10.GL_TEXTURE_MAG_FILTER, GL10.GL_LINEAR);
    bmp.recycle();
}
}
```

Next we need to tell OpenGL to use the texture coordinates. Add this to the beginning of the `draw()` method:

[Download](#) `OpenGL/src/org/example/opengl/GLCube.java`

```
gl.glEnable(GL10.GL_TEXTURE_2D); // workaround bug 3623
gl.glTexCoordPointer(2, GL10.GL_FIXED, 0, mTextureBuffer);
```



Figure 10.6: Applying a texture

And finally we need to call the `loadTexture()` method in `GLRenderer`. Add these lines to the end of the `onSurfaceCreated()` method:

[Download](#) `OpenGL/src/org/example/opengl/GLRenderer.java`

```
// Enable textures
gl.glEnableClientState(GL10.GL_TEXTURE_COORD_ARRAY);
gl.glEnable(GL10.GL_TEXTURE_2D);

// Load the cube's texture from a bitmap
GLCube.loadTexture(gl, context, R.drawable.android);
```

This code enables textures and texture coordinates and then calls our `loadTexture()` method, passing it the Activity context and resource ID so it can load the texture image.

`R.drawable.android` is a PNG file 128 pixels square that I copied to `res/drawable-nodpi/android.png`. You can find it in the downloadable code package



Figure 10.7: The final version: a see-through cube

that accompanies this book. Note the number 128 doesn't appear anywhere in the code, so you substitute a larger or smaller image easily.

You can see our progress so far in Figure 10.6, on the previous page.

10.9 Peekaboo

Just for fun, let's make the cube partially transparent. Add this to `GLRenderer.onSurfaceCreated()`:

[Download](#) `OpenGL/src/org/example/opengl/GLRenderer.java`

```
boolean SEE_THRU = true;
// ...
if (SEE_THRU) {
    gl.glDisable(GL10.GL_DEPTH_TEST);
    gl.glEnable(GL10.GL_BLEND);
    gl.glBlendFunc(GL10.GL_SRC_ALPHA, GL10.GL_ONE);
}
```

This turns off depth testing, because we want to see obscured objects as well as foreground ones. It also turns on a blending mode that lets the opacity of objects be based on their alpha (transparency) channel. The net effect is that the back faces of the cube will appear through the front faces. For the final result, see Figure 10.7, on the preceding page.

I'll leave it to you to implement an option to turn that on and off. Try playing around with different blend modes to get cool effects.

10.10 Measuring Smoothness

How smooth is smooth? The smoothness of a game or other graphics-heavy program is defined by how fast it can update the display screen. This is typically measured by counting the number of screens or frames per second (FPS) that are displayed. Different people perceive different speeds as “smooth.” 15–30FPS is sometimes acceptable to casual gamers, but more serious players have come to expect a higher rate such as 60FPS or more. I recommend that you make every effort to reach a consistent rate of 60FPS. That corresponds to the maximum refresh rate of current Android devices, and is also the speed used on popular gaming platforms such as Sony’s Playstation and Playstation Portable (PSP).

A high frame rate is challenging, because at 60FPS you only have 1/60th of a second (16.67 milliseconds) between calls to `onDrawFrame()` to do everything that needs to be done, including any animation, physics, and game calculations, plus the time it takes to actually draw the scene for the current frame. The only way to tell if you’re making your FPS target is to measure it. To do that, try adding this bit of code to the end of the `onDrawFrame()` method:

[Download](#) `OpenGL/src/org/example/opengl/GLRenderer.java`

```
numFrames++;
long fpsElapsed = System.currentTimeMillis() - fpsStartTime;
if (fpsElapsed > 5 * 1000) { // every 5 seconds
    float fps = (numFrames * 1000.0F) / fpsElapsed;
    Log.d(TAG, "Frames per second: " + fps + " (" + numFrames
        + " frames in " + fpsElapsed + " ms)");
    fpsStartTime = System.currentTimeMillis();
    numFrames = 0;
}
```

Every five seconds it will display your average FPS number to the Android system log (see Section 3.10, *Debugging with Log Messages*, on page 74). If this number drops below your target rate, then adjust your algorithm and try again. Keep iterating until you reach your target. A profiler like `traceview`⁴ may also come in handy. Note that you should avoid the temptation to display this on the screen on top of your other graphics because the act of displaying it will throw off the number.

If you try this now, you may notice that the emulator runs much more slowly than the actual device. In my tests I saw about 12FPS on the emulator and closer to 60FPS on a real phone. The lesson here is that for performance testing you can't trust the emulator.

10.11 Fast-Forward >>

In this chapter, you learned how to use Android's 3D graphics library. Because Android uses the industry-standard OpenGL ES API, a wide variety of additional information is available if you want to learn more. In particular, I recommend the Javadoc for the JSR 239 API specification.⁵ For other graphics tips check out the developer talks at the Google I/O conference.⁶

4. <http://d.android.com/guide/developing/tools/traceview.html>

5. <http://java.sun.com/javame/reference/apis/jsr239>

6. <http://code.google.com/events/io/sessions/WritingRealTimeGamesAndroid.html>

Part IV

The Next Generation

Chapter 11

Multi-touch

With each new version of Android, new features are added to the platform. In part IV we'll concentrate on those newer features and on making your programs available to others.

In this chapter we'll learn how to use the new multi-touch features in Android 2.0, warts and all. Then we'll cover home screen widgets, introduced in Android 1.6, and live wallpaper, introduced in Android 2.1. Android's popularity and its rapid pace of development has created a problem with fragmentation, so there's a whole chapter dedicated to dealing with all the different versions and screen sizes you'll encounter in the field. Finally, there's a chapter that discusses how to get your program into users' hands by publishing it on the Android Market.

11.1 Introducing Multi-Touch

Multi-touch is simply an extension of the regular touch-screen user interface, using two or more fingers instead of one. We've used single-finger gestures before,¹ although we didn't call it that. Remember in Section 4.3, *Entering Numbers*, on page 93 when we let the user touch a tile in the Sudoku game in order to change it? That's called a "tap" gesture. Another gesture is called "drag". That's where you hold one finger on the screen and move it around, causing the content under your finger to scroll.

Tap, drag, and a few other single-fingered gestures have always been supported in Android. But due to the popularity of the Apple iPhone, early Android users suffered from a kind of gesture envy. The iPhone

1. Some people use them more than others.

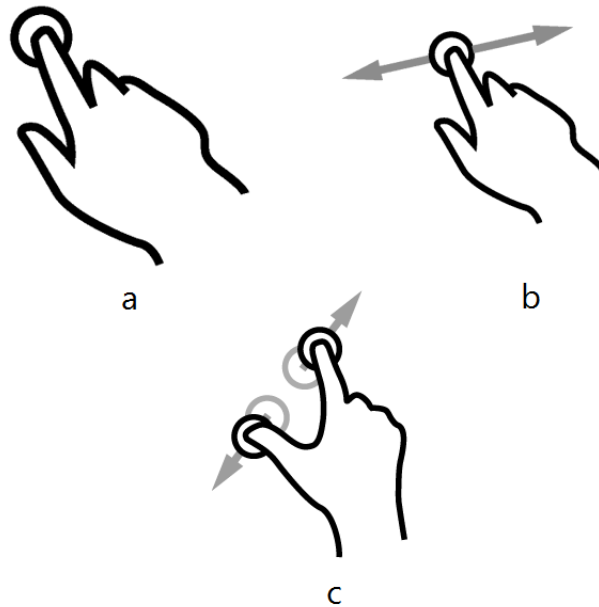


Figure 11.1: Three common touch gestures: a) tap, b) drag, and c) pinch zoom.

supported multi-touch, in particular the “pinch zoom” gesture (see Figure 11.1).

With pinch zoom, you place two fingers on the screen and squeeze them together to make the item you’re viewing smaller, or pull them apart to make it bigger. Before Android 2.0 you had to use a clunky zoom control with icons that you pressed to zoom in and out (see the `setBuiltInZoomControls()` method in Section 8.3, *Getting Ready*, on page 178). But thanks to its new multi-touch support, you can now pinch to zoom on Android too! As long as the application supports it, of course.

Note: If you try to run the example in this chapter on Android 1.5 or 1.6, it will crash because those versions do not support multi-touch. We’ll learn how to work around that in Section 13.3, *Evolving with Android APIs*, on page 262.

Warning: Multi-Bugs Ahead

Multi-touch, as implemented on current Android phones is extremely buggy. In fact it's so buggy that it borders on the unusable. The API routinely reports invalid or impossible data points, especially during the transition from one finger to two fingers on the screen and vice-versa.

On the developer forums you can find complaints of fingers getting swapped, x and y axes flipping, and multiple fingers sometimes being treated as one. Some of these problems can be traced back to hardware limitations in the touch screen sensors used in certain phones, but many could be fixed or improved with software updates.

With a lot of trial and error, I was able to get the example in this chapter working because the gesture it implements is so simple. Until Google acknowledges and fixes the issues with multi-touch, that may be about all you can do. Luckily, pinch zoom seems to be the only multi-touch gesture most people want.

11.2 Building the Touch Example

To demonstrate multi-touch, we're going to build a simple image viewer application that lets you zoom in and scroll around an image. See Figure 11.2, on the following page for a screenshot of the finished product.

Begin by creating a new “Hello, Android” project with the following parameters in the New Android Project dialog box:

```
Project name: Touch
Build Target: Android 2.1
Application name: Touch
Package name: org.example.touch
Create Activity: Touch
Min SDK Version: 7
```

This will create Touch.java to contain your main activity. Let's edit it to show a sample image, put in a touch listener, and add a few imports we'll need later:

[Download](#) Touchv1/src/org/example/touch/Touch.java

```
package org.example.touch;

import android.app.Activity;
import android.graphics.Matrix;
```



Figure 11.2: The Touch example implements a simple image viewer with drag and pinch zoom.

```

import android.graphics.PointF;
import android.os.Bundle;
import android.util.FloatMath;
import android.util.Log;
import android.view.MotionEvent;
import android.view.View;
import android.view.View.OnClickListener;
import android.widget.ImageView;

public class Touch extends Activity implements OnClickListener {
    private static final String TAG = "Touch";
    @Override
    public void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.main);
        ImageView view = (ImageView) findViewById(R.id.imageView);
        view.setOnClickListener(this);
    }

    @Override
    public boolean onTouch(View v, MotionEvent event) {
        // Handle touch events here...
    }
}

```

We'll fill out that `onTouch()` method in a moment. First we need to define the layout for our activity:

[Download](#) Touchv1/res/layout/main.xml

```

<?xml version="1.0" encoding="utf-8"?>
<FrameLayout
    xmlns:android="http://schemas.android.com/apk/res/android"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent">
    <ImageView android:id="@+id/imageView"
        android:layout_width="fill_parent"
        android:layout_height="fill_parent"
        android:src="@drawable/butterfly"
        android:scaleType="matrix">
    </ImageView>
</FrameLayout>

```

The entire interface is a big `ImageView` control that covers the whole screen. The `android:src="@drawable/butterfly"` value refers to the butterfly image used in the example. You can use any JPG or PNG format image you like, just put it in the `res/drawable-nodpi` directory. The `android:scaleType="matrix"` attribute indicates we're going to use a matrix to control the position and scale of the image. More on that later.

The `AndroidManifest.xml` file is untouched except for the addition of the `android:theme=` attribute:

[Download](#) Touchv1/AndroidManifest.xml

```
<?xml version="1.0" encoding="utf-8"?>
<manifest xmlns:android="http://schemas.android.com/apk/res/android"
    package="org.example.touch"
    android:versionCode="1"
    android:versionName="1.0">
    <application android:icon="@drawable/icon"
        android:label="@string/app_name"
        android:theme="@android:style/Theme.NoTitleBar.Fullscreen">
        <activity android:name=".Touch"
            android:label="@string/app_name">
            <intent-filter>
                <action android:name="android.intent.action.MAIN" />
                <category android:name="android.intent.category.LAUNCHER" />
            </intent-filter>
        </activity>
    </application>
    <uses-sdk android:minSdkVersion="3" android:targetSdkVersion="7" />
</manifest>
```

`@android:style/Theme.NoTitleBar.Fullscreen`, as the name suggests, tells Android to use the entire screen with no title bar or status bar at the top.

You can run the application now and it will simply display the picture.

11.3 Understanding Touch Events

Whenever I first learn a new API, I like to first put in some code to dump everything out so I can get a feel for what the methods do and in what order events happen. So let's start with that. First add a call to the `dumpEvent()` method inside `onTouch()`:

[Download](#) Touchv1/src/org/example/touch/Touch.java

```
@Override
public boolean onTouch(View v, MotionEvent event) {
    // Dump touch event to log
    dumpEvent(event);
    return true; // indicate event was handled
}
```

Note that we need to return `true` to indicate to Android that the event has been handled. Next, define the `dumpEvent()` method. The only parameter is the event that we want to dump.

Download `Touchv1/src/org/example/touch/Touch.java`

```

/** Show an event in the LogCat view, for debugging */
private void dumpEvent(MotionEvent event) {
    String names[] = { "DOWN", "UP", "MOVE", "CANCEL", "OUTSIDE",
        "POINTER_DOWN", "POINTER_UP", "7?", "8?", "9?" };
    StringBuilder sb = new StringBuilder();
    int action = event.getAction();
    int actionCode = action & MotionEvent.ACTION_MASK;
    sb.append("event ACTION_").append(names[actionCode]);
    if (actionCode == MotionEvent.ACTION_POINTER_DOWN
        || actionCode == MotionEvent.ACTION_POINTER_UP) {
        sb.append("(pid ").append(
            action >> MotionEvent.ACTION_POINTER_ID_SHIFT);
        sb.append(")");
    }
    sb.append("[");
    for (int i = 0; i < event.getPointerCount(); i++) {
        sb.append("#").append(i);
        sb.append("(pid ").append(event.getPointerId(i));
        sb.append(")=").append((int) event.getX(i));
        sb.append(",").append((int) event.getY(i));
        if (i + 1 < event.getPointerCount())
            sb.append(";");
    }
    sb.append("]");
    Log.d(TAG, sb.toString());
}

```

Output will go to the Android debug log, which you can see by opening the LogView view (see Section 3.10, *Debugging with Log Messages*, on page 74).

The easiest way to understand this code is to run it. Unfortunately you can't run this program on the Emulator (actually you can, but the Emulator doesn't support multi-touch so the results won't be very interesting). So hook up a real phone to your USB port and run the sample there (see Section 1.4, *Running on a Real Phone*, on page 30).

When I tried it on my phone and performed a few quick gestures, I received the output below:

```

Line 1 event ACTION_DOWN[#0(pid 0)=135,179]
- event ACTION_MOVE[#0(pid 0)=135,184]
- event ACTION_MOVE[#0(pid 0)=144,205]
- event ACTION_MOVE[#0(pid 0)=152,227]
5 event ACTION_POINTER_DOWN(pid 1)[#0(pid 0)=153,230;#1(pid 1)=380,538]
- event ACTION_MOVE[#0(pid 0)=153,231;#1(pid 1)=380,538]
- event ACTION_MOVE[#0(pid 0)=155,236;#1(pid 1)=364,512]
- event ACTION_MOVE[#0(pid 0)=157,240;#1(pid 1)=350,498]
- event ACTION_MOVE[#0(pid 0)=158,245;#1(pid 1)=343,494]

```

```

10 event ACTION_POINTER_UP(pid 0)[#0(pid 0)=158,247;#1(pid 1)=336,484]
- event ACTION_MOVE[#0(pid 1)=334,481]
- event ACTION_MOVE[#0(pid 1)=328,472]
- event ACTION_UP[#0(pid 1)=327,471]

```

Here's how to interpret the events:

- On line 1 we see an ACTION_DOWN event so the user must have pressed one finger on the screen. The finger was positioned at coordinates x=135, y=179, which is near the upper left of the display. You can't tell yet whether they're trying to do a tap or a drag.
- Next, starting on line 2 there are some ACTION_MOVE events, indicating the user moved their finger around a bit to those coordinates given in the events. (It's actually very hard to put your finger on the screen and *not* move it at all, so you'll get a lot of these.) By the amount moved you can tell the user is doing a drag gesture.
- The next event, ACTION_POINTER_DOWN on line 5, means the user pressed down another finger. "pid 1" means that pointer id 1 (that is, finger number 1) was pressed. Finger number 0 was already down, so we now have two fingers being tracked on the screen. In theory, the Android API can support up to 256 fingers at once, but the first crop of Android 2.x phones is limited to 2.² The coordinates for both fingers come back as part of the event. It looks like the user is about to start a pinch zoom gesture.
- Here's where it gets interesting. The next thing we see is a series of ACTION_MOVE events starting on line 6. Unlike before, now we have two fingers moving around. If you look closely at the coordinates you can see the fingers are moving closer together as part of a pinch zoom.
- Then on line 10 we see an ACTION_POINTER_UP on pid 0. This means that finger number 0 was lifted off the screen. Finger number 1 is still there. Naturally, this ends the pinch zoom gesture.
- We see a couple more ACTION_MOVE events starting on line 11, indicating the remaining finger is still moving around a little. If you compare these to the earlier move events, you'll notice a different

2. While the idea of 256 fingers may seem silly outside of MiB headquarters, keep in mind that Android is designed for a wide variety of devices, not just phones. If you have a table-top sized screen with several people gathered around it you could easily have more than a handful of fingers on the display.

pointer id is reported. Unfortunately the touch API is so buggy you can't always count on that (see the sidebar).

- Finally, on line 13 we get an ACTION_UP event as the last finger is removed from the screen.

Now the code for `dumpEvent()` should make a little more sense. The `getAction()` method returns the action being performed (up, down, or move). The lowest 8 bits of the action is the action code itself, and the next 8 bits is the pointer (finger) id, so we have to use a bitwise AND (&) and a right shift (>>) to separate them.

Then we call the `getPointerCount()` method to see how many finger positions are included. `getX()` and `getY()` return the X and Y coordinates, respectively. The fingers can appear in any order, so we have to call the `getPointerId()` to find out which fingers we're really talking about.

That covers the raw mouse event data. The trick, as you might imagine, is in interpreting and acting on that data.

11.4 Setting up for Image Transformation

In order to move and zoom the image we'll use a neat little feature on the `ImageView` class called matrix transformation. Using a matrix we can represent any kind of translation, rotation, or skew that we want to do to the image. We already turned it on by specifying `android:scaleType="matrix"` in the `res/layout/main.xml` file. In the `Touch` class, we need to declare two matrices as fields (one for the current value and one for the original value before the transformation). We'll use them in the `onTouch()` method to transform the image. We also need a mode variable to tell whether we're in the middle of a drag or zoom gesture:

[Download](#) `Touchv1/src/org/example/touch/Touch.java`

```
public class Touch extends Activity implements OnTouchListener {
    // These matrices will be used to move and zoom image
    Matrix matrix = new Matrix();
    Matrix savedMatrix = new Matrix();

    // We can be in one of these 3 states
    static final int NONE = 0;
    static final int DRAG = 1;
    static final int ZOOM = 2;
    int mode = NONE;

    @Override
    public boolean onTouch(View v, MotionEvent event) {
```

```

    ImageView view = (ImageView) v;

    // Dump touch event to log
    dumpEvent(event);

    // Handle touch events here...
    switch (event.getAction() & MotionEvent.ACTION_MASK) {
    }

    view.setImageMatrix(matrix);
    return true; // indicate event was handled
}
}

```

The matrix variable will be calculated inside the **switch** statement when we implement the gestures.

11.5 Implementing the Drag Gesture

A drag gesture starts when the first finger is pressed to the screen (ACTION_DOWN) and ends when it is removed (ACTION_UP or ACTION_POINTER_UP).

[Download](#) Touchv1/src/org/example/touch/Touch.java

```

switch (event.getAction() & MotionEvent.ACTION_MASK) {
case MotionEvent.ACTION_DOWN:
    savedMatrix.set(matrix);
    start.set(event.getX(), event.getY());
    Log.d(TAG, "mode=DRAG");
    mode = DRAG;
    break;
case MotionEvent.ACTION_UP:
case MotionEvent.ACTION_POINTER_UP:
    mode = NONE;
    Log.d(TAG, "mode=NONE");
    break;
case MotionEvent.ACTION_MOVE:
    if (mode == DRAG) {
        matrix.set(savedMatrix);
        matrix.postTranslate(event.getX() - start.x,
            event.getY() - start.y);
    }
    break;
}
}

```

When the gesture starts we remember the current value of the transformation matrix and the starting position of the pointer. Every time the finger moves, we start the transformation matrix over at its original value and call the `postTranslate()` method to add a translation vector, the difference between the current and starting positions.



Joe Asks...

Why not use the built-in gesture library?

The `android.gesture` package provides a way to create, recognize, load, and save gestures.* Unfortunately it is not very useful in practice. Among other problems, it doesn't come with a standard collection of built-in gestures (like tap and drag) and it doesn't support multi-touch gestures such as pinch zoom. Perhaps a future version of Android will include a better gesture library so the code in this chapter could be simplified.

*, <http://d.android.com/reference/android/gesture/package-summary.html>

If you run the program now you should be able to drag the image around the screen using your finger. Neat, huh?

11.6 Implementing the Pinch Zoom Gesture

The pinch zoom gesture is similar, except it starts when the *second* finger is pressed to the screen (`ACTION_POINTER_DOWN`).

Download `Touchv1/src/org/example/touch/Touch.java`

```
case MotionEvent.ACTION_POINTER_DOWN:
    oldDist = spacing(event);
    Log.d(TAG, "oldDist=" + oldDist);
    if (oldDist > 10f) {
        savedMatrix.set(matrix);
        midPoint(mid, event);
        mode = ZOOM;
        Log.d(TAG, "mode=ZOOM");
    }
    break;
case MotionEvent.ACTION_MOVE:
    if (mode == DRAG) {
        // ...
    }
    else if (mode == ZOOM) {
        float newDist = spacing(event);
        Log.d(TAG, "newDist=" + newDist);
        if (newDist > 10f) {
            matrix.set(savedMatrix);
            float scale = newDist / oldDist;
            matrix.postScale(scale, scale, mid.x, mid.y);
        }
    }
}
```

```

    }
}
break;

```

When we get the down event for the second finger, we calculate and remember the distance between the two fingers. In my testing, Android would sometimes tell me (incorrectly) that there were two fingers pressed down in almost exactly the same position. So I added an check to ignore the event if the distance is smaller than some arbitrary number of pixels. If it's bigger than that, we remember the current transformation matrix, calculate the midpoint of the two fingers, and start the zoom.

When a move event arrives while we're in zoom mode, we calculate the distance between the fingers again. If it's too small, the event is ignored, otherwise we restore the transformation matrix and scale the image around the midpoint.

The scale is simply the ratio of the new distance divided by the old distance. If the new distance is bigger (that is, the fingers have gotten further apart), then the scale will be greater than 1, making the image bigger. If it's smaller (fingers closer together), then the scale will be less than one, making the image smaller. And of course if everything is the same, the scale is equal to 1 and the image is not changed.

Now let's define the `spacing()` and `midPoint()` methods.

Distance Between Two Points

To find out how far apart two fingers are, we first construct a vector (x, y) which is the difference between the two points. Then we use the formula for Euclidean distance to calculate the spacing:³

[Download](#) `Touchv1/src/org/example/touch/Touch.java`

```

private float spacing(MotionEvent event) {
    float x = event.getX(0) - event.getX(1);
    float y = event.getY(0) - event.getY(1);
    return FloatMath.sqrt(x * x + y * y);
}

```

The order of the points doesn't matter because any negative signs will be lost when we square them. Note that all math is done using Java's **float** type. While some Android devices may not have floating point hardware, we're not doing this often enough to worry about its performance.

3. http://en.wikipedia.org/wiki/Euclidean_distance

Midpoint of Two Points

Calculating a point in the middle of two points is even easier:

[Download](#) Touchv1/src/org/example/touch/Touch.java

```
private void midPoint(PointF point, MotionEvent event) {
    float x = event.getX(0) + event.getX(1);
    float y = event.getY(0) + event.getY(1);
    point.set(x / 2, y / 2);
}
```

All we do is take the average of their X and Y coordinates. To avoid garbage collections that can cause noticeable pauses in the application, we reuse an existing object to store the result rather than allocating and returning a new one each time.

Try running the program now on your phone. Drag the image with one finger, and zoom it by pinching two fingers in or out. For best results, don't let your fingers get closer than an inch or so apart. Otherwise you'll start to run into some of those bugs in the API I mentioned earlier.

11.7 Fast-Forward >>

In this chapter we learned how to use the multi-touch API to create a pinch zoom gesture. There's a nice site called *GestureWorks*⁴ that describes a whole library of gestures that have been implemented on the Adobe Flash platform. If you're willing to push the limits of Android's quirky multi-touch support, then perhaps you can find ideas there for other gestures to implement in your Android programs.

Because multi-touch code uses new methods that didn't exist before Android 2.0, if you try to run the Touch example on earlier versions it will fail with a "Force close" error. Luckily there are ways around this limitation described in Section 13.3, *Evolving with Android APIs*, on page 262. You can't teach an old phone new tricks, but you can at least keep it from crashing.

In the next chapter we'll investigate home screen extensions, including live wallpaper.

4. <http://gestureworks.com>

There's No Place Like Home

No matter how deeply you get into a game or other Android program, it's reassuring to know that you can press the Home button to return to a familiar place—the Android Home screen. It's the central location where you start the web browser, make a phone call, open email, run apps, and everything else that makes Android fun.

Since you're going to be spending a lot of time there, Android lets you customize the Home screen in many different ways such as setting a static background image and rearranging icons. In this chapter you'll learn about two more ways: widgets and live wallpaper. Now click your heels together and let's get started.

12.1 Hello, Widget

Introduced in Android 1.5 (Cupcake), *widgets* are miniature application views that can be embedded in the Home screen. A few widgets are provided with Android including an analog clock, a music controller, and one that just shows a picture. Many developers have created interesting widgets to display the weather, news headlines, horoscopes, and more, and you can too. This section will show you how.

Creating Your First Widget

For this example we're going to create a widget that shows today's date. See Figure 12.5, on page 245 if you'd like a peek at the final result.

Unfortunately, there is no special Eclipse wizard for making a widget so we'll first create a regular "Hello, Android" application like we did in Section 1.2, *Creating Your First Program*, on page 26 and then tweak it a little. Select File > New > Project... to open the New Project dialog

box. Then select Android > Android Project, and click Next. Enter the following information:

```
Project name: Widget
Build Target: Android 2.1
Application name: Widget
Package name: org.example.widget
Min SDK Version: 7
```

Instead of entering a name for the Activity, leave that field blank and turn off the check mark next to Create Activity. When you're done, it should look something like Figure 12.1, on the following page.

Click Finish. The Android plug-in will create the project and fill it in with some default files. The files will not be correct for a widget project so let's fix them up now.

Calling All Widgets!

Our first stop is the AndroidManifest.xml file. While it's technically possible (and common) to put widgets and activities in the same application, this example will only have a widget. We don't need an `<activity>` tag but we do need to add a `<receiver>` to define the widget. Here is the revised manifest file:

[Download](#) Widget/AndroidManifest.xml

```
<?xml version="1.0" encoding="utf-8"?>
<manifest xmlns:android="http://schemas.android.com/apk/res/android"
    package="org.example.widget"
    android:versionCode="1"
    android:versionName="1.0">
    <application android:icon="@drawable/icon"
        android:label="@string/app_name">
        <!-- Broadcast Receiver that will process AppWidget updates -->
        <receiver android:name=".Widget"
            android:label="@string/widget_name">
            <intent-filter>
                <action android:name=
                    "android.appwidget.action.APPWIDGET_UPDATE" />
            </intent-filter>
            <meta-data android:name="android.appwidget.provider"
                android:resource="@xml/widget" />
        </receiver>
    </application>
    <uses-sdk android:minSdkVersion="3" android:targetSdkVersion="7" />
</manifest>
```

The `<meta-data>` tag tells Android it can find the widget definition in `res/xml/widget.xml`. Here's the definition:

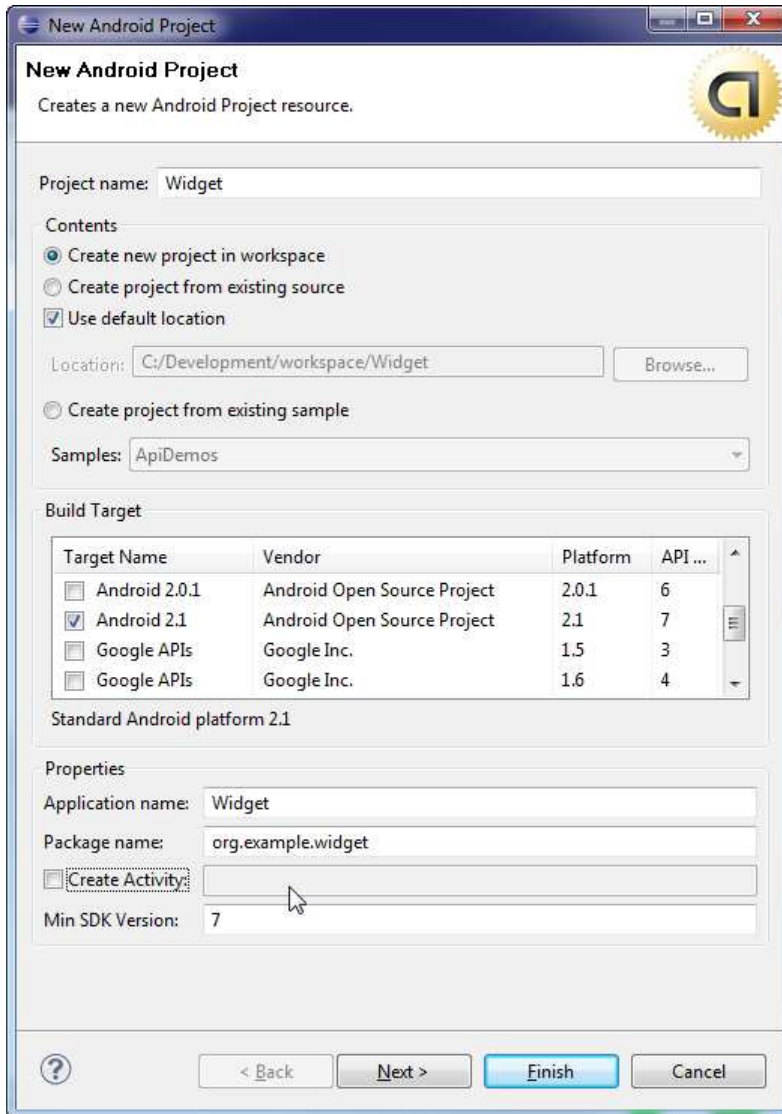


Figure 12.1: New Android widget project

Download Widget/res/xml/widget.xml

```
<?xml version="1.0" encoding="utf-8"?>
<appwidget-provider
    xmlns:android="http://schemas.android.com/apk/res/android"
    android:minWidth="146dip"
    android:minHeight="72dip"
    android:updatePeriodMillis="1800000"
    android:initialLayout="@layout/main"
/>
```

This specifies a minimum size for the widget, how often it should be updated (more on that later), and a reference to its starting layout.

The layout is defined in res/layout/main.xml:

Download Widget/res/layout/main.xml

```
<?xml version="1.0" encoding="utf-8"?>
<LinearLayout xmlns:android="http://schemas.android.com/apk/res/android"
    android:orientation="vertical"
    android:layout_width="fill_parent"
    android:layout_height="fill_parent"
    android:background="@drawable/widget_bg"
    >
    <TextView android:id="@+id/text"
        android:layout_width="fill_parent"
        android:layout_height="fill_parent"
        android:text="@string/hello"
        android:textSize="18sp"
        android:gravity="center"
        android:textColor="@android:color/black"
    />
</LinearLayout>
```

You may have noticed that this layout is almost the same as the one we used for the “Hello, Android” example except that this version specifies centered black text and a background image.

Stretch to Fit

For the background we could have used any Android Drawable, such as a solid color or a bitmap (see Section 4.1, *Drawable*, on page 80). We could have even left it off to get a completely transparent background. But for this example I wanted to show you how to use a NinePatch image.

A NinePatch image is a stretchable PNG image often used for the background of resizable buttons. You use the Draw 9-patch tool¹ included

1. <http://d.android.com/guide/developing/tools/draw9patch.html>

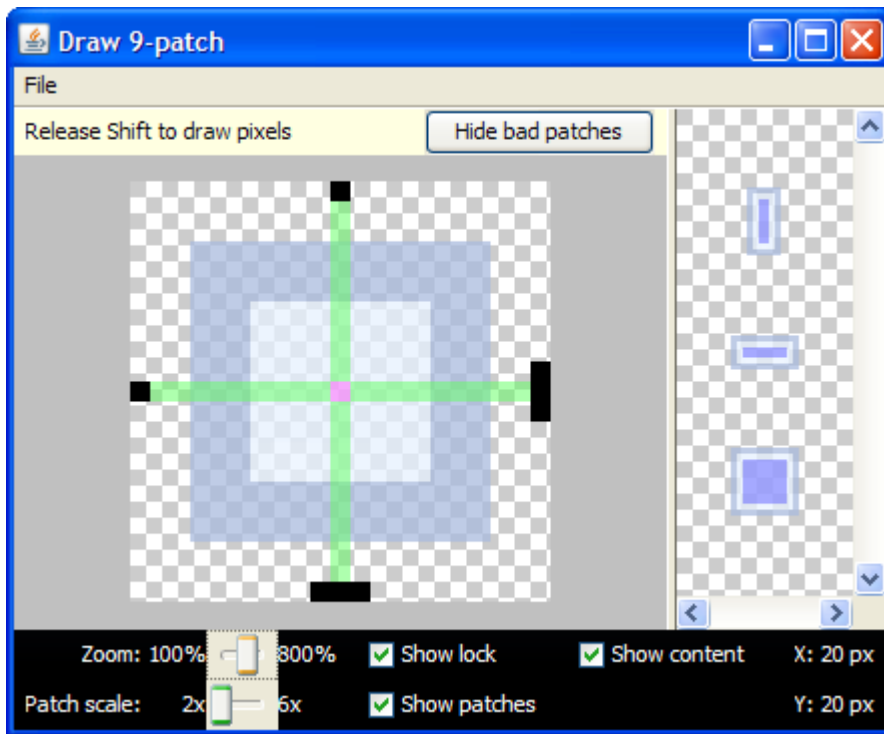


Figure 12.2: Defining a stretchable background with the Draw 9-patch tool.

with the SDK to create one, as shown in Figure 12.2, on the following page.

A one-pixel border around the real image contains additional information about how to stretch the image and insert padded content. Lines on the bottom and right edge tell Android where content should go. If the content doesn't fit in that area (which is usually the case) then the lines on the left and top edge tell Android which pixel rows and columns should be duplicated in order to stretch the image.

The resulting file must use the extension `.9.png` and be placed in the project's `res/drawable` directory.

The next thing we need is the `Widget` class.

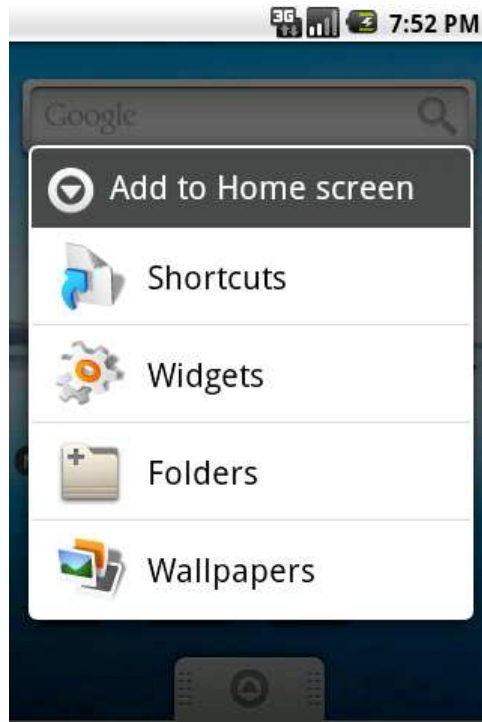


Figure 12.3: Customizing your Home screen with widgets

Embrace and Extend

The Widget needs to extend the `AppWidgetProvider` class provided by Android. By using that class we get a bunch of built-in functionality for free, which is always a plus. So here's the definition for the Widget class:

[Download](#) `Widget/src/org/example/widget/Widget.java`

```
package org.example.widget;

import android.appwidget.AppWidgetProvider;

public class Widget extends AppWidgetProvider {
    // ...
}
```

We'll come back to fill in this class in a moment but for now we can just use the default behavior provided by `AppWidgetProvider`.

Finally, let's get rid of a few pesky error messages by defining these string values:

[Download](#) Widget/res/values/strings.xml

```
<?xml version="1.0" encoding="utf-8"?>
<resources>
    <string name="hello">Hello World!</string>
    <string name="app_name">Widget</string>
    <string name="widget_name">Widget</string>
</resources>
```

All that's left now is to run it.

Running the Widget

To run your new widget, go to the Package Explorer window, right-click the Widget project, and select Run As > Android Application. Nothing much will appear to happen as Eclipse builds and installs the widget on your emulator or device.

To see the new widget, bring up the Home screen's context menu: press and hold your finger (or mouse) on the Home screen. A menu will appear with options listing all the types of things you can add (see Figure 12.3, on the previous page).

Select Widgets from the menu, and then select the widget named Widget (clever, huh?). At last, your widget should appear (see Figure 12.4, on the following page).

Try moving it around by pressing and holding your finger on the widget. Rotate the display to see how the widget automatically resizes itself. To remove it, drag it to the trash can icon at the bottom of the screen.

As exciting as that was, let's do it one better by displaying the current date and time inside our widget.

Keeping Up to Date

In Android 1.5, widget hosts (programs like the Home screen that can contain widgets) send a message to all their little widget kids whenever the widgets should display something. The Android way to send a message is to broadcast an intent. In this case, the intent is `android.appwidget.action.APPWIDGET_UPDATE`.

Back when we set up the `AndroidManifest.xml` file, we told Android that we could receive that intent and do something interesting with it. Now it's time to fill out the `Widget` class to do just that:



Figure 12.4: Hello, Widget

[Download](#) Widget/src/org/example/widget/Widget.java

```

Line 1 package org.example.widget;
-
- import java.text.SimpleDateFormat;
- import java.util.Date;
5
- import android.appwidget.AppWidgetManager;
- import android.appwidget.AppWidgetProvider;
- import android.content.Context;
- import android.widget.RemoteViews;
10
- public class Widget extends AppWidgetProvider {
-     // ...
-     // Define the format string for the date
-     private SimpleDateFormat formatter = new SimpleDateFormat(
15         "EEEEEEEE\nd MMM yyyy");
-
-     @Override
-     public void onUpdate(Context context,

```

```

-         AppWidgetManager appWidgetManager, int[] appWidgetIds) {
20     // Retrieve and format the current date
-     String now = formatter.format(new Date());
-
-     // Change the text in the widget
-     RemoteViews updateViews = new RemoteViews(
25         context.getPackageName(), R.layout.main);
-     updateViews.setTextViewText(R.id.text, now);
-     appWidgetManager.updateAppWidget(appWidgetIds, updateViews);
-
-     // Not really necessary, just a habit
30     super.onUpdate(context, appWidgetManager, appWidgetIds);
- }
- }

```

Whenever the `APPWIDGET_UPDATE` intent comes in, Android will call our `onUpdate()` method. On line 21, we format the current date using a `SimpleDateFormat` created on line 14. This will show the day of the week, day of the month, month name, and year on the first row of the widget, and then the hour, minute, second, and milliseconds on the second row.

Next, on line 24 we create a `RemoteViews` instance for the new view layout that the widget will display. It just so happens that this example uses the same layout, `R.layout.main`, when updating as it did when it was started. Line 26 replaces the original “Hello, World” text with the current date and time.

Finally, on line 27 we send our updated view to replace the current contents of the widget. The call to `super.onUpdate()` on line 30 is just there for code hygiene.

Remove the widget from your Home screen and re-install it from Eclipse. When you add it back to the Home screen, you should see something like Figure 12.5, on the next page.

The frequency of updates is controlled by the `android:updatePeriodMillis=` parameter in `res/xml/widget.xml`. A value of 1800000 represents 30 minutes, so our widget will be updated twice an hour. Note that this is only an approximate number. The actual update event may be delayed (possibly a long time) because of other things happening on the phone.

Google recommends you set widgets to update infrequently, for example once a day or once an hour, in order to conserve battery power. Starting in Android 1.6, the `android:updatePeriodMillis=` parameter will not honor any values under 30 minutes. If you need more frequent updates, you’ll



Figure 12.5: Displaying the date and time

have to set up your own timer using the `AlarmManager` class. This is left as an exercise for the reader.

Go Wild

Now that you know the basics of widget building, there's no end to the interesting doodads you can create. If you need more advanced features such as responding to events, background processing, and specifying an initial activity for configuration, consult the online documentation.² Try to keep your widgets simple and useful, though. By cleverly using widgets you can make the Android experience more personal and dynamic for your users.

2. <http://d.android.com/guide/topics/appwidgets/index.html>

Do you find yourself wishing for a bit more room to express than a widget provides? Then follow the yellow brick road to the land of Live Wallpapers.

12.2 Live Wallpaper

Regular wallpaper just sits there. It looks nice, but it never changes.

Yawn.

Live Wallpaper is a new feature in Android 2.1 (Eclair Maintenance Release 1). It lets you replace boring static wallpaper images with everything from vibrant and pulsing music visualizations to quiet, meditative ponds that respond to your touch with gentle ripples.

Displaying current weather conditions, slide shows, Magic 8-balls, and pyrotechnics are just a few of the ideas that are possible. Let's pull back the curtain to see how the magic is done.

Creating the Wallpaper Project

In this example, we'll create a live wallpaper that displays a rotating cube using OpenGL. See Figure 12.6, on the following page for a screenshot of the final result.

Start by creating a new Android project using these values in the project wizard:

```
Project name: Wallpaper
Build Target: Android 2.1
Application name: Wallpaper
Package name: org.example.wallpaper
Min SDK Version: 7
```

As with the Widget project, leave the Activity name blank and turn off the check mark next to Create Activity. After the project is created, we need to perform some major changes to the AndroidManifest.xml file. Here's what it should look like:

[Download Wallpaper/AndroidManifest.xml](#)

```
<?xml version="1.0" encoding="utf-8"?>
<manifest xmlns:android="http://schemas.android.com/apk/res/android"
    package="org.example.wallpaper"
    android:versionCode="1"
    android:versionName="1.0">
    <application android:label="@string/app_name">
        <service android:name=".Wallpaper"
            android:label="@string/service_name"
```



Figure 12.6: The Wallpaper example reuses code from the OpenGL chapter

```

        android:permission="android.permission.BIND_WALLPAPER">
    <intent-filter>
        <action android:name=
            "android.service.wallpaper.WallpaperService" />
    </intent-filter>
    <meta-data android:name="android.service.wallpaper"
        android:resource="@xml/wallpaper" />
    </service>
</application>
<uses-sdk android:minSdkVersion="7" android:targetSdkVersion="7" />
</manifest>

```

The `<service>` tag is new. It defines an Android Service that will run in the background and respond to events. The `android:permission=` attribute means that any program that calls our service will need to have the specified permission. The Android Home screen program already has that permission set so it will work fine.

The `<intent-filter>` tag tells Android what type of service this is, and the `<meta-data>` tag lets it know where to find extra information about the wallpaper. The `android:resource="@xml/wallpaper"` setting refers to the `res/xml/wallpaper.xml` file, which is a new file you should create now using the following contents:

[Download](#) Wallpaper/res/xml/wallpaper.xml

```
<?xml version="1.0" encoding="utf-8"?>
<wallpaper xmlns:android="http://schemas.android.com/apk/res/android"
    android:author="@+string/author"
    android:description="@string/description"
    android:thumbnail="@drawable/thumbnail" />
```

The wallpaper metadata specifies the author of the wallpaper (that's you), a short description of what it does, and a thumbnail image. The image and description will appear in a list when the user is asked to pick a wallpaper to display.

Before we get any further, let's define all the strings we'll need for the project in `res/values/strings.xml`:

[Download](#) Wallpaper/res/values/strings.xml

```
<?xml version="1.0" encoding="utf-8"?>
<resources>
    <string name="app_name">Wallpaper</string>
    <string name="service_name">Hello, Android!</string>
    <string name="author">Hello, Android!</string>
    <string name="description">Sample live wallpaper
        from Hello, Android!</string>
</resources>
```

You should delete the layout file, `res/layout/main.xml`, because we won't be using it. We'll fill in the Wallpaper class (`Wallpaper.java`) after we learn a few things about Android Services.

Introducing Services

One of the distinguishing features of Android is the ability to run programs in the background. To contrast them with foreground activities, Android calls these programs *services*.

The main Java class for a service inherits from the `Service` class. Services have a life-cycle similar to activities (see Section 2.2, *It's Alive!*, on page 39), but a little simpler. There's an `onCreate()` method that is called when the service is first created and an `onDestroy()` method that is called when it is destroyed.

In between, Android will call the `onStartCommand()` method (`onStart()` prior to version 2.0) when a client requests that the service be started. Services can be sticky or not sticky, depending upon whether or not you want the service to hang around between requests.

There are a few other methods for things like low memory conditions that you can implement if you like. See the online documentation for all the gory details.³

For the Wallpaper example, we don't need to worry about any of these methods because they're all handled by the `WallpaperService` class, which is a subclass of `Service`. Our main class needs to extend `WallpaperService` like this:

[Download](#) Wallpaper/src/org/example/wallpaper/Wallpaper.java

```
package org.example.wallpaper;

import android.service.wallpaper.WallpaperService;

public class Wallpaper extends WallpaperService {
    private class MyEngine extends Engine {
        // Engine implementation goes here...
    }

    @Override
    public Engine onCreateEngine() {
        return new MyEngine();
    }
}
```

All we had to do was implement the `onCreateEngine()` method, which is a single line. Its sole purpose is to create and return another class called `MyEngine`.

Building a Drawing Engine

The `MyEngine` class has to be an inner class of `Wallpaper`, so in Java it's declared inside the enclosing class's curly brackets. `MyEngine` extends the `Engine` class provided by Android. Here's the outline for `MyEngine` with all the methods stubbed out:

[Download](#) Wallpaper/src/org/example/wallpaper/Wallpaper.java

```
private class MyEngine extends Engine {
    @Override
    public void onCreate(final SurfaceHolder holder) {
```

3. <http://d.android.com/reference/android/app/Service.html>

```

        super.onCreate(holder);
    }

    @Override
    public void onDestroy() {
        super.onDestroy();
    };

    @Override
    public void onSurfaceCreated(final SurfaceHolder holder) {
        super.onSurfaceCreated(holder);
    }

    @Override
    public void onSurfaceDestroyed(final SurfaceHolder holder) {
        super.onSurfaceDestroyed(holder);
    }

    @Override
    public void onSurfaceChanged(final SurfaceHolder holder,
        final int format, final int width, final int height) {
        super.onSurfaceChanged(holder, format, width, height);
    }

    @Override
    public void onVisibilityChanged(final boolean visible) {
        super.onVisibilityChanged(visible);
    }

    @Override
    public void onOffsetsChanged(final float xOffset,
        final float yOffset, final float xOffsetStep,
        final float yOffsetStep, final int xPixelOffset,
        final int yPixelOffset) {
        super.onOffsetsChanged(xOffset, yOffset, xOffsetStep,
            yOffsetStep, xPixelOffset, yPixelOffset);
    }
}

```

Note that every method should always call its superclass method. You can get Eclipse to generate these stubs for you in the Java editor by selecting the class name `MyEngine`, right clicking, selecting `Source > Override/Implement Methods`, and picking the methods you want to create. There's one difference in what Eclipse generates and what is shown above, however. I've added the **final** keyword to every method parameter. That will be needed later so inner classes within those methods can access the parameters. If you forget and leave them out, the compiler will let you know.

During the engine's life-cycle, Android will call these methods in a specific order. Here is the entire sequence:

```
onCreate
    onSurfaceCreated
        onSurfaceChanged (1+ calls in any order)
        onOffsetsChanged (0+ calls in any order)
        onVisibilityChanged (0+ calls in any order)
    onSurfaceDestroyed
onDestroy
```

We'll be filling out all these methods in the rest of the chapter.

We'll also need a few more **import** statements to prevent compiler errors. I usually let Eclipse create those for me as I'm coding (using Content Assist (`Ctrl+Space`) or Quick Fix (`Ctrl+1`) or in a batch with the Source > Organize Imports command (`Ctrl+Shift+O`)). But if you prefer, you can just type them all in now. Here's the full list:

Download Wallpaper/src/org/example/wallpaper/Wallpaper.java

```
import java.util.concurrent.ExecutorService;
import java.util.concurrent.Executors;

import javax.microedition.khronos.egl.EGL10;
import javax.microedition.khronos.egl.EGL11;
import javax.microedition.khronos.egl.EGLConfig;
import javax.microedition.khronos.egl.EGLContext;
import javax.microedition.khronos.egl.EGLDisplay;
import javax.microedition.khronos.egl.EGLSurface;
import javax.microedition.khronos.opengles.GL10;

import android.service.wallpaper.WallpaperService;
import android.view.SurfaceHolder;
```

Next we need to borrow some code to draw our cube.

Reusing the OpenGL code

You don't have to use OpenGL for live wallpapers but I like it because it's faster than the regular Android 2D graphics libraries (see Chapter 4, *Exploring 2D Graphics*, on page 77). Also, we just so happen to have a nice rotating 3D cube example already written from another chapter (Chapter 10, *3D Graphics in OpenGL*, on page 201).

Grab three files from that project now: `GLCube.java`, `GLRenderer.java`, and `android.png`. Put the Java files in the `org.example.wallpaper` package (in other words, the `org/example/wallpaper` directory), and place the PNG file in the `res/drawable-nodpi` directory.

If you haven't done that chapter yet, you can download all these files from the book's web site. Unzip the source code archive to a temporary location and copy the files from the OpenGL project.

You shouldn't have to make any changes to the source code except for the package name at the top of both Java files, which should read:

Download `Wallpaper/src/org/example/wallpaper/GLRenderer.java`

```
package org.example.wallpaper;
```

Now we just have to figure out how to call the code from our new wallpaper project.

Creating and Destroying the Engine

To begin, let's define a few fields for the engine to use. Put these at the start of the `MyEngine` class:

Download `Wallpaper/src/org/example/wallpaper/Wallpaper.java`

```
private GLRenderer glRenderer;
private GL10 gl;
private EGL10 egl;
private EGLContext glc;
private EGLDisplay glDisplay;
private EGLSurface glSurface;

private ExecutorService executor;
private Runnable drawCommand;
```

The most important variable here is `executor`. In Java, an executor is an object that can run snippets of code (called `Runnable`s) asynchronously in another thread. When the wallpaper engine is first created, we're going to create one of these executors to handle all interaction with OpenGL.

We have to do that because OpenGL can only be called from a single thread. The service has to create a thread to do drawing in the background anyway, and we can't call some of the OpenGL code in the background thread and some in the foreground thread. So we use a single executor for everything. The definition of `onCreate()` shows how to initialize it:

[Download](#) Wallpaper/src/org/example/wallpaper/Wallpaper.java

```
@Override
public void onCreate(final SurfaceHolder holder) {
    super.onCreate(holder);
    executor = Executors.newSingleThreadExecutor();

    drawCommand = new Runnable() {
        public void run() {
            glRenderer.onDrawFrame(gl);
            egl.eglSwapBuffers(eglDisplay, glSurface);
            if (isVisible()
                && egl.eglGetError() != EGL11.EGL_CONTEXT_LOST) {
                executor.execute(drawCommand);
            }
        }
    };
}
```

Besides the executor, we also create a Runnable called `drawCommand` which will be used later to draw each frame of the cube animation. This is a Java anonymous inner class, so it has access to all the fields and **final** parameters of its parents. Note that we haven't initialized any of those variables yet (such as `glRenderer` and `glDisplay`), but that's OK because we're just defining this code to be run later, after everything is ready.

The opposite of `onCreate()` is `onDestroy()`. `onDestroy()` is called when Android is finished with the wallpaper engine. All it needs to do is shut down the executor we created in `onCreate()`:

[Download](#) Wallpaper/src/org/example/wallpaper/Wallpaper.java

```
@Override
public void onDestroy() {
    executor.shutdownNow();
    super.onDestroy();
};
```

Note that we call `super.onDestroy()` at the end of the method, not at the beginning like we do in most places. That's just a standard Java idiom to let the superclass clean up after itself in a mirror image of the way creation was done. I don't know if it's really necessary in this case, but by following the convention we don't even have to think about it.

Managing the Surface

During the engine's lifetime, Android will create a Surface representing the background of the Home screen for the the engine to draw on.

When the surface is first created, `onSurfaceCreated()` is called. We use this opportunity to initialize OpenGL and our `GLRenderer` class that we copied from the other project:

[Download](#) Wallpaper/src/org/example/wallpaper/Wallpaper.java

```
@Override
public void onSurfaceCreated(final SurfaceHolder holder) {
    super.onSurfaceCreated(holder);
    Runnable surfaceCreatedCommand = new Runnable() {
        @Override
        public void run() {
            // Initialize OpenGL
            egl = (EGL10) EGLContext.getEGL();
            glDisplay = egl.eglGetDisplay(EGL10.EGL_DEFAULT_DISPLAY);
            int[] version = new int[2];
            egl.eglInitialize(glDisplay, version);
            int[] configSpec = { EGL10.EGL_RED_SIZE, 5,
                                EGL10.EGL_GREEN_SIZE, 6, EGL10.EGL_BLUE_SIZE,
                                5, EGL10.EGL_DEPTH_SIZE, 16, EGL10.EGL_NONE };
            EGLConfig[] configs = new EGLConfig[1];
            int[] numConfig = new int[1];
            egl.eglChooseConfig(glDisplay, configSpec, configs,
                               1, numConfig);
            EGLConfig config = configs[0];

            glc = egl.eglCreateContext(glDisplay, config,
                                     EGL10.EGL_NO_CONTEXT, null);

            glSurface = egl.eglCreateWindowSurface(glDisplay,
                                                  config, holder, null);
            egl.eglMakeCurrent(glDisplay, glSurface, glSurface,
                              glc);
            gl = (GL10) (glc.getGL());

            // Initialize Renderer
            glRenderer = new GLRenderer(Wallpaper.this);
            glRenderer.onSurfaceCreated(gl, config);
        }
    };
    executor.execute(surfaceCreatedCommand);
}
```

It would be nice if Android would provide a helper class to hide some of this OpenGL boilerplate detail from the programmer (something like `GLSurfaceView`, but for wallpapers), but until then, just hold your nose and copy the code.

The `onSurfaceDestroyed()` method is called when the background surface is about to go away. This is a good place to terminate all that OpenGL stuff we initialized earlier:

```
Download Wallpaper/src/org/example/wallpaper/Wallpaper.java

@Override
public void onSurfaceDestroyed(final SurfaceHolder holder) {
    Runnable surfaceDestroyedCommand = new Runnable() {
        public void run() {
            // Free OpenGL resources
            egl.eglMakeCurrent(glDisplay, EGL10.EGL_NO_SURFACE,
                             EGL10.EGL_NO_SURFACE, EGL10.EGL_NO_CONTEXT);
            egl.eglDestroySurface(glDisplay, glSurface);
            egl.eglDestroyContext(glDisplay, glc);
            egl.eglTerminate(glDisplay);

        };
    };
    executor.execute(surfaceDestroyedCommand);
    super.onSurfaceDestroyed(holder);
}
```

While the surface is up, Android will call the `onSurfaceChanged()` method to tell you its width and height.

```
Download Wallpaper/src/org/example/wallpaper/Wallpaper.java

@Override
public void onSurfaceChanged(final SurfaceHolder holder,
                             final int format, final int width, final int height) {
    super.onSurfaceChanged(holder, format, width, height);
    Runnable surfaceChangedCommand = new Runnable() {
        public void run() {
            glRenderer.onSurfaceChanged(gl, width, height);
        };
    };
    executor.execute(surfaceChangedCommand);
}
```

So far the surface has not been visible to the user so we shouldn't draw anything on it yet. That's about to change.

Making the Wallpaper Visible

After the `WallpaperService` is initialized, and the `Engine` is initialized, and the `Surface` is initialized (whew!), the only thing left to do is to make the surface visible. When it's ready to do that, Android calls the `onVisibilityChanged()` method with a boolean parameter that says whether it has become visible or invisible:

Download Wallpaper/src/org/example/wallpaper/Wallpaper.java

```
@Override
public void onVisibilityChanged(final boolean visible) {
    super.onVisibilityChanged(visible);
    if (visible) {
        executor.execute(drawCommand);
    }
}
```

If it's visible, all we need to do is queue up a call to the `drawCommand` runnable, which will draw one frame of the animation and, if the surface is still visible, queue itself up again over and over. To save the battery, it is very important that a wallpaper only run while it is visible.

At this point you should be able to try the example in the emulator or on a real device. Right-click on the project and select **Run As > Android Application**. As with widgets, the wallpaper will only be installed, not executed, by running it from Eclipse. To really run it, go to the device or emulator and press and hold your finger (or mouse) on the Home screen. A menu will appear with options listing all the types of things you can add (see Figure 12.3, on page 241).

Select **Wallpapers** from the menu, and then **Live wallpapers**. A list of all live wallpapers will appear. Pick the one called **Hello, Android!** and the wallpaper should start spinning around happily in preview mode (if it doesn't, then follow the instructions in Section 3.10, *Debugging with Log Messages*, on page 74 to diagnose the problem). Touch the **Set wallpaper** button to make this the wallpaper for your Home screen, or the **Back** button to return to the list. See Figure 12.6, on page 247 for a screenshot of the live wallpaper in action.

Responding to User Input

When you use regular, static wallpaper and you pan the Home screen left or right with your finger, the wallpaper moves a little as well. However if you try that with the live wallpaper example now, nothing happens.

To get that functionality we have to implement the `onOffsetsChanged()` method:

Download Wallpaper/src/org/example/wallpaper/Wallpaper.java

```
@Override
public void onOffsetsChanged(final float xOffset,
    final float yOffset, final float xOffsetStep,
    final float yOffsetStep, final int xPixelOffset,
```



```

        final int yPixelOffset) {
    super.onOffsetsChanged(xOffset, yOffset, xOffsetStep,
        yOffsetStep, xPixelOffset, yPixelOffset);
    Runnable offsetsChangedCommand = new Runnable() {
        public void run() {
            glRenderer.setParallax(xOffset - xOffsetStep);
        }
    };
    executor.execute(offsetsChangedCommand);
}

```

Now I'm about to go back on what I said earlier about not modifying GLRenderer. Since the OpenGL example did not have any user input, we have to add an extra field and a setter method to the GLRenderer class:

[Download](#) Wallpaper/src/org/example/wallpaper/GLRenderer.java

```

class GLRenderer implements GLSurfaceView.Renderer {
    // ...
    private float xOffset;

    public void setParallax(float xOffset) {
        this.xOffset = -xOffset;
    }
}

```

Then in the middle of the GLRenderer.onDrawFrame() method we have to change one line to use that new field to translate the model a little to the left or right:

[Download](#) Wallpaper/src/org/example/wallpaper/GLRenderer.java

```

public void onDrawFrame(GL10 gl) {
    // ...
    // Position model so we can see it
    gl.glMatrixMode(GL10.GL_MODELVIEW);
    gl.glLoadIdentity();
    gl.glTranslatef(xOffset, 0, -3.0f);

    // Other drawing commands go here...
}

```

We could have moved the eye point instead, but it was easier just to move the cube. That's it! Now try the example again, and you can pan left or right with ease.

There are two other ways to interact with live wallpaper that you can support if you like: commands and touch events. To support commands, implement the onCommand() method, and to support raw touch events, implement the onTouchEvent() method. I'll leave that as an exercise for the reader.

12.3 Fast-Forward >>

In this chapter we learned how to jazz up the Android Home screen with widgets and a live wallpaper. The Android Market is full of examples of both that people like you have created. I'd love to see yours there, so read Chapter 14, *Publishing to the Android Market*, on page 272 for directions and encouragement.

When Android first came out, there was only one version and one phone model to worry about. Now there are several dozen devices of various shapes and sizes running at least four different versions of Android. You're not in Kansas any more, but the next chapter will help you avoid the flying monkeys.

Write Once, Test Everywhere

Today, Android can be found in a bewildering array of mobile phones, tablets, and other devices. This is both a blessing and a curse. It's a blessing for consumers because they can choose between Android-powered devices of different shapes, sizes, and prices. But for developers it can be a curse to try and support all those variations.

To complicate things, the rapid pace of Android development has left a fragmented trail of devices running different versions of the platform in its wake. The following table shows all the versions of Android ever released:¹

Version	Code name ²	API	Released	Comments
1.0	BASE	1	Oct 2008	No longer in use
1.1	BASE_1_1	2	Feb 2009	No longer in use
1.5	CUPCAKE	3	May 2009	Widgets
1.6	DONUT	4	Sep 2009	High- and low-density displays
2.0	ECLAIR	5	Nov 2009	No longer in use
2.0.1	ECLAIR_0_1	6	Dec 2009	Multi-touch
2.1	ECLAIR_MR1	7	Jan 2010	Live wallpaper
?	FROYO	8?	?	? (under development)

This chapter will cover how to support multiple Android versions and screen resolutions in one program. The first step is testing.

1. See <http://d.android.com/resources/dashboard/platform-versions.html> for an up to date chart showing the percentage of devices running each version of Android.

2. Android version codes and API levels are specified in the `Build.VERSION_CODES` class.

13.1 Gentlemen, Start Your Emulators

For most of this book I've been telling you to target your applications to version 2.1 of the Android platform (also known as Eclair MR1). However, there's one little problem with this advice: your programs may not run on phones that have one of the older versions of Android installed.

The only reliable way of telling whether or not it will work is to test it. And short of buying one of every Android phone on the market, the best way to test your program on different Android versions and screen sizes is to try it in the emulator.

To do this, you'll need to set up several virtual devices with different versions and emulator skins. A skin specifies the width, height, and pixel density for an emulated device. In addition to the em21 AVD you created in Section 1.3, *Creating an AVD*, on page 27, I recommend that you create the following virtual devices for testing:

Name	Target	Skin	Inspired by device...
em15	1.5	HVGA (320×480)	HTC G1, Eris
em16	1.6	HVGA (320×480)	HTC Hero
em16-qvga	1.6	QVGA (200×320)	HTC Tatoo
em201-854	2.0.1	WVGA854 (480×854)	Motorola Droid (Sholes)
em21-800	2.1	WVGA800 (480×800)	HTC Nexus One
em21-1024	2.1	Custom (1024×600)	Notion Ink Adam

You can use the em21 AVD for development, then test your program in the other AVDs before you release the application. And don't forget to try it out in both portrait and landscape modes. In the emulator, press `Ctrl+F11` or use the `[7]` or `[9]` keys on the keypad (NumLock off) to toggle between portrait and landscape.

Unless you have a very powerful desktop computer, you probably won't be able to run all these AVDs at once. In practice, I find that running only one at a time works best. Try it now by starting up the em16 (Android 1.6) emulator. Wait until the emulator comes up to the home screen, and turn off the screen lock if it appears. Now let's see some of the things that can go wrong.

13.2 Building for Multiple Versions

First, we'll try running the "Hello, Android" program from Section 1.2, *Creating Your First Program*, on page 26 in the 1.6 emulator. From the menu, select Run > Run Configurations. Locate the configuration for

HelloAndroid and select it, or create a new Android Application configuration if it doesn't exist. Click on the Target tab, and set the Deployment Target Selection Mode to Manual. Then click on the Run button.

Eclipse will show a dialog asking you to choose a running Android device. You may notice a red X next to the emulator name – ignore it. Select the device called em16 and then click OK. The following error will appear in the Console view:

```
ERROR: Application requires API version 7. Device API version
       is 4 (Android 1.6).
Launch canceled!
```

Note: If you get a warning that says “Application does not specify an API level requirement” then you need to specify a minimum SDK version (see below). If you don't get an error and the application launches in the em16 emulator, it means you've already applied the change in this section. And finally, if Eclipse launches a new emulator window, then you probably have your target selection mode set to Automatic. Change it to Manual and try again.

The error occurs because we specified version 2.1 as the target version of Android when we created the project. Unless we change something, it won't run at all on older versions. On those devices, it won't even appear in the Android Market. But I happen to know that this program will work just fine on any version of Android. So how do we tell Android that?

Easy: In the Android manifest, just set your target SDK version to one number, and your minimum SDK version to another number. This lets you target a new version of Android but still work on phones that have an older version.

To do this, edit the AndroidManifest.xml file and change the line that says:

```
<uses-sdk android:minSdkVersion="7" />
```

to read:

```
<uses-sdk android:minSdkVersion="3" android:targetSdkVersion="7" />
```

If you don't have this line, then add it right before the `</manifest>` tag.

This tells Android that your program is built for Android 2.1 (API level 7) but it will work fine on Android 1.5 (API level 3). Save the file, and try running the project again. It should work this time without any errors. If you get a warning about “Manifest min SDK version (3) is lower than project target API level (7),” just ignore it.



Figure 13.1: The Touch example crashes on Android 1.6.

Unfortunately, for some programs just saying that we support version 3 doesn't make it so. We'll see an example of that next.

13.3 Evolving with Android APIs

Sometimes you need to use an API that does not appear in all versions of Android. For instance, in the Touch example (Chapter 11, *Multi-touch*, on page 223) we used some new methods of the `MotionEvent` class that were not there before Android 2.0. If you try to run that example in the em16 emulator, you will get the error in Figure 13.1.

If you then open the LogCat view in Eclipse (Window > Show View > Other > Android Log) and scroll back a little, you'll find a more detailed error message, which will look something like this:

```
Could not find method android.view.MotionEvent.getPointerCount,
    referenced from method org.example.touch.Touch.dumpEvent
VFX: unable to resolve virtual method 11:
    Landroid/view/MotionEvent;.getPointerCount ()I
Verifier rejected class Lorg/example/touch/Touch;
Class init failed in newInstance call (Lorg/example/touch/Touch;)
Uncaught handler: thread main exiting due to uncaught exception
java.lang.VerifyError: org.example.touch.Touch
    at java.lang.Class.newInstanceImpl(Native Method)
    at java.lang.Class.newInstance(Class.java:1472)
...
```

The important part is the `VerifyError` exception. At run time, Android throws a `VerifyError` exception whenever it tries to load one class that uses methods that don't exist in a second class. In this case, the `Touch` class references the `getPointerCount()` method of the `MotionEvent` class. `MotionEvent` exists in 1.5, but the `getPointerCount()` method was not introduced until version 2.0. Note that it didn't complain about the constants we used like `ACTION_POINTER_DOWN` because they are baked into our program by the compiler and build time.

It would be nice if we could modify the definition of `MotionEvent` to add the missing method, but unlike JavaScript or Ruby, Java doesn't support that. We can do something similar, though, using one of three techniques:

1. **Subclassing.** We could make a new class that extends `MotionEvent` and adds the new method. Unfortunately `MotionEvent` is `final`, which in Java means it can't be extended, so that won't work here.
2. **Reflection.** Using utilities from the `java.lang.reflect` package, we could write code to test for the existence of the new method. If it exists, we'd call it, and if doesn't exist, we'd do something else like return 1. That would work, but Java reflection is slow to run and messy to program.
3. **Delegation and Factory.** We could create two classes, one that will be used on older versions of Android and one that will be used on newer versions. The first one will implement dummy versions of the new methods, while the second one will delegate all calls to the real new methods. Then we pick which class to create using a static factory method (a method the caller uses instead of the **new** keyword to create a class). This technique is simple and can be used to handle most API differences, so we'll use it here.

One of our goals should be to minimize the changes to the original `Touch` class. We start by replacing all references to `MotionEvent` with a new class, `WrapMotionEvent`, like this:

[Download](#) Touchv2/src/org/example/touch/Touch.java

```
@Override
public boolean onTouch(View v, MotionEvent rawEvent) {
    WrapMotionEvent event = WrapMotionEvent.wrap(rawEvent);
    // ...
}

private void dumpEvent(WrapMotionEvent event) {
```

```

    // ...
}

private float spacing(WrapMotionEvent event) {
    // ...
}

private void midPoint(PointF point, WrapMotionEvent event) {
    // ...
}

```

In the `onTouch()` method we take the raw `MotionEvent` passed in by Android and convert it to a `WrapMotionEvent` by calling the static factory method `WrapMotionEvent.wrap()`. Other than these changes, the rest of the `Touch` class is... untouched.

Now let's create the `WrapMotionEvent` class. Delegation is a pretty common thing to do in Java so Eclipse provides a command to make it easy. Click on the `org.example.touch` package in the Package Explorer view, and then select the `File > New > Class` command. Enter the new class name (`WrapMotionEvent`) and press Return. Now add a field inside the class for the event we want to wrap. The code should look like this so far:

[Download](#) Touchv2/src/org/example/touch/WrapMotionEvent.java

```

package org.example.touch;

import android.view.MotionEvent;

public class WrapMotionEvent {
    protected MotionEvent event;
}

```

In the Java editor, click on the event variable, then select the `Source > Generate Delegate Methods` command from the menu. Eclipse will give you a big list of possible methods, but we don't need the whole list so deselect all of them and select only the ones that are actually used in the program: `getAction()`, `getPointerCount()`, `getPointerId(int)`, `getX()`, `getX(int)`, `getY()`, and `getY(int)`. The dialog should look like Figure 13.2, on the following page when you're done. Select OK to generate the code.

Before doing anything else, save the `WrapMotionEvent.java` file and make a copy called `EclairMotionEvent.java`. We'll come back to that one in a moment.

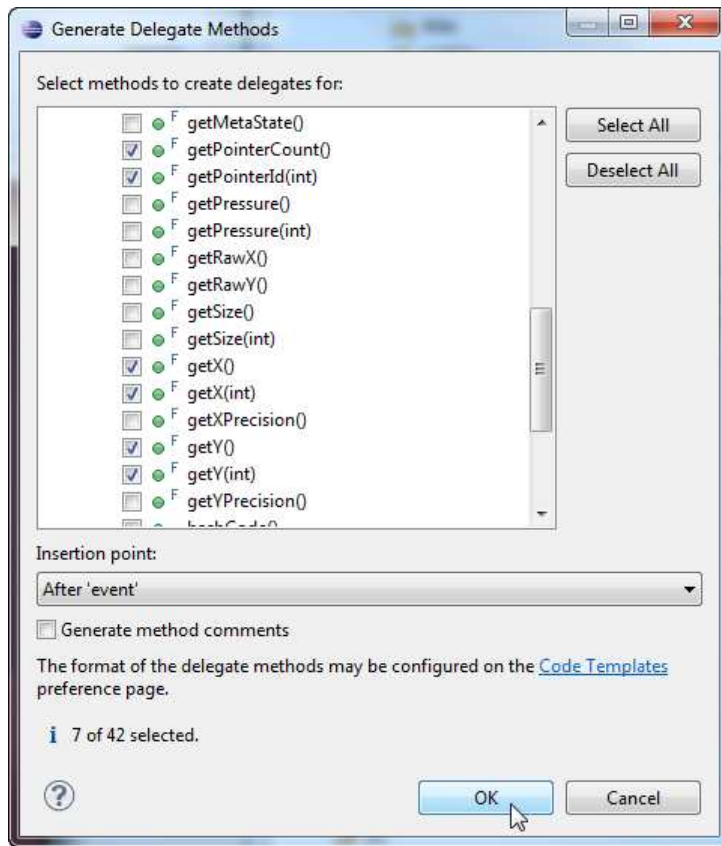


Figure 13.2: Let Eclipse create the delegate methods for you.

As it currently stands, WrapMotionEvent calls several methods that don't exist in older Android versions so we need to replace those. You can tell which ones are a problem by hovering your mouse cursor over each method call. The new methods will say "Since: API Level 5" and the old methods will say "Since: API Level 1". Another way to tell would be to temporarily change your build target to Android 1.6, rebuild, and see where the errors are.

Here's the new code that will work under Android 1.6:

[Download](#) Touchv2/src/org/example/touch/WrapMotionEvent.java

```
package org.example.touch;

import android.view.MotionEvent;
```

```

public class WrapMotionEvent {
    protected MotionEvent event;

    public int getAction() {
        return event.getAction();
    }

    public float getX() {
        return event.getX();
    }

    public float getX(int pointerIndex) {
        verifyPointerIndex(pointerIndex);
        return getX();
    }

    public float getY() {
        return event.getY();
    }

    public float getY(int pointerIndex) {
        verifyPointerIndex(pointerIndex);
        return getY();
    }

    public int getPointerCount() {
        return 1;
    }

    public int getPointerId(int pointerIndex) {
        verifyPointerIndex(pointerIndex);
        return 0;
    }

    private void verifyPointerIndex(int pointerIndex) {
        if (pointerIndex > 0) {
            throw new IllegalArgumentException(
                "Invalid pointer index for Donut/Cupcake");
        }
    }
}

```

In this version, `getPointerCount()` will always return 1 indicating there is only one finger pressed. That should ensure that `getX(int)` and `getY(int)` will never be called with a pointer index greater than zero, but just in case I've added a `verifyPointerIndex()` method to check for that error.

Next, we need to add the `wrap()` method and the constructor for the `WrapMotionEvent` class:

Download Touchv2/src/org/example/touch/WrapMotionEvent.java

```
protected WrapMotionEvent(MotionEvent event) {
    this.event = event;
}

static public WrapMotionEvent wrap(MotionEvent event) {
    try {
        return new EclairMotionEvent(event);
    } catch (VerifyError e) {
        return new WrapMotionEvent(event);
    }
}
```

The `wrap()` method is our static factory method. First it tries to create an instance of the `EclairMotionEvent` class. That will fail under Android 1.5 and 1.6 because `EclairMotionEvent` uses the new methods introduced in Android 2.0 (Eclair). If it can't create an `EclairMotionEvent` class then it creates an instance of the `WrapMotionEvent` class instead.³

Now it's time for us to work on the `EclairMotionEvent` class that we saved earlier. We'll finish it by making it extend `WrapMotionEvent` and adding a constructor. We can also take out the `getAction()` method and the zero-parameter versions of `getX()` and `getY()` because they exist in all versions of Android and are already implemented in `WrapMotionEvent`. Here's the full definition:

Download Touchv2/src/org/example/touch/EclairMotionEvent.java

```
package org.example.touch;

import android.view.MotionEvent;

public class EclairMotionEvent extends WrapMotionEvent {

    protected EclairMotionEvent(MotionEvent event) {
        super(event);
    }

    public float getX(int pointerIndex) {
        return event.getX(pointerIndex);
    }

    public float getY(int pointerIndex) {
```

3. Design pattern purists will probably deride this code, saying I should have created a separate class to hold the factory method and a common interface for both `WrapMotionEvent` and `EclairMotionEvent` to implement. But this is simpler and it works, which is more important in my book.

```

        return event.getY(pointerIndex);
    }

    public int getPointerCount() {
        return event.getPointerCount();
    }

    public int getPointerId(int pointerIndex) {
        return event.getPointerId(pointerIndex);
    }
}

```

If you try to run the program now it will work in the 1.6 emulator as well as new versions (2.0 and beyond). On old versions, of course, you'll lose some functionality. Multi-touch is not supported on 1.6, so you won't be able to use the pinch zoom gesture to shrink or grow the image. But you will be able to move the image around using the drag gesture.

In a real program you might have to implement some alternate way to resize the picture when pinch zoom is not available. For example, you could add buttons to zoom in and out.

Just for fun, start up the em15 (1.5 emulator) and run the program there. It looks ok, but try doing the drag gesture. Nothing happens! We've discovered a bug in Android 1.5.

13.4 Bug on Parade

It turns out that Android 1.5 (Cupcake) has a bug in the `ImageView` class. The bug prevents the `setImageMatrix()` method from working when the `ImageView` is in "matrix" mode, which is pretty ironic if you think about it.

Unfortunately, there is no complete list of bugs, so figuring out this was a bug in Android (as opposed to a bug in our code or a misunderstanding of how something works) took a bit of sleuthing. In case you find yourself in a similar situation, here are the steps that I went through:

1. My first suspect was the new code we just added: The `WrapMotionEvent` and `EclairMotionEvent` classes. I put in a few logging statements to verify events were being handled correctly and the transformation matrix was created correctly. They turned up no problems, so I began to suspect something was wrong with the `ImageView` class or matrix manipulation.

2. Next, I checked the release notes⁴ for each version of Android to see if there were any breaking changes mentioned that might effect the `ImageView` class. Breaking changes are updates that cause code that was working to stop working, or vice-versa. I didn't find any that seemed related.
3. Then I searched the Android bug database⁵ for the keywords "ImageView" and "matrix". Unfortunately the public bug database is incomplete because Google keeps their own private list of bugs, so I didn't find anything.
4. Next, I searched all the Android Developer Forums⁶ to see if anybody else was having the same problem. The groups all have search forms of their own, but the quickest and most accurate way to search the forums is just to use the Google search engine and search the entire web. Using the same keywords (ImageView matrix), I found a posting from 2009 that looked exactly the same. Unfortunately there was no followup or workaround posted, but I knew I was on the right track.
5. Finally, I went to the source.⁷ With a few exceptions, all the code for Android is available in a public repository online. I had a clue about where the source to the `ImageView` class was located in the source tree because one of the earlier searches had revealed the path name. It was in the `platform/frameworks/base.git` project, under the `core/java/widget` directory. I opened the history using the repository's web interface.⁸ And there it was, a change made on July 30, 2009 with the comment: "Fix a bug in `ImageView`: The drawing matrix is not updated when `setImageMatrix` is called." This bug fix was performed in between the Cupcake and Donut versions of Android, which explained why the problem happened in 1.5 but not in 1.6.

In almost all cases, you'll be able to find a solution without resorting to reading the Android source code. But it's nice to know it's there if you need it. By studying the code and trying a few things, I was able to create a workaround for the bug. Add these lines to the end of the `onCreate()` method in the `Touch` class:

4. <http://d.android.com/sdk/RELEASENOTES.html>

5. <http://b.android.com>

6. <http://d.android.com/resources/community-groups.html>

7. <http://source.android.com>

8. <https://android.git.kernel.org/?p=platform/frameworks/base.git;a=history;f=core/java/android/widget/ImageView.java>

Download `Touchv2/src/org/example/touch/Touch.java`

```
@Override
public void onCreate(Bundle savedInstanceState) {
    // ...
    // Work around a Cupcake bug
    matrix.setTranslate(1f, 1f);
    view.setImageMatrix(matrix);
}
```

By running the program in the emulator using various versions of Android you can verify that this fixes the problem in Android 1.5 and doesn't break anything in later versions. Once your program is working with different versions of Android, you should try it at different screen sizes as well.

13.5 All Screens Great and Small

Supporting different screen sizes, resolutions, and pixel densities is important because you want your application to look its best on as many Android devices as possible. Unlike the iPhone, which just has one standard screen (two, if you count the iPad), Android powered devices come in all shapes and sizes.

Android will try to scale your user interface to fit the device but it doesn't always do a great job of it. The only way to tell is through, you guessed it, testing. Use the emulator skins recommended in Section 13.1, *Gentlemen, Start Your Emulators*, on page 260 to make sure your program works on the most common sizes. If you need to tweak the layouts or images for particular configurations, you can use suffixes in the resource directory names.

For example, you can put images for high density displays in the `res/drawable-hdpi` directory, medium density in `res/drawable-mdpi`, and low density `res/drawable-ldpi`. All the examples do that for their program icons which will be shown on the home screen. Graphics that are density-independent (that should not be scaled) go in the `res/drawable-nodpi` directory.

Here is a list of the valid directory name qualifiers, in order of precedence:⁹

9. See <http://d.android.com/guide/topics/resources/resources-i18n.html#best-match> for a full explanation of how Android finds the best matching directory.

Qualifier	Values
MCC and MNC	Mobile country code and optional mobile network code. I don't recommend using this.
Language and region	Two letter language and optional two letter region code (preceded by lowercase "r"). For example: fr, en-rUS, fr-rFR, es-rES.
Screen dimensions	small, normal, large
Wider/taller screens	long, notlong
Screen orientation	port, land, square
Screen pixel density	ldpi, mdpi, hdpi, nodpi
Touchscreen type	notouch, stylus, finger
Keyboard available?	keysexposed, keyshidden, keyssoft
Keyboard type	nokeys, qwerty, 12key
Navigation available?	navexposed, navhidden
Navigation type	nonav, dpad, trackball, wheel
Screen dimensions	320x240, 640x480, etc. (deprecated, not recommended)
SDK version	API level supported by the device (preceded by lowercase "v"). For example: v3, v7.

To use more than one qualifier, just string them together with a dash ("-") in between. For example, the `res/drawable-fr-land-ldpi` directory could contain pictures for low density displays in landscape mode in French.

13.6 Fast-Forward >>

Supporting multiple versions of Android, running on multiple hardware devices with multiple screen sizes is not easy. In this chapter we've covered the most common issues and solutions to get you started. If you find yourself wanting more, I recommend the excellent best practices document on "Supporting Multiple Screens" at the Android web site.¹⁰

You've worked hard to get your application to this point. Now comes the fun part: letting other people use it. The next chapter will cover how to publish your app to the Android Market.

10. http://d.android.com/guide/practices/screens_support.html

Publishing to the Android Market

Up to now you've just been creating software to run in the emulator or to download to your personal Android phone. Are you ready to take the next step? By publishing to the Android Market¹ you can make your application available to millions of other Android users. This chapter will show you how.

14.1 Preparing

The first step of publishing an application to the Market is, well, to write the application. See the rest of the book for directions on how to do that. But simply writing code is not enough. Your program needs to be of a high quality, free of bugs (yeah right), and compatible with as many devices as possible. Here are a few tips to help you out:

- Test it on at least one real device before letting anyone else see it. If you forget all the other tips, remember this one.
- Keep your program simple, and polish the heck out of it. Make your program do one thing well, rather than a lot of things poorly.
- Pick a good Java package name, such as `com.yourcompany.prog-name`, that you can live with for a long time. Android uses the package name defined in `AndroidManifest.xml` as the primary identifier for your application. No two programs can have the same package name, and once you upload a program to the Market with that name you cannot change it without completely removing it, requiring all users to uninstall, and publishing a new program.

1. <http://market.android.com>

- Pick a meaningful value for `android:versionCode=` and `android:versionName=` in your `AndroidManifest.xml` file.² Consider future updates and leave room for them in your naming scheme.
- Follow the Android best practices,³ such as designing for performance, responsiveness, and seamlessness.
- Follow the user interface guidelines,⁴ such as icon design, menu design, and proper use of the Back button.

Compatibility with multiple devices is one of the toughest challenges facing the Android programmer. One issue you'll have to deal with is users having different versions of the platform installed on their phones. See Chapter 13, *Write Once, Test Everywhere*, on page 259 for advice.

Although first impressions and compatibility are important, you'll need to strike a balance between tweaking and polishing your application to make it perfect versus releasing it in a timely fashion. Once you think it's ready, the next step is to sign it.

14.2 Signing

Android requires that all applications be packaged up into an `.apk` and signed with a digital certificate before it will consider running them. This is true for the emulator and for your personal testing devices, but it's especially true for programs that you want to publish on the Market.

"But wait," you say, "I haven't been packaging or signing anything up to now." Actually, you have. The Android SDK tools have been secretly building and signing everything using a certificate that Google created using a known alias and password. Because the password was known, you were never prompted for it and probably never even knew it existed. However, the debug certificate cannot be used for applications in the Market, so now it's time to take off the training wheels and make your own certificate.

There are two ways to do it: by hand with the standard Java `keytool` and `jarsigner` commands,⁵ or automatically with Eclipse. I'm just going to cover the Eclipse way.

2. <http://d.android.com/guide/publishing/versioning.html>

3. <http://d.android.com/guide/practices/design>

4. http://d.android.com/guide/practices/ui_guidelines

5. <http://d.android.com/guide/publishing/app-signing.html>

Right click the project in the Package Explorer and select Android Tools > Export Signed Application Package. The wizard will guide you through the process of signing your application, including creating a new key-store and private key if you don't already have one. You should use the same key for all versions of all your applications, and take the appropriate precautions for preventing your private key from falling into the wrong hands.

Note: If you use the Google Maps API (see Section 8.3, *Embedding a MapView*, on page 175) then you'll need to get a new Maps API Key from Google because it is tied to your digital certificate. Export the program once, obtain a new Maps API Key using the online instructions,⁶ change your XML layout file to use the new key, and then export the program again.

When you're done you'll have an .apk file that is ready for publishing.

14.3 Publishing

The Android Market is a Google-hosted service you can use for posting all your programs. To get started with publishing you first need to sign up as a registered developer on the publisher's web site (also known as the Developer Console).⁷ There is a small registration fee.

As an additional step, if you want to charge for your program you'll need to sign up with a payment processor. The publisher's web site will instruct you on how to do that. As of this writing, only Google Checkout is supported, but in the future other processors like PayPal may be supported.

Now you're ready to upload. Click the "Upload Application" link and fill out the form. Three tips:

- Turn Copy Protection off. Android's copy protection is completely insecure and performs no useful function other than to irritate your users.
- Unless you have a reason not to, set the Locations option to "All Current and Future Countries." New countries are being added all the time, and this way your application will be available to all of them.

6. <http://code.google.com/android/add-ons/google-apis/mapkey.html>

7. <http://market.android.com/publish>

- *Do not* supply your phone number in the application Contact Information. All Market users will be able to see this number and they will call it when they have problems. Of course, if you have a dedicated number and staff for phone support, then this tip doesn't apply.

Just to give you an example, here's how I filled out the form for an application I published called Re-Translate Pro (an updated version of the Translate example from Section 7.4, *Using Web Services*, on page 149):

Application .apk file: (select Browse and Upload)

Language: English (en_US)

Title (en_US): Re-Translate Pro

Description (en_US):

Re-Translate translates a phrase from one language to another and then back again so you can make sure you're saying what you meant.

Try the Lite version to see if you like it first.

Features:

- Translates instantly as you type
- Long press for copy/paste
- Directly send SMS/Email

Application Type: Applications

Category: Tools

Price: USD \$0.99

Copy Protection Off

Locations All Current and Future Countries with Payment

Website: <http://blogs.zdnet.com/Burnette/index.php?cat=44>

Email: ed.burnette@gmail.com

Phone: (blank)

When you click the Publish button, your application will appear *immediately* on the Android Market on all applicable devices. That's right, there is no approval process, no waiting period (other than a few seconds to update the download servers), and no limits to what you can do in your programs. Well, almost. You still have to follow the Android Content Guidelines.⁸ Failure to adhere to the guidelines could result in your application being removed from the Android Market. Among other things, the guidelines say that your content must not be illegal, obscene, promote hate or violence, or be unsuitable for anyone under 18 years of age. In addition it must not knowingly violate an Autho-

8. <http://www.android.com/market/terms/developer-content-policy.html>

rized Carrier's terms of service. There have been rare cases of programs being pulled due to user or carrier complaints, but as long as you use common sense you shouldn't have anything to worry about.

The next section covers updates to already published applications.

14.4 Updating

Let's say your app has been in the Market for a little while and you want to make a change. The simplest kind of change is to the program's metadata; that is, the title, description, price, and all the other information you filled out in the last section. To change this non-code info, simply select your program from the list on the Developer's Console, make the change, and then click Save.

Do you have a new version of your code? No problem, you can upload it from this page too. Before you do that, however, take a moment to verify that you have changed the two version numbers in your `AndroidManifest.xml` file. Increment `android:versionCode=` by one every time you upload (for example, from 1 to 2), and bump the human-readable version number in `android:versionName=` by the appropriate amount (for example, from 1.0.0 to 1.0.1 for a minor bug fix). Once the version number is correct and the package has been rebuilt and re-signed, select Upload Upgrade, then click Browse, find your new .apk file, and click Upload to send it to the server.

Regardless of the change, you must click the Publish button for your changes to be visible to Android Market users. If you click Save instead, changes will be kept in draft form until you finally commit and click Publish.

If possible, I suggest you perform frequent updates, every two weeks or so. This performs two functions:

- It makes users happy, because they feel you are supporting them and listening to their suggestions.
- It keeps your app near the top of the Recently Updated list in the Market. That's one of the best ways for new users to discover your program and give it the chance it deserves.

14.5 Closing Thoughts

Here are a few final tips about the Market that I learned the hard way by publishing my own programs there:

- You can make a paid app free but you can't make a free app paid. If there's any chance you might want to have a free (light) version and a paid (pro) version of your program, then create them both up front. Never take anything away that you put in the free version, or you risk a fire storm of protests.
- In the current version of the Market, you won't be able to buy your own paid application. Hopefully that will be fixed in a future version.
- Read all the comments left by users, but don't hesitate to report especially rude or vulgar ones as spam. Keep your comment area clean for useful feedback, both positive and negative.
- Don't get discouraged. People can be cruel, especially when posting anonymous comments. A thick skin and a sense of humor are invaluable tools of the trade.

Part V

Appendixes

Appendix A

Java vs. the Android Language and APIs

For the most part, Android programs are written in the Java language, and they use the Java 5 Standard Edition (SE) library APIs. I say “for the most part” because there are a few differences. This appendix highlights the differences between regular Java and what you’ll find in Android. If you’re already proficient in Java development on other platforms, you should take a close look to see what things you need to “unlearn.”

A.1 Language Subset

Android uses a standard Java compiler to compile your source code into regular bytecodes and then translates those bytecodes into Dalvik instructions. Therefore, the entire Java language is supported, not just a subset. Compare this to the Google Web Toolkit (GWT), which has its own Java to JavaScript translator. By using the stock compiler and bytecodes, you don’t even need to have the source code for libraries that you want to use in your applications.

Language Level

Android supports code compatible with Java Standard Edition 5 or earlier. Java 6 and 7 class formats and features are not yet supported but could be added in future releases.

Intrinsic Types

All Java intrinsic types including **byte**, **char**, **short**, **int**, **long**, **float**, **double**, **Object**, **String**, and arrays are supported. However, on current hardware commonly found in mobile devices, floating point is emulated. That means it's performed in software instead of hardware, making it much slower than normal. Simple operations on real numbers could take a millisecond to complete. Although occasional use is fine, do not use **float** or **double** in performance-critical code.

Multithreading and Synchronization

Multiple threads are supported by *time slicing*: giving each thread a few milliseconds to run and then performing a *context switch* to let another thread have a turn. Although Android will support any number of threads, in general you should use only one or two. One thread is dedicated for the main user interface (if you have one), and another thread is used for long-running operations such as calculations or network I/O.

The Dalvik VM implements the **synchronized** keyword and synchronization-related library methods such as `Object.wait()`, `Object.notify()`, and `Object.notifyAll()`. It also supports the `java.util.concurrent` package for more sophisticated algorithms. Use them as you would in any Java program to keep multiple threads from interfering with each other.

Reflection

Although the Android platform supports Java reflection, as a general rule you should not use it. The reason is simple performance: reflection is slow. Consider alternatives such as compile-time tools and preprocessors instead.

Finalization

The Dalvik VM supports object finalization during garbage collection just like regular Java VMs. However, most Java experts advise you not to rely on finalizers because you cannot predict when (or if) they will run. Instead of finalizers, use explicit `close()` or `terminate()` methods. Android is targeted toward resource-constrained hardware, so it's important that you release all resources as soon as you no longer need them.

A.2 Standard Library Subset

Android supports a relatively large subset of the Java Standard Edition 5.0 library. Some things were left out because they simply didn't make sense (such as printing), and others were omitted because better APIs are available that are specific to Android (such as user interfaces).

Supported

The following standard packages are supported in Android. Consult the Java 2 Platform Standard Edition 5.0 API documentation¹ for information on how to use them:

- `java.awt.font`: A few constants for Unicode and fonts
- `java.beans`: A few classes and interfaces for JavaBeans property changes
- `java.io`: File and stream I/O
- `java.lang` (except `java.lang.management`): Language and exception support
- `java.math`: Big numbers, rounding, precision
- `java.net`: Network I/O, URLs, sockets
- `java.nio`: File and channel I/O
- `java.security`: Authorization, certificates, public keys
- `java.sql`: Database interfaces
- `java.text`: Formatting, natural language, collation
- `java.util` (including `java.util.concurrent`): Lists, maps, sets, arrays, collections
- `javax.crypto`: Ciphers, public keys
- `javax.microedition.khronos`: OpenGL graphics (from Java Micro Edition)
- `javax.net`: Socket factories, SSL
- `javax.security` (except `javax.security.auth.kerberos`, `javax.security.auth.spi`, and `javax.security.sasl`)
- `javax.sql` (except `javax.sql.rowset`): More database interfaces
- `javax.xml.parsers`: XML parsing
- `org.w3c.dom` (but not subpackages): DOM nodes and elements
- `org.xml.sax`: Simple API for XML

Note that although the regular Java SQL database APIs (JDBC) are included, you don't use them to access local SQLite databases. Use the

1. <http://java.sun.com/j2se/1.5.0/docs/api>

android.database APIs instead (see Chapter 9, *Putting SQL to Work*, on page 181).

Not Supported

These packages, normally part of the Java 2 Platform Standard Edition, are *not* supported by Android:

- java.applet
- java.awt
- java.lang.management
- java.rmi
- javax.accessibility
- javax.activity
- javax.imageio
- javax.management
- javax.naming
- javax.print
- javax.rmi
- javax.security.auth.kerberos
- javax.security.auth.spi
- javax.security.sasl
- javax.sound
- javax.swing
- javax.transaction
- javax.xml (except javax.xml.parsers)
- org.ietf.*
- org.omg.*
- org.w3c.dom.* (subpackages)

A.3 Third-Party Libraries

In addition to the standard libraries listed earlier, the Android SDK comes with a number of third-party libraries for your convenience:

- org.apache.http: HTTP authentication, cookies, methods, and protocol
- org.json: JavaScript Object Notation
- org.xml.sax: XML parsing
- org.xmlpull.v1: XML parsing

Appendix B

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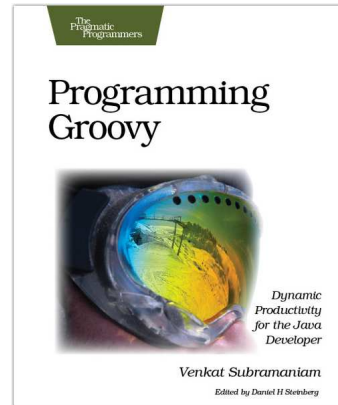
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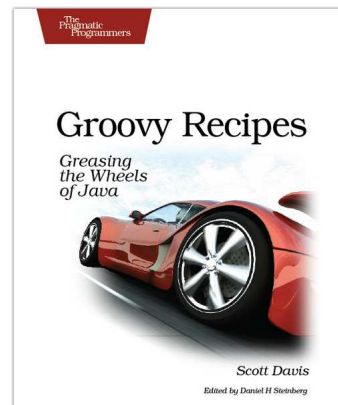
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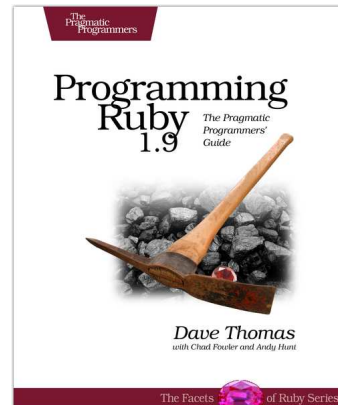
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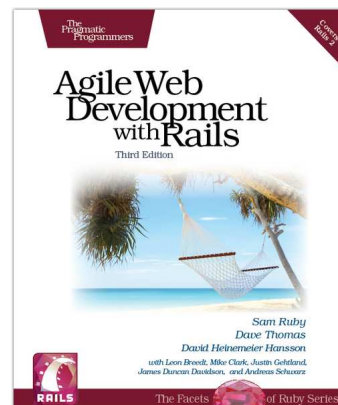
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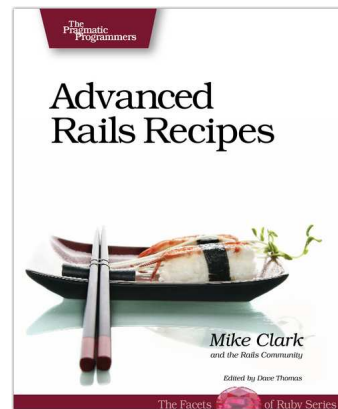
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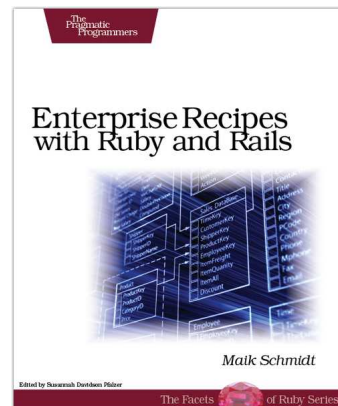
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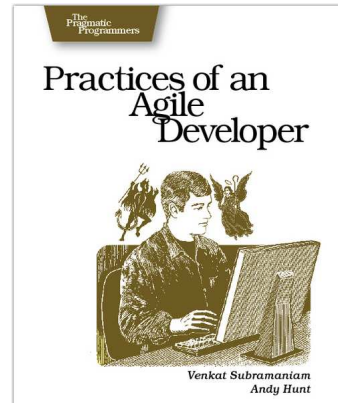
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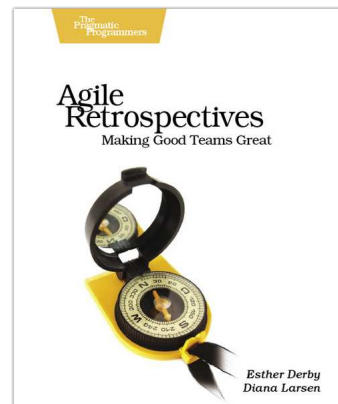
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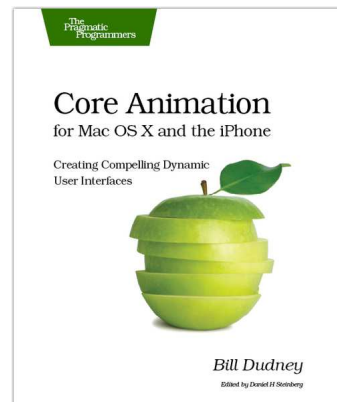
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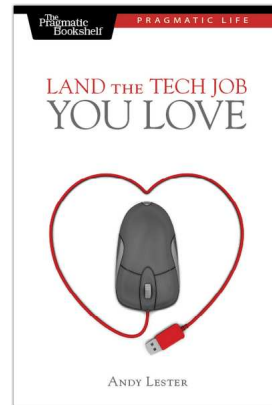
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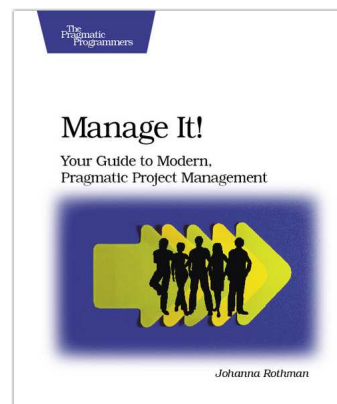
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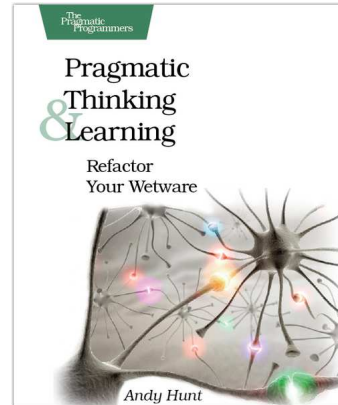
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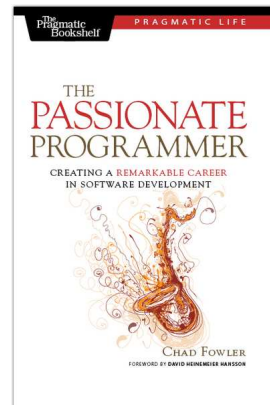
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