

Android Development: Lecture Notes

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Contents

I	Lectures	11
1	Introduction	13
1.1	Android History	13
1.1.1	Android Versions	14
1.1.2	Legal Battles	15
1.2	Android Architecture and Code	16
1.2.1	Programming Languages	18
1.2.2	Building Apps	18
1.3	Development Tools	20
1.3.1	Hardware	20
1.3.2	Software	20
1.4	Hello World	21
1.4.1	The Emulator	22
1.4.2	Project Contents	22
2	Activities and Logging	25
2.1	Making Activities	26
2.2	The Activity Lifecycle	26
2.2.1	Overriding the Callback Methods	29
2.3	Logging & ADB	29
2.3.1	Log Methods	30
2.3.2	Logcat	31
2.4	Basic Events	32
2.5	Multiple Activities	33
2.5.1	Intents and Context	33
2.6	Back & Tasks	35
2.6.1	Up Navigation	36
3	Resources and Layouts	39
3.1	Resources	39
3.1.1	Alternate Resources	40
3.1.2	XML Details	41
3.1.3	R	41
3.2	Views	43

3.2.1	View Properties	43
3.2.2	Practice	45
3.3	Layouts	46
3.3.1	LinearLayout	46
3.3.2	RelativeLayout	46
3.3.3	ConstraintLayout	47
3.3.4	Other Layouts	47
3.3.5	Combining and Inflating Layouts	48
4	Interactive Views	51
4.1	Inputs	51
4.2	ListView and Adapters	53
4.3	Network Data	56
5	Fragments	61
5.1	Creating a Fragment	64
5.1.1	Activity-to-Fragment Communication	66
5.2	Dynamic Fragments	67
5.2.1	Instantiating Fragments	67
5.2.2	Transactions	69
5.2.3	Inter-Fragment Communication	70
5.2.4	The Back Stack	71
6	UI Components	73
6.1	The Action Bar	73
6.2	Menus	74
6.2.1	Context Menus	76
6.3	Dialogs	76
6.3.1	DialogFragments	78
6.4	Toasts	79
7	Providers and Loaders	81
7.1	Content Providers	81
7.2	Cursors	83
7.3	Loaders	84
7.4	Other Provider Actions	86
7.4.1	Adding Words	86
8	Intents	87
8.1	Intents for Another Activity (Explicit)	88
8.1.1	Extras	88
8.2	Intents for Another App (Implicit)	89
8.3	Intents for a Response	90
8.4	Listening for Intents	91
8.5	Broadcasts and Receivers	92
8.6	An Example: SMS	94

8.7	ShareActionProvider	95
9	UI Components II	97
9.1	Notifications	97
9.2	Settings	100
9.2.1	SharedPreferences	100
9.2.2	Preference Settings	101
10	Files and Permissions	105
10.1	File Storage Locations	105
10.2	Permissions	107
10.3	External Storage	109
10.4	Internal Storage & Cache	111
10.5	Example: Saving Pictures	112
10.6	Sharing Files	113
10.6.1	Bonus: Sharing with a FileProvider	114
11	Location	117
11.1	Localization Techniques	118
11.1.1	GPS	118
11.1.2	Cell Tower Localization	119
11.1.3	WiFi Localization	119
11.1.4	Representing Location	120
11.2	Android Location	121
11.2.1	Google Play Services	121
11.2.2	Accessing Location	123
12	Sensors	127
12.1	Motion Sensors	127
12.1.1	Accessing Sensors	128
12.1.2	Composite Sensors	130
12.2	Rotation	131
12.2.1	Coordinates	133
13	Services	135
13.1	IntentServices	136
13.1.1	The Service Lifecycle	137
13.2	Example: A Music Service	140
13.2.1	MediaPlayer	140
13.2.2	Creating a Service	141
13.3	Foreground Services	142
13.4	Bound Services	143
14	Material Design	147
14.1	Resources:	147
15	Animation and Graphics	149

15.1 Drawing Graphics	149
15.1.1 Custom Views	149
15.1.2 SurfaceViews	152
15.2 Touch and Gestures	153
15.2.1 Advanced Gestures	154
15.3 Property Animation	155
16 Databases and Providers	161
16.1 Review: Providers and Loaders	161
16.2 SQLite Databases	163
16.3 Implementing <code>ContentProvider</code>	166
16.3.1 URIs and Types	167
16.3.2 Query Methods	168
17 Publishing	173
17.1 Signing an App	173
17.1.1 A Release <code>.apk</code>	175
18 Special Topics: Kotlin	177
18.1 Kotlin Syntax	177
18.1.1 Variables	178
18.1.2 Functions	179
18.1.3 Classes	182
18.2 Kotlin for Android	184
18.2.1 The Android Extension	185
18.2.2 Anko	185
II Additional Topics (Labs)	187
19 Accessibility	189
19.1 Universal Usability	189
19.2 Implementing Accessibility	190
19.2.1 Supporting Vision Impairment	190
19.2.2 Supporting Alternative Inputs	191
19.2.3 Supporting Internationalization	192
19.2.4 Further Testing	194
20 Fragments: <code>ViewPager</code>	195
20.1 Define a <code>SearchFragment</code>	195
20.2 Add the <code>ViewPager</code> and <code>Adapter</code>	196
20.3 Add User Interaction	197
21 Bluetooth	199
22 Maps	203
22.1 Create a Map Activity	203

22.1.1	Getting an API Key	203
22.1.2	The <code>SupportMapFragment</code>	204
22.2	Specifying the User Interface	205
22.3	Markers and Drawings	205
22.3.1	Drawing Shapes	205
23	Styles & Themes	207
23.1	Defining Styles	207
23.1.1	Style Inheritance	208
23.1.2	Built-in Styles	210
23.2	Themes	210
23.2.1	Material Themes	211
23.2.2	Theme Attributes	211
24	Multi-Touch	213
24.1	Identifying Fingers	213
24.2	Drawing Touches	214
24.3	Moving Fingers	215
24.4	Other Multi-Touch Gestures	216
25	Memory Management	217
25.1	Memory Allocation	217
25.2	The Memory Monitor	219
25.2.1	Garbage Collection	220
25.3	Memory Leaks	220
	Appendix	222
A	Java Review	223
A.1	Building Apps with Gradle	223
A.2	Class Basics	224
A.3	Inheritance	226
A.4	Interfaces	226
A.5	Polymorphism	227
A.6	Abstract Methods and Classes	229
A.7	Generics	230
A.8	Nested Classes	231
B	Swing Framework	233
B.1	Events	234
B.2	Layouts and Composites	236
C	Threads and HTTP Requests	237
C.1	Concurrency	237
C.1.1	An Example: Algorithm Races!	237
C.1.2	Threading the Race	238
C.2	HTTP Requests	240

About this Book

This book compiles lecture notes and tutorials for the **INFO 448 Mobile Development: Android** course taught at the University of Washington Information School (most recently in Spring 2017). The goal of these notes is to provide learning materials for students in the course or anyone else who wishes to learn the basics of developing Android applications.

These notes are primarily adapted from the official Android developer documentation, compiling and synthesizing those guidelines for pedagogical purposes (and the author's own interpretation/biases). Please refer to that documentation for the latest information and official guidance.

This book is currently in **alpha** status, as pure lecture notes are converted into more generic formats.



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Part I

Lectures

Chapter 1

Introduction

This course focuses on **Android Development**. But what is Android?

Android is an operating system. That is, it's software that connects hardware to software and provides general services. But more than that, it's a *mobile specific* operating system: an OS designed to work on *mobile* (read: handheld, wearable, carry-able) devices.

- Note that the term “Android” also is used to refer to the “platform” (e.g., devices that use the OS) as well as the ecosystem that surrounds it. This includes the device manufacturers who use the platform, and the applications that can be built and run on this platform. So “Android Development” technically means developing applications that run on the specific OS, it also gets generalized to refer to developing any kind of software that interacts with the platform.

1.1 Android History

If you're going to develop systems for Android, it's good to have some familiarity with the platform and its history, if only to give you perspective on how and why the framework is designed the way it is.

- **2003:** The platform was originally founded by a start-up “Android Inc.” which aimed to build a mobile OS operating system (similar to what Nokia's Symbian was doing at the time)
- **2005:** Android was acquired by Google, who was looking to get into mobile
- **2007:** Google announces the Open Handset Alliance, a group of tech companies working together to develop “open standards” for mobile platforms. Members included phone manufacturers like HTC, Samsung, and

Sony; mobile carriers like T-Mobile, Sprint, and NTT DoCoMo; hardware manufacturers like Broadcom and Nvidia; and others. The Open Handset Alliance now (2017) includes 86 companies.

– Note this is the same year the first iPhone came out!

- **2008:** First Android device is released: the HTC Dream (a.k.a. T-Mobile G1)

Specs: 528Mhz ARM chip; 256MB memory; 320x480 resolution capacitive touch; slide-out keyboard! Author’s opinion: a fun little device.

- **2010:** First Nexus device is released: the Nexus One. These are Google-developed “flagship” devices, intended to show off the capabilities of the platform.

Specs: 1Ghz Scorpion; 512MB memory; .37” at 480x800 AMOLED capacitive touch.

– For comparison, the iPhone 7 Plus (2016) has: 2.34Ghz dual core A10 64bit Fusion; 3GB RAM; 5.5” at 1920x1080 display.

As of 2016, this program has been superceded by the Pixel range of devices.

- **2014:** Android Wear, a version of Android for wearable devices (watches) is announced.
- **2016:** Daydream, a virtual reality (VR) platform for Android is announced

In short, Google keeps pushing the platform wider so it includes more and more capabilities.

Today, Android is incredibly popular (to put it mildly). Android is incredibly popular! (see e.g., [here](#), [here](#), and [here](#))

- In any of these analyses there are some questions about what exactly is counted... but what we care about is that there are *a lot* of Android devices out there! And more than that: there are a lot of **different** devices!

1.1.1 Android Versions

Android has gone through a large number of “versions” since it’s release:

Date	Version	Nickname	API Level
Sep 2008	1.0	Android	1
Apr 2009	1.5	Cupcake	3
Sep 2009	1.6	Donut	4
Oct 2009	2.0	Eclair	5
May 2010	2.2	Froyo	8
Dec 2010	2.3	Gingerbread	9

Date	Version	Nickname	API Level
Feb 2011	3.0	Honeycomb	11
Oct 2011	4.0	Ice Cream Sandwich	14
July 2012	4.1	Jelly Bean	16
Oct 2013	4.4	KitKat	19
Nov 2014	5.0	Lollipop	21
Oct 2015	6.0	Marshmallow	23
Aug 2016	7.0	Nougat	24
Mar 2017	O preview	<i>Android O Developer Preview</i>	

Each different “version” is nicknamed after a dessert, in alphabetical order. But as developers, what we care about is the **API Level**, which indicates what different programming *interfaces* (classes and methods) are available to use.

- You can check out an interactive version of the history through Marshmallow at <https://www.android.com/history/>
- For current usage breakdown, see <https://developer.android.com/about/dashboards/>

Additionally, Android is an “open source” project released through the “Android Open Source Project”, or ASOP. You can find the latest version of the operating system code at <https://source.android.com/>; it is very worthwhile to actually dig around in the source code sometimes!

While new versions are released fairly often, this doesn’t mean that all or even many devices update to the latest version. Instead, users get updated phones historically by purchasing new devices (every 18m on average in US). Beyond that, updates—including security updates—have to come through the mobile carriers, meaning that most devices are never updated beyond the version that they are purchases with.

- This is a problem from a consumer perspective, particularly in terms of security! There are some efforts on Google’s part to work around this limitation by moving more and more platform services out of the base operating system into a separate “App” called Google Play Services.
- But what this means for developers is that you can’t expect devices to be running the latest version of the operating system—the range of versions you need to support is much greater than even web development!

1.1.2 Legal Battles

When discussing Android history, we would be remiss if we didn’t mention some of the legal battles surrounding Android. The biggest of these is **Oracle v Google**. In a nutshell, Oracle claims that the *Java API* is copyrighted (that the method signatures themselves and how they work are protected), so because Google uses that API in Android, Google is violating the copyright. In 2012

a California federal judge decided in Google favor (that one can't copyright an API). This was then reversed by the Federal Circuit court in 2014. The verdict was appealed to the Supreme court in 2015, who refused to hear the case. It then went back to the district court, which ruled that Google's use of the API was fair use. See <https://www.eff.org/cases/oracle-v-google> for a summary, as well as <https://arstechnica.com/series/series-oracle-v-google/>

- One interesting side effect of this battle: the latest version of Android (Nougat) uses the OpenJDK implementation of Java, instead of Google's own in-violation-but-fair-use implementation see [here](#). This change *shouldn't* have any impact on us as developers, but it's worth keeping an eye out for potentially differences between Android and Java SE.

There have been other legal challenges as well. While not directly about Android, the other major relevant court battle is **Apple v Samsung**. In this case, Apple claims that Samsung infringed on their intellectual property (their design patents). This has gone back and forth in terms of damages and what is considered infringing; the latest development is that the Supreme Court heard the case and sided with Samsung that infringing design patents shouldn't lead to damages in terms of the entire device... it's complicated (the author is not a lawyer).

So overall: Android is a growing, evolving platform that is embedded in and affecting the social infrastructures around information technology in numerous ways.

1.2 Android Architecture and Code

Developing Android applications involves interfacing with the Android platform and framework. Thus you need a high level understanding of the architecture of the Android platform. See <https://source.android.com/devices/> for more details.

Like so many other systems, the Android platform is built as a layered architecture:

- At its base, Android runs on a Linux kernel for interacting with the device's processor, memory, etc. Thus an Android device can be seen as a Linux computer.
- On top of that kernel is the Hardware Abstraction Layer: an interface to drivers that can programmatically access hardware elements, such as the camera, disk storage, Wifi antenna, etc.
 - These drivers are generally written in C; we won't interact with them directly in this course.
- On top of the HAL is the Runtime and Android Framework, which provides a set of abstraction in the Java language which we all know and love.

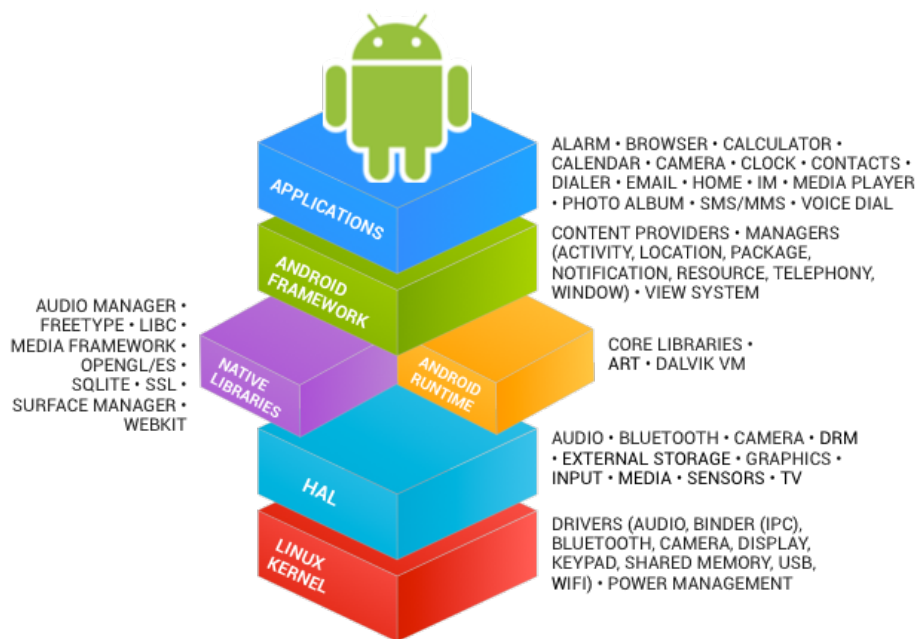


Figure 1.1: Android Architecture (image from: hub4tech)

For this course, Android Development will involve writing Java applications that interact with the Android Framework layer, which handles the task of interacting with the device hardware for us.

1.2.1 Programming Languages

There are two programming languages we will be working with in this course:

1. **Java:** Android code (program control and logic, as well as data storage and manipulation) is written in Java.

Writing Android code will feel a lot writing any other Java program: you create classes, define methods, instantiate objects, and call methods on those objects. But because you're working within a **framework**, there is a set of code that *already exists* to call specific methods. As a developer, your task will be to fill in what these methods do in order to run your specific application.

- In web terms, this is closer to working with Angular (a framework) than jQuery (a library).
 - Importantly: this course expects you to have “journeyman”-level skills in Java (apprenticeship done, not yet master). We'll be using a number of intermediate concepts (like generics and inheritance) without much fanfare or explanation (though see the appendix).
2. **XML:** Android user interfaces and resources are specified in XML (EXtensible Markup Language). To compare to web programming: the XML contains what would normally go in the HTML/CSS, while the Java code will contain what would normally go in the JavaScript.

XML is just like HTML, but you get to make up your own tags. Except we'll be using the ones that Android made up; so it's like defining web pages, except with a new set of elements. This course expects you to have some familiarity with HTML or XML, but if not you should be able to infer what you need from the examples.

1.2.2 Building Apps

As stated above, we will write code in Java and XML. But how does that code get run on the phone's hardware?

Pre-Lollipop (5.0), Android code ran on Dalvik: a virtual machine similar to the JVM used by Java SE.

- Fun fact for people with a Computer Science background: Dalvik uses a register-based architecture rather than a stack-based one!

A developer would write *Java code*, which would then be compiled into *JVM bytecode*, which would then be translated into *DVM* (Dalvik virtual machine) bytecode, that could be run on Android devices. This DVM bytecode was stored in `.dex` or `.odex` (“[Optimized] Dalvik Executable”) files, which is what was loaded onto the device. The process of converting from Java code to `dex` files is called “**dexing**” (so code that has been built is “dexed”).

Dalvik does include JIT (“Just In Time”) compilation to native code that runs much faster than the code interpreted by the virtual machine, similar to the Java HotSpot. This native code is faster because no translation step is needed to talk to the actual hardware (the OS).

From Lollipop (5.0) on, Android instead uses Android Runtime (ART) to run code. ART’s biggest benefit is that it compiles the `.dex` bytecode into native code *on installation* using AOT (“Ahead of Time”) compilation. ART continues to accept `.dex` bytecode for backwards compatibility (so the same dexing process occurs), but the code that is actually installed and run on a device is native. This allows for applications to have faster execution, but at the cost of longer install times—but since you only install an application once, this is a pretty good trade.

After being built, Android applications (the source, dexed bytecode, and any resources) are packaged into `.apk` files. These are basically zip files (they use the same gzip compression); if you rename the file to be `.zip` and you can unpack them! The `.apk` files are then cryptographically signed to specify their authenticity, and either “side-loaded” onto the device or uploaded to an App Store for deployment.

- The signed `.apk` files are basically the “executable” versions of your program!
- Note that the Android application framework code is actually “pre-DEXed” (pre-compiled) on the device; when you write code, you’re actually compiling against empty code stubs (rather than needing to include those classes in your `.apk`)! That said, any other 3rd-party libraries you include will be copied into your built App, which can increase its file size both for installation and on the device.

To summarize, in addition to writing Java and XML code, when building an App you need to:

1. Generate Java source files (e.g., from resource files, which are written XML used to generate Java code)
2. Compile Java code into JVM bytecode
3. “dex” the JVM bytecode into Dalvik bytecode
4. Pack in assets and graphics into an APK
5. Cryptographically sign the APK file to verify it
6. Load it onto the device

There are a lot of steps here, but there are tools that take care of it for us. We’ll

just write Java and XML code and run a “build” script to do all of the steps!

1.3 Development Tools

There are a number of different hardware and software tools you will need to do Android development:

1.3.1 Hardware

Since Android code is written for a virtual machine anyway, Android apps can be developed and built on any computer’s operating system (unlike some other mobile OS...).

But obviously Android apps will need to be run on Android devices. Physical devices are the best for development (they are the fastest, easiest way to test), though you’ll need USB cable to be able to wire your device into your computer. Any device will work for this course; you don’t even need cellular service (just WiFi should work). Note that if you are unfamiliar with Android devices, you should be sure to play around with the interface to get used to the interaction language, e.g., how to click/swipe/drag/long-click elements to use an app.

- You will need to turn on developer options in order to install development apps on your device!

If you don’t have a physical device, it is also possible to use the Android Emulator, which is a “virtual” Android device. The emulator represents a generic device with hardware you can specify... but it does have some limitations (e.g., no cellular service, no bluetooth, etc).

- While it has improved recently, the Emulator historically does not work very well on Windows; I recommend you develop on either a Mac or a physical device. In either case, make sure you have enabled HAXM (Intel’s Acceleration Manager, which allows the emulator to utilize your GPU for rendering): this speeds things up considerably.

1.3.2 Software

Software needed to develop Android applications includes:

- The Java 7 **SDK** (not just the JRE!) This is because you’re writing Java code!
- Gradle or Apache ANT. These are *automated build tools*—in effect, they let you specify a single command that will do a bunch of steps at once (e.g., compile files, dex files, move files, etc). These are how we make the “build script” that does the 6 build steps listed above.

- ANT is the “old” build system, Gradle is the “modern” build system (and so what we will be focusing on).
- Note that you do not need to install Gradle separately for this course.
- Android Studio & Android SDK is the official IDE for developing Android applications. Note that the IDE comes bundled with the SDK. Android Studio provides the main build system: all of the other software (Java, Gradle) goes to support this.

The SDK comes with a number of useful command-line tools. These include:

- `adb`, the “Android Device Bridge”, which is a connection between your computer and the device (physical *or* virtual). This tool is used for console output!
- `emulator`, which is a tool used to run the Android emulator
- *deprecated/removed* `android`: a tool that does SDK/AVD (Android Virtual Device) management. Basically, this command-line utility did everything that the IDE did, but from the command-line! It has recently been removed from the IDE.

I recommend making sure that the SDK command-line tools are installed. Put the `tools` and `platform-tools` folders on your computer’s `PATH`; you can run `adb` to check that everything works. All of these tools are built into the IDE, but they can be useful fallbacks for debugging.

1.4 Hello World

As a final introductory steps, this lecture will walk you through creating and running a basic App so that you can see what you will actually be working with. You will need to have Android Studio installed for this to work.

1. Launch Android Studio if you have it (may take a few minutes to open)
2. Start a new project.
 - Use your UW NetID in the domain.
 - Make a mental note of the project location so you can find your code later!
 - *Target*: this is the “minimum” SDK you support. We’re going to target Ice Cream Sandwich (4.0.3, API 15) for most this class, as the earliest version of Android most our apps will support.
 - Note that this is different than the “target SDK”, which is the version of Android you tested your application against (e.g., what system did you run it on?) For this course we will be testing on API 21 (Lollipop); we’ll specify that in a moment.

3. Select an *Empty Activity*

- **Activities** are “Screens” in your application (things the user can do). Activities are discussed in more detail in the next lecture.

4. And boom, you have an Android app! Aren’t frameworks lovely?

1.4.1 The Emulator

We can run our app by clicking the “Play” or “Run” button at the top of the IDE. But we’ll need a device to run the app on, so let’s make an emulator!

The **Nexus 5** is a good choice for supporting “older” devices. The new Pixel is also a reasonable device to test against.

- You’ll want to make sure you create a Lollipop device, using the Google APIs (so we have special classes available to us), and almost certainly running on x86 (Intel) hardware
- Make sure that you’ve specified that it accepts keyboard input. You can always edit this emulator later (**Tools > Android > AVD Manager**).

After the emulator boots, you can slide to unlock, and there is our app!

1.4.2 Project Contents

So what does our app look like in code? What do we have?

Note that Android Studio by default shows the “**Android**” view, which organizes files thematically. If you go to the “**Project**” view you can see what the actual file system looks like. In Android view, files are organized as follows:

- **app/** folder contains our application
 - **manifests/** contains the **Android Manifest** files, which is sort of like a “config” file for the app
 - **java/** contains the Java source code for your project. You can find the **MyActivity** file in here
 - **res/** contains resource files used in the app. These are where we’re going to put layout/appearance information
- Also have the **Gradle** scripts. There are a lot of these:
 - **build.gradle**: Top-level Gradle build; project-level (for building!)
 - **app/build.gradle**: Gradle build specific to the app **use this one to customize project!**. We can change the *Target SDK* in here!
 - **proguard-rules.pro**: config for release version (minimization, obfuscation, etc).
 - **gradle.properties**: Gradle-specific build settings, shared
 - **local.properties**: settings local to this machine only
 - **settings.gradle**: Gradle-specific build settings, shared

Note that ANT would instead give:

- `build.xml`: Ant build script integrated with Android SDK
- `build.properties`: settings used for build across all machines
- `local.properties`: settings local to this machine only

We’re using Gradle, but it is good to be aware of ANT stuff for legacy purposes

- `res` has resource files. These are **XML** files that specify details of the app—such as layout.
 - `res/drawable/`: contains graphics (PNG, JPEG, etc)
 - `res/layout/`: contains UI XML layout files
 - `res/mipmap/`: contains launcher icon files in different resolutions
 - * Fun fact: MIP stands for “*multum in parvo*”, which is Latin for “much in little” (because multiple resolutions of the images are stored in a single file). “Map” is used because Mipmaps are normally used for texture mapping.
 - `res/values/`: contains XML definitions for general constants

See also: <http://developer.android.com/guide/topics/resources/available-resources.html>, or Lecture 3.

We can also consider what the application code does. While we’ll revisit this in more detail in the next lecture, it’s useful to start seeing how the framework is structured:

We’ll start with the **MyActivity** Java source file. This class extends **Activity** (actually it extends a subclass that supports Material Design components), allowing us making our own customizations to what the app does.

In this class, we override the `onCreate()` method that is called by the framework when the Activity starts (see next lecture).

- We call the super method, and then `setContentView()` to specify what the content (appearance) of our Activity is. This is passed in a value from something called `R`. `R` is a class that is **generated at compile time** and contains constants that are defined by the XML “resource” files! Those files are converted into Java variables, which we can access through the `R` class.

`R.layout` refers to the “layout” XML resource, so can go there (remember: inside `res/`). Opening these XML files they appear in a “design” view. This view lets you use a graphical system to lay out your application (similar to a PowerPoint slide).

- However, even as the design view becomes more powerful, using it is still frowned upon by many developers for historical reasons. It’s often cleaner to write out the layouts and content in code. This is the same difference between writing your own HTML and using something like `FrontPage`

or DreamWeaver or Wix to create a page. While those are legitimate applications, they are less “professional”.

In the code view, we can see the XML: tags, attributes, values. Tags nested inside one another. The provided XML code defines a layout, and inside that is a `TextView` (a View representing some text), which has a value: `text!` We can change that and then *re-run the app* to see it update!

- It’s also possible to define this value in `values/strings` (e.g., as a constant), then refer to as `@string/message`. More on this proces later.

Finally, as a fun demonstration, try to set an icon for the App (in Android Studio, go to: `File > New > Image Asset`)

Chapter 2

Activities and Logging

This lecture introduces **Activities**, which are the basic component used in Android applications. It aims to demonstrate how the interactive patterns used in other graphical applications are utilized in Android.

This lecture references code found at <https://github.com/info448-s17/lecture02-activities>, in the `android/` folder. As a first step, you'll need to create a new Android application with a single **Empty** Activity (e.g., `MainActivity`). Future chapters will have starter code to work from, but it is good practice to make a new application from scratch!

According to Google:

An Activity is an application component that provides a screen with which users can interact in order to do something.

You can think of an Activity as a single *screen* in your app, the equivalent of a “window” in a GUI system (or a `JFrame` in a Swing app). Note that Activities don't **need** to be full screens: they can also be floating modal windows, embedded inside other Activities (like half a screen), etc. But we'll begin by thinking of them as full screens. We can have lots of Activities (screens) in an application, and they are loosely connected so we can easily move between them.

In many ways, an Activity is a “bookkeeping mechanism”: a place to hold *state* and *data*, and tell to Android what to show on the display. It functions much like a Controller (in Model-View-Controller sense) in that regard!

Also to note from the documentation¹:

An activity is a single, focused thing that the user can do.

which implies a design suggestion: Activities (screens) break up your App into “tasks”. Each Activity can represent what a user is doing at one time. If the

¹<https://developer.android.com/reference/android/app/Activity.html>

user does something else, that should be a different Activity (and so probably a different screen).

2.1 Making Activities

We create our own activities by *subclassing* (extending) the framework’s `Activity` class. We use **inheritance** to make a specialized type of `Activity` (similar to extending `JFrame` in Swing apps). By extending this class we inherit all of the methods that are needed to control how the Android OS interacts with the `Activity`.

If you look at the default Empty `MainActivity`, it actually subclasses `AppCompatActivity`, which is a already specialized kind of `Activity` that provides an `ActionBar` (the toolbar at the top of the screen with the name of you app). If you change the class to just extend `Activity`, that bar disappears.

To make this change, you will need to import the `Activity` class! The keyboard shortcut in Android Studio is `alt+return`, or you can do it by hand (look up the package)! You can also set Android Studio to automatically import classes you use.

There are a number of other built-in `Activity` subclasses that we could subclass instead. We’ll mention them as they become relevant. Many on the books have been deprecated in favor of **Fragments**, which are sort of like “sub-activities” that get nested in larger `Activities`. We’ll talk about `Fragments` more in a later lecture.

Other important point to note: does this activity have a **constructor** that we call? No! We never write code that **instantiates** our `Activity` (we never call `new MainActivity()`). There is no `main` method in Android. `Activities` are created and managed by the Android operating system when the app is launched.

2.2 The Activity Lifecycle

Although we never call a constructor or `main`, `Activities` do have an *incredibly* well-defined lifecycle—that is, a series of **events** that occur during usage (e.g., when the `Activity` is created, when it is stopped, etc).

When each of these events occur, Android executes a **callback method**, similar to how you call `actionPerformed()` to react to a “button press” event in Swing. We can **override** these methods in order to do special actions (read: run our own code) when these events occur.

What is the lifecycle?

³http://developer.android.com/images/activity_lifecycle.png

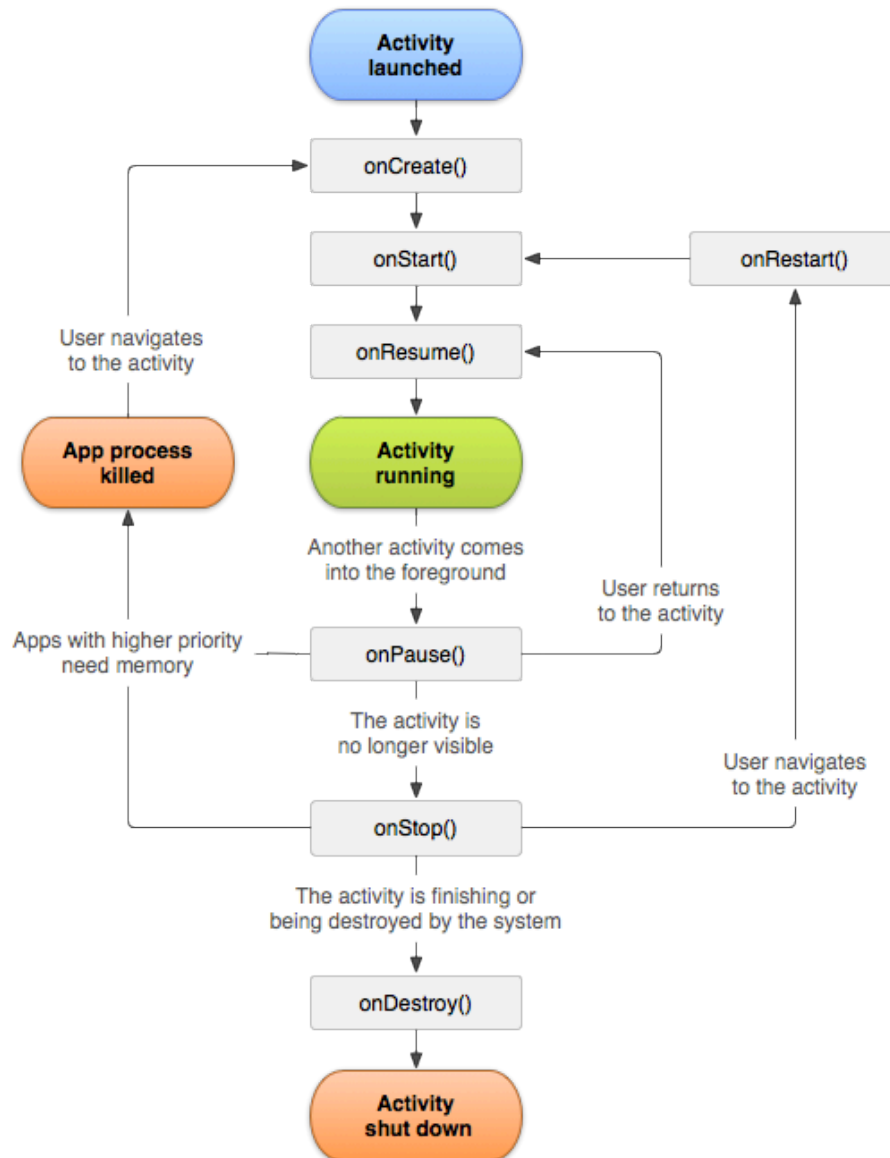


Figure 2.1: Lifecycle state diagram, from Google³. See also an alternative, simplified diagram [here](#).

There are 7 “events” that occur in the Activity Lifecycle, which are designated by the *callback function* that they execute:

- **onCreate()**: called when the Activity is **first** created/instantiated. This is where you initialize the UI (e.g., specify the layout to use), similar to what might go in a constructor.

- **onStart()**: called just before the Activity becomes **visible** to the user.

The difference between `onStart()` and `onCreate()` is that `onStart()` can be called more than once (e.g., if you leave the Activity, thereby hiding it, and come back later to make it visible again).

- **onResume()**: called just before **user interaction** starts, indicating that the Activity is ready to be used! This is a little bit like when that Activity “has focus”.

While `onStart()` is called when the Activity becomes visible, `onResume()` is called when then it is ready for interaction. It is possible for an Activity to be visible but not interactive, such as if there is a modal pop-up in front of it (partially hiding it).

- **onPause()**: called when the system is about to start another Activity (so about to lose focus). This is the “mirror” of `onResume()`. *When paused, the activity stays visible!*

This callback is usually used to *quickly and temporarily* store unsaved changes (like saving an email draft in memory) or stop animations or video playback. The Activity may be being left (on its way out), but could just be losing focus.

- **onStop()**: called when the activity is no longer visible. (e.g., another Activity took over, but this also be because the Activity has been destroyed. This callback is a mirror of `onStart()`).

This callback is where you should persist any state information (e.g., saving the user’s document or game state). It is intended to do more complex “saving” work than `onPause()`.

- **onRestart()**: called when the Activity is coming back from a “stopped” state. This event allows you to run distinct code when the App is being “restarted”, rather than created for the first time. It is the least commonly used callback.

- **onDestroy()**: called when the Activity is about to be closed. This can happen because the user ended the application, *or* (and this is important!) because the OS is trying to save memory and so kills the App.

Android apps run on devices with significant hardware constraints in terms of both memory and battery life. Thus the Android OS is very aggressive about not leaving Apps running “in the background”. If it determines that an App is no longer necessary (such as because it has been hidden for a while), that App will be destroyed. Note that this destruction is

unpredictable, as the “necessity” of an App being open is dependent on the OS’s resource allocation rules.

The `onDestroy()` callback can do final app cleanup, but its better to have such functionality in `onPause()` or `onStop()`.

Note that apps may not need to use all of these callbacks! For example, if there is no difference between starting from scratch and resuming from stop, then you don’t need an `onRestart()` (since `onStart()` goes in the middle). Similarly, `onStart()` may not be needed if you just use `onCreate()` and `onResume()`. But these lifecycles allow for more granularity and the ability to avoid duplicate code.

2.2.1 Overriding the Callback Methods

In the default `MainActivity` the `onCreate()` callback has already been overridden for us, since that’s where the layout is specified.

Notice that this callback takes a `Bundle` as a parameter. A `Bundle` is an object that stores **key-value** pairs, like a super-simple `HashMap` (or an `Object` in JavaScript, or dictionary in Python). Bundles can only hold basic types (numbers, Strings) and so are used for temporarily “bundling” *small* amounts of information.

This `Bundle` parameter in particular stores information about the Activity’s current state (e.g., what text they may have typed into a search box), so that if the App gets killed it can be restarted in the same state and the user won’t notice that it was ever lost! The `Bundle` stores current layout information in it by default (if the Views have ids)—technically, it calls a `onSaveInstanceState()` callback for each View in the layout, and the provided Views that we utilize tend to save important state information (like entered text) already. See Saving and restoring activity state for details.

Also note that we call `super.onCreate()`. *Always call up the inheritance chain!* This allows the system-level behavior to continue without any problem.

We can also add other callbacks: for example, `onStart()` (see the documentation for examples).

But how can we know if the lifecycle events are getting called?

2.3 Logging & ADB

In Android, we can’t use `System.out.println()` because we don’t actually have a terminal to print to! More specifically, the device (which is where the application is running) doesn’t have access to standard out (`stdout`), which is what Java means by `System.out`.

- It is possible to get access to `stdout` with `adb` using `adb shell stop; adb shell setprop log.redirect-stdio true; adb shell start`, but this is definitely not ideal.

Instead, Android provides a Logging system that we can use to write out debugging information, and which is automatically accessible over the `adb` (Android Debugging Bridge). Logged messages can be filtered, categorized, sorted, etc. Logging can also be disabled in production builds for performance reasons (though it often isn't).

To perform this logging, we'll use the `android.util.Log`⁴ class. This class includes a number of `static` methods, which all basically wrap around `println` to print to the device's log file, which is then accessible through the `adb`.

- Remember to import the `Log` class!

The device's log file is stored persistently... sort of. It's a 16k file, but it is shared across the *entire* system. Since every single app and piece of the system writes to it, it fills up fast. Hence filtering/searching becomes important, and you tend to watch the log (and debug your app) in real time!

2.3.1 Log Methods

`Log` provides methods that correspond to different level of priority (importance) of the messages being recorded. From low to high priority:

- **`Log.v()`**: VERBOSE output. This is the most detailed, for everyday messages. This is often the go-to, default level for logging.

Ideally, `Log.v()` calls should only be compiled into an application during development, and removed for production versions.

- **`Log.d()`**: DEBUG output. This is intended for lower-level, less detailed messages (but still code-level, that is referring to specific programming messages).

These messages can be compiled into the code but are removed at runtime in production builds through Gradle.

- **`Log.i()`**: INFO output. This is intended for “high-level” information, such at the user level (rather than specifics about code)
- **`Log.w()`**: WARN output. For warnings
- **`Log.e()`**: ERROR output. For errors
- Also if you look at the API... `Log.wtf()`!

These different levels are used to help “filter out the noise”. So you can look just at errors, at errors and warnings, at error, warn, and info... all the way down

⁴<http://developer.android.com/reference/android/util/Log.html>

to seeing *everything* with verbose. A huge amount of information is logged, so filtering really helps!

Each `Log` method takes two `Strings` as parameters. The second is the message to print. The first is a “tag”—a `String` that’s prepended to the output which you can search and filter on. This tag is usually the App or Class name (e.g., “AndroidDemo”, “MainActivity”). A common practice is to declare a `TAG` constant you can use throughout the class:

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

2.3.2 Logcat

You can view the logs via `adb` (the debugging bridge) and a service called `Logcat` (from “log” and “conCATenation”, since it concatenates the logs). The easiest way to check Logcat is to use Android Studio. The Logcat browser panel is usually found at the bottom of the screen after you launch an application. It “tails” the log, showing the latest output as it appears.

You can use the dropdown box to filter by priority, and the search box to search (e.g., by tag if you want). Android Studio also lets you filter to only show the current application, which is hugely awesome. Note that you may see a lot of Logs that you didn’t produce, including possibly Warnings (e.g., I see a lot of stuff about how OpenGL connects to the graphics card). *This is normal!*

It is also possible to view Logcat through the command-line using `adb`, and includes complex filtering arguments. See Logcat Command-line Tool for more details.

Demo: And now we can finally log out some of the Lifecycle callbacks to see them being executed!

- Start by implementing `onResume()`. Note the wonders of tab completion! Have it log out at `INFO` level. On the device, hit the main menu (circle) button to send the Activity to the background, and watch the callback be executed.
- Implement `onStop()` and switch out of the app to watch it be stopped.
- `onDestroy()` can easily be called if you set the phone to “Don’t Keep Activities” (at bottom of developer settings). Or you can simply *rotate* the phone (which causes the Activity to be destroyed and then recreated in the new orientation).
- Something else to test: Cause the app to throw a runtime `Exception` in one of the handlers. For example, you could make a new local array and try to access an item out of bounds. Or just `throw new RuntimeException()` (which is slightly less interesting). *Can you see the **Stack Trace** in the logs?*

Logging is fantastic and one of the the best techniques we have for debugging, both in how Activities are being used or for any kind of bug (also `RuntimeEx-`

ceptions). It harkens back to printline debugging, which is still a legitimate debugging process.

Note that Android Studio does have a built-in debugger if you're comfortable with such systems.

2.4 Basic Events

Once you can “output” some content (via Log), the next step is to add some “input” via an interface element: for example, a Button we can click.

In **res/layouts/activity_main.xml** (the Activity's layout), add the following code inside the `<android.support.constraint.ConstraintLayout>` element, **replacing** the current `<TextView>` element.

```
<Button
    android:id="@+id/my_button"
    android:layout_width="wrap_content"
    android:layout_height="wrap_content"
    android:text="Start Activity"
/>
```

This XML defines a Button. The `android:text` attribute specifies the text that is on the button. The next lecture will describe in more detail how exactly this XML works (and what's meant by the `id`, and `layout_width/height`), but you should be able to make a pretty good educated guess based on the names.

- Defining this in XML is basically the same process as creating the `JButton` and adding it to the `JFrame` in Java!

Now we have a button, but we want to be able to click on it. So we need to register a “listener” for it (in Java), just like with Swing apps:

```
Button button = (Button)findViewById(R.id.my_button);
button.setOnClickListener(new View.OnClickListener() {
    public void onClick(View v) {
        // Perform action on click
    }
});
```

First we need to get access to a variable that represents that Button we defined in the XML. The `findViewById()` method “finds” the appropriate XML element with the given `id`. We discuss why we wrote the parameter as `R.id.my_button` in the next lecture tomorrow. Note that this method returns a `View`, so we want to **cast** the value into the more specific `Button` (which has methods we want to use).

We can register a listener with that button through the `.setOnClickListener()` method, passing in an **anonymous class** to act as the listener. (Again,

tab-completion is our friend!). This is *just like* what you would do with a Swing app.

Finally, we can fill in the method to have it log out something when clicked.

Overall, this button is an example of an Input Control. These will be discussed in more detail in Lecture 4.

2.5 Multiple Activities

The whole point of interfacing with the Activity Lifecycle is handle the fact that Android applications can have multiple activities and interact with multiple other applications. In this section we'll briefly discuss how to include multiple Activities within an app (in order to sense how the life cycle may affect them). Note that working with multiple Activities will be discussed in more detail in a later lecture.

We can easily create a New Activity through Android Studio by using **File > New > Activity**. We could also just add a new `.java` file with the Activity class in it, but using Android Studio will also provide the `onCreate()` method stub as well as a layout resource.

- For practice, make a new **Empty** Activity called **SecondActivity**. You should edit this Activity's layout resource so that the `<TextView>` displays an appropriate message.

Importantly, for every Activity we make, an entry gets added to the **Manifest** file `AndroidManifest.xml`. This file acts like the "*table of contents*" for our application, telling the device Operating System information about what our app looks (that is, what Activities it has) like so that the OS can open appropriate Activities as needed.

Activities are listed as `<activity>` elements nested in the `<application>` element. If you inspect the file you will be able to see an element representing the first `MainActivity`; that entry's child elements will be discussed later.

- We can add `android:label` attributes to these `<activity>` elements in order to give the Activities nicer display names (e.g., in the ActionBar).

2.5.1 Intents and Context

In Android, we don't start new Activities by instantiating them (remember, *we never instantiate Activities!*). Instead, we send the operating system a message requesting that the Activity perform a particular action (i.e., start up and display on the screen). These messages are called **Intents**, and are used to communicate between app components like Activities. The Intent system allows Activities to communicate, even though they don't have references to each other (we can't just call a method on them).

- I don't have a good justification for the name, other than Intents announce an "intention" for the OS to do something (like start an Activity)
- You can think of Intents as like *envelopes*: they are addressed to a particular target (e.g., another Activity—or more properly a `Context`), and contain a brief message about what to do.

An `Intent` is an object we *can* instantiate: for example, we can create a new `Intent` in the event handler for when we click the button on `MainActivity`. The `Intent` class has a number of different constructors, but the one we'll start with looks like:

```
Intent intent = new Intent(MainActivity.this, SecondActivity.class);
```

The second parameter to this constructor is the *class* we want to send the `Intent` to (the `.class` property fetches a reference to the class type; this is metaprogramming!). Effectively, it is the "address" on the envelope for the message we're sending.

The first parameter refers to the current **Context**⁵ in which the message should be delivered. `Context` is an **abstract class** (and a superclass of `Activity`) that acts as a reference for information about the current running environment: it represents environmental data (information like "What OS is running? Is there a keyboard plugged in?"). You can *almost* think of the `Context` as representing the "Application", though it's broader than that (`Application` is actually a subclass of `Context`!)

The `Context` is *used* to do "application-level" actions: mostly working with resources (accessing and loading them), but also communicating between Activities like we're doing now. Effectively, it lets us refer to the state in which we are running: the "context" for our code (e.g., "where is this occurring?"). It's a kind of *reflection* or meta-programming, in a way.

There are a couple of different kinds of `Contexts` we might wish to refer to:

- The Application context (e.g., an `Application` object) references the state of the entire application. It's basically the Java object that is built out of the `<application>` element in the Manifest (and so contains that level of information).
- The Activity context (e.g., an `Activity` object) that references the state of that Activity. Again, this roughly corresponds to the Java objects created out of the `<activity>` tags from the Manifest.

Each of these `Context` objects exist for the life of its respective component: that is, an `Activity Context` is available as long as the Activity exists (disappearing after `onDestroy()`), whereas `Application Contexts` survive as long as the application does. Note that we'll almost always use the `Activity context`, as it's safer and less likely to cause memory leaks.

⁵<https://developer.android.com/reference/android/content/Context.html>

- Inside an `Activity` object (e.g., in a lifecycle callback function), you can refer to the current `Activity` using `this`. And since `Activity` is a `Context`, you can also use `this` to refer to the current `Activity` context. You'll often see `Context` methods called as undecorated methods (without an explicit `this`).

After having instantiated the new `Intent`, we can use that message to start an `Activity` by calling the `startActivity()` method (inherited from `Activity`), passing it the `Intent`:

```
startActivity(intent);
```

This method will “send” the message to the operating system, which will deliver the `Intent` to the appropriate `Activity`, telling that `Activity` to start as soon as it receives the message.

With this interaction in place, we can now click a button to start a second activity, and see how that impacts our Lifecycle callbacks.

- And we can use the **back** button to go backwards!

There are actually a couple of different kinds of `Intents` (this is an **Explicit Intent**, because it is explicit about what `Activity` it's sent to), and a lot more we can do with them. We'll dive into `Intents` in more detail later; for now we're going to focus on mostly Single `Activities`.

- For example, if you look back at the Manifest, you can see that the `Main-Activity` has an `<intent-filter>` child element that allows it to receive particular kinds of `Intents`—including ones for when an App is launched for the first time!

2.6 Back & Tasks

We've shown that we can have lots of `Activities` (and of course many more can exist cross multiple apps), and we are able to move between them by sending `Intents` and clicking the “Back” button. But how exactly is that “Back” button able to keep track of where to go to?

The abstract data type normally associated with “back” or “undo” functionality is a **stack**, and that is exactly what Android uses. Every time you *start* a new `Activity`, Android instantiates that object and puts it on the top of a stack. Then when you hit the back button, that activity is “popped” off the stack and you're taken to the `Activity` that is now at the top.

However, you might have different “sequences” of actions you're working on: maybe you start writing an email, and then go to check your Twitter feed through a different set of `Activities`. Android breaks up these sequences into

⁶http://developer.android.com/images/fundamentals/diagram_backstack.png

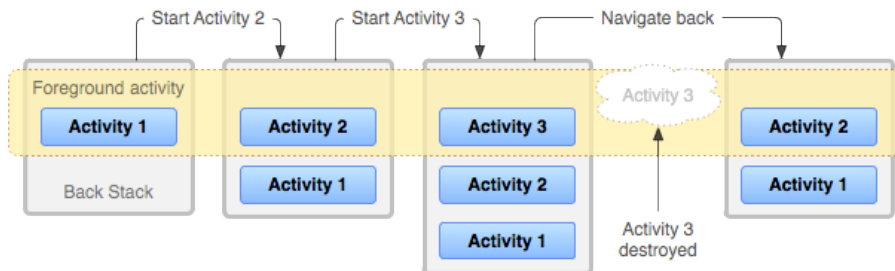


Figure 2.2: An example of the Activity stack, from Google⁶.

groups called **Tasks**. A *Task* is a collection of Activities arranged in a Stack, and there can be multiple Tasks in the background of your device.

Tasks usually start from the Android “Home Screen”—when you launch an application, that then starts a new Task. Starting new Activities from that application will add them to the Stack of the task. If you go *back* to the Home Screen, the Task you’re currently on is moved to the background, so the “back” button won’t let you navigate that Stack.

- It’s useful to think of Tasks as being like different tabs or browsers, with the “back stack” being the history of web pages visited within that tab.
- As a demonstration, try switching to another (built-in) app and then back to the example app; how does the back button work in each situation?

An important caveat: Tasks are distinct from one another, so you can have different copies of the same Activity on multiple stacks (e.g., the Camera activity could be part of both Facebook and Twitter app Tasks if you are on a selfie binge). It is possible to modify this behavior though, see - Though it is possible to modify this, see Managing Tasks

2.6.1 Up Navigation

We can make this “back” navigation a little more intuitive for users by providing explicit up navigation, rather than just forcing users to go back through Activities in the order they viewed them (e.g., if you’re swiping through emails and want to go back to the home list). To do this, we just need to add a little bit of configuration to our Activities:

- In the Java code, we want to add more functionality to the `ActionBar`. *Think*: which lifecycle callback should this specification be put in?

```
//specify that the ActionBar should have an "home" button
getSupportActionBar().setHomeButtonEnabled(true);
```

- Then in the **Manifest**, add an `android:parentActivityName` attribute to the `SecondActivity`, with a value set to the full class name (including package **and** appname!) of your `MainActivity`. This will let you be able to use the “back” visual elements (e.g., of the `ActionBar`) to move back to the “parent” activity. See Up Navigation for details.

```
<activity android:name=".SecondActivity"
    android:label="Second Activity"
    android:parentActivityName="edu.uw.activitydemo.MainActivity">
    <meta-data
        android:name="android.support.PARENT_ACTIVITY"
        android:value="edu.uw.activitydemo.MainActivity" />
</activity>
```

The `<meta-data>` element is to provide backwards compatibilit for API level 15 (since the `android:parentActivityName` is only defined for API level 16+).

Chapter 3

Resources and Layouts

This lecture discusses **Resources**, which are used to represent elements or data that are separate from the behavior (functional logic) of the app. In particular, this lecture focuses on how resources are used to define **Layouts** for user interfaces. While the Activities lecture focused on the Java portion of Android apps; this lecture focuses on the XML.

This lecture references code found at <https://github.com/info448-s17/lecture03-layouts>.

3.1 Resources

Resources can be found in the **res/** folder, and represent elements or data that are “external” to the code. You can think of them as “media content”: often images, but also things like text clippings (or short String constants). Textual resources are usually defined in XML files. This is because resources represent elements (e.g., content) that is *separate* from the code (the behavior of the app), so is kept separate from the Java code to support the **Principle of Separation of Concerns**

- By defining resources in XML, they can be developed (worked on) *without* coding tools (e.g., with systems like the graphical “layout design” tab). Theoretically you could have a Graphic Designer create these resources, which can then be integrated into the code without the designer needing to do a lick of Java.
- Similarly, keeping resources separate allows you to choose what resources to include *dynamically*. You can choose to show different images based on device screen resolution, or pick different Strings based on the language of the device (internationalization!)—the behavior of the app is the same, but the “content” is different!

- This is similar to how in web development we may want to have the same JavaScript from different HTML.

What should be a resource? In general:

- Layouts should **always** be resources
- UI controls (buttons, etc) should *mostly* be defined as resources (part of layouts), though behavior will be defined programmatically (in Java)
- Any graphic images (drawables) should be resources
- Any *user-facing* strings should be resources
- Style and theming information should be resources

As introduced in Lecture 1, there are a number of different resource types used in Android, many of which can be found in the `res/` folder of a default Android project, including:

- `res/drawable/`: contains graphics (PNG, JPEG, etc)
- `res/layout/`: contains UI XML layout files
- `res/mipmap/`: contains launcher icon files in different resolutions
- `res/values/`: contains XML definitions for general constants
 - `/strings`: short string constants (e.g., labels)
 - `/colors`: color constants
 - `/styles`: constants for style and theme details
 - `/dimen`: dimensional constants (like default margins); not created by default in Android Studio 2.3+.

The details about these different kinds of resources is a bit scattered throughout the documentation, but Resource Types¹ is a good place to start, as is Providing Resources.

3.1.1 Alternate Resources

These aren't the only names for resource folders: as mentioned above, part of the goal of resources is that they can be **localized**: changed depending on the device! You are thus able to specify folders for “alternative” resources (e.g., special handling for another language, or for low-resolution devices). At runtime, Android will check the configuration of the device, and try to find an alternative resource that matches that config. If it *can't* find a relevant alternative resource, it will fall back to the “default” resource.

There are many different configurations that can be used to influence resources; see Providing Resources². To highlight a few options, you can specify different resources based on:

- Language and region (e.g., via two-letter ISO codes)
- Screen size (`small`, `normal`, `medium`, `large`, `xlarge`)
- Screen orientation (`port` for portrait, `land` for landscape)

¹<https://developer.android.com/guide/topics/resources/available-resources.html>

²<http://developer.android.com/guide/topics/resources/providing-resources.html>

- Specific screen pixel density (dpi) (ldpi, mdpi, hdpi, xhdpi, xxhdpi, etc.). xxhdpi is pretty common for high-end devices. Note that dpi is “dots per inch”, so these values represent the number of pixels across *relative* to the device size!
- Platform version (v1, v4, v7... for each API number)

Configurations are indicated using the **directory name**, giving them the form `<resource_name>(-<config_qualifier>)+`

- You can see this in action by using the *New Resource* wizard (File > New > Android resource file) to create a welcome message (a string resource, such as for the app_name) in another language³, and then changing the device’s language settings to see the content automatically adjust!

```
<?xml version="1.0" encoding="utf-8"?>
<resources>
    <string name="app_name">Mon Application</string>
</resources>
```

- Switch to the Package view in Android Studio to see how the folder structure for this works.

3.1.2 XML Details

Resources are usually defined as XML (which is similar in syntax to HTML). The `strings.xml` example used above involves fairly simple elements but more complex resource is pretty simple, but more complex details can be seen in the `activity_main.xml` resource inside `layout/`.

- Android-specific attributes are namespaced with a `android:` prefix, to avoid any potential conflicts (e.g., so we know we’re talking about Android’s `text` instead of something else).
- We can use the `@` symbol to reference one resource from another, following the schema `@[<package_name>:]<resource_type>/<resource_name>`
- We can also use the `+` symbol to create a *new* resource that we can refer to; this is a bit like declaring a variable inside an attribute. This is most commonly used with the `android:id` attribute (`android:id="@+id/identifier"`), see below for details.

3.1.3 R

Although XML resources are defined separately from the Java code, resources can be accessed from within Java. When an application is compiled, the build tools (e.g., gradle) **generate** an additional Java class called **R** (for “resource”). This class contains what is basically a giant list of static “constants”—one for

³<https://www.webucator.com/blog/2010/03/saying-hello-world-in-your-language-using-javascript/>

each resource! These constants are organized into subclasses, one for each resource type. This allows you to refer to a specific resource in the Java code as `[(package_name).]R.resource_type.identifier` similar to the kind of syntax used to refer to a nested JSON object! For example: `R.string.hello` (the `hello` string resource), `R.drawable.icon` or `R.layout.activity_main`

- For most resources, the identifier is defined as an element attribute (`id` for specific View elements in layouts, `name` attribute for values). For more complex resources such as entire layouts or drawables, the identifier is the *filename* (without the XML); hence `R.layout.activity_main` refers to the root element of the `layout/activity_main.xml` file.
- Note that that `@` symbol used in the XML goes to the R Java file to look things up, so follows the same reference syntax.

You can find the generated `R.java` file inside `app/build/generated/source/r/debug/...` (Use the Project Files view in Android Studio).

The static constants inside the `R.java` file are often just `ints` that are *pointers* to element references (similar to passing a `pointer*` around in the C language). So in the Java, we usually work with `int` as the data type for XML resources, because we're actually working with pointers *to* those resources.

- You can think of each `int` constant as a “key” or “index” for that resource (in the list of all resources). Android does the hard work of taking that `int`, looking it up in an internal resource table, finding the associated XML file, and then getting the right element out of that XML. (By hard work, I mean in terms of implementation. Android is looking up these references directly in memory, so the look-up is a fast $O(1)$).

Because the `R` class is included in the Java, we can access these constants directly in our code (as `R.resource_type.identifier`). For example, the `setContentView()` call in an Activity's `onCreate()` takes in a resource `int`.

- The other common method that utilizes resources will be `findViewById()`, which is used to reference a `View` element (e.g., a button) from the resource in order to call methods on it in Java. This is the same method used with the Button example in the Activities lecture

The `R` class is regenerated all time (any time you change a resource, which is often); when Eclipse was the recommended Android IDE, you often needed to manually regenerate the class so that the IDE's index would stay up to date! You can perform a similar task in Android Studio by using `Build > Clean Project` and `Build > Rebuild Project`.

3.2 Views

The most common type of element we'll define in resources are **Views**⁴. **View** is the superclass for visual interface elements—a visual component on the screen is a **View**. Specific types of Views include: **TextViews**, **ImageViews**, **Buttons**, etc.

- **View** is a superclass for these components because it allows us to use **polymorphism** to treat all these visual elements the same way as instances of the same type. We can lay them out, draw them, click on them, move them, etc. And all the behavior will be the same—though subclasses can also have “extra” features

Here's the big trick: one subclass of **View** is **ViewGroup**⁵. A **ViewGroup** can contain other “child” Views. But since **ViewGroup** is a **View**... it can contain more **ViewGroups** inside it! Thus we can **nest** Views within Views, following the Composite Pattern. This ends up working a lot like HTML (which can have DOM elements like `<div>` inside other DOM elements), allowing for complex user interfaces.

- Thus Views are structured into a *tree*, what is known as the **View hierarchy**.

Views are defined inside of Layouts—that is, inside a layout resource, which is an XML file describing Views. These resources are “inflated” (rendered) into UI objects that are part of the application.

Technically, **Layouts** are simply **ViewGroups** that provide “ordering” and “positioning” information for the Views inside of them. they let the system “lay out” the Views intelligently and effectively. *Individual views shouldn't know their own position*; this follows from good object-oriented design and keeps the Views encapsulated.

Android studio does come with a graphical Layout Editor (the “Design” tab) that can be used to create layouts. However, most developers stick with writing layouts in XML. This is mostly because early design tools were pathetic and unusable, so XML was all we had. Although Android Studio's graphical editor can be effective, for this course you should create layouts “by hand” in XML. This is helpful for making sure you understand the pieces underlying development, and is a skill you should be comfortable with anyway (similar to how we encourage people to use **git** from the command-line).

3.2.1 View Properties

Before we get into how to group Views, let's focus on the individual, basic **View** classes. As an example, consider the **activity_main** layout in the lecture

⁴<http://developer.android.com/reference/android/view/View.html>

⁵<http://developer.android.com/reference/android/view/ViewGroup.html>

code. This layout contains two individual `View` elements (inside a `Layout`): a `TextView` and a `Button`.

All `View` have **properties** which define the state of the `View`. Properties are usually defined within the resource XML as element *attributes*. Some examples of these property attributes are described below.

- **android:id** specifies a unique identifier for the `View`. This identifier needs to be unique within the layout, though ideally is unique within the entire app (for clarity).

Identifiers must be legal Java variable names (because they are turned into a variable name in the `R` class), and by convention are named in `lower_case` format.

- *Style tip*: it is useful to prefix each `View`'s id with its type (e.g., `btn`, `txt`, `edt`). This helps with making the code self-documenting.

You should give each interactive `View` a unique id, which will allow its state to automatically be saved as a `Bundle` when the `Activity` is destroyed. See [here](#) for details.

- **android:layout_width** and **android:layout_height** are used to specify the `View`'s size on the screen (see `ViewGroup.LayoutParams` for documentation). These values can be a specific value (e.g., `12dp`), but more commonly is one of two special values:

- `wrap_content`, meaning the dimension should be as large as the content requires, plus padding.
- `match_parent`, meaning the dimension should be as large as the *parent* (container) element, minus padding. This value was renamed from `fill_parent` (which has now been deprecated).

Android utilizes the following dimensions or units:

- **dp** is a “density-independent pixel”. On a 160-dpi (dots-per-inch) screen, `1dp` equals `1px` (pixel). But as dpi increases, the number of pixels per `dp` increases. These values should be used instead of `px`, as it allows dimensions to work independent of the hardware's dpi (which is *highly* variable).
- **px** is an actual screen pixel. *DO NOT USE THIS* (use `dp` instead!)
- **sp** is a “scale-independent pixel”. This value is like `dp`, but is scale by the system's font preference (e.g., if the user has selected that the device should display in a larger font, `1sp` will cover more `dp`). *You should **always** use `sp` for text dimensions, in order to support user preferences and accessibility.*
- **pt** is 1/72 of an inch of the physical screen. Similar units `mm` and `in` are available. *Not recommended for use.*
- **android:padding**, **android:paddingLeft**, **android:margin**, **android:marginLeft**, etc. are used to specify the margin and padding for

Views. These work basically the same way they do in CSS: padding is the space between the content and the “edge” of the View, and margin is the space between Views. Note that unlike CSS, margins between elements do not collapse.

- **android:textSize** specifies the “font size” of textual Views (use **sp** units!), **android:textColor** specifies the color of text (reference a color resource!), etc.
- There are lots of other properties as well! You can see a listing of generic properties in the `View`⁶ documentation, look at the options in the “Design” tab of Android Studio, or browse the auto-complete options in the IDE. Each different `View` class (e.g., `TextView`, `ImageView`, etc.) will also have their own set of properties.

Note that unlike CSS, styling properties specified in the layout XML resources are not inherited; we’re effectively specifying an inline `style` attribute for that element, and one that won’t affect child elements. In order to define shared style properties, you’ll need to use styles resources, which are discussed in a later lecture.

While it is possible to specify these visual properties dynamically via Java methods (e.g., `setText()`, `setPadding()`). You should **only** use Java methods to specify View properties when they *need* to be dynamic (e.g., the text changes in response to a button click)—it is much cleaner and effective to specify as much visual detail in the XML resource files as possible. It’s also possible to simply replace one layout resource with another (see below).

- Views also have inspection methods such as `isVisible()` and `hasFocus()`; we will point to those as we need them.

Do not define Views or View appearances in an Activity’s `onCreate()` callback, unless the properties (e.g., content) truly cannot be determined before runtime! Specify layouts in the XML instead.

3.2.2 Practice

Add a new `ImageView` element that contains a picture. Be sure and specify its `id` and size (experiment with different options).

You can specify the content of the image in the XML resource using the **android:src** attribute (use `@` to reference a `drawable`), or you can specify the content dynamically in Java code:

```
ImageView imageView = (ImageView)findViewById(R.id.img_view);
imageView.setImageResource(R.drawable.my_image);
```

⁶<http://developer.android.com/reference/android/view/View.html#lattr>

3.3 Layouts

As mentioned above, a Layout is a grouping of Views (specifically, a `ViewGroup`). A Layout acts as a container for other Views, to help organize things. Layouts are all subclasses of `ViewGroup`, so you can use its inheritance documentation to see a (mostly) complete list of options, though many of the listed classes are deprecated in favor of later, more generic/powerful options.

3.3.1 LinearLayout

Probably the simplest Layout to understand is the `LinearLayout`. This Layout simply orders the children View in a line (“linearly”). All children are laid out in a single direction, but you can specify whether this is horizontal or vertical with the `android:orientation` property. See `LinearLayout.LayoutParams` for a list of all attribute options!

- Remember: since a Layout is a `ViewGroup` is a `View`, you can also utilize all the properties discussed above; the attributes are inherited!

Another common property you might want to control in a `LinearLayout` is how much of any remaining space the elements should occupy (e.g., should they expand). This is done with the `android:layout_weight` property. After all element sizes are calculated (via their individual properties), the remaining space within the Layout is divided up proportionally to the `layout_weight` of each element (which defaults to 0 so they get no extra space). See the example in the guide for more details.

- *Useful tip:* Give elements 0dp width or height and 1 for weight to make everything in the Layout the same size!

You can also use the `android:layout_gravity` property to specify the “alignment” of elements within the Layout (e.g., where they “fall” to). Note that this property is specified on individual child Views.

An important point Since Layouts *are* Views, you can of course nest `LinearLayouts` inside each other! So you can make “grids” by creating a vertical Layout containing “rows” of horizontal Layouts (which contain Views). As with HTML, there are lots of different options for achieving any particular interface layout.

3.3.2 RelativeLayout

A `RelativeLayout` is more flexible (and hence powerful), but can be more complex to use. In a `RelativeLayout`, children are positioned “relative” to the parent **OR** *to each other*. All children default to the top-left of the Layout, but you can give them properties from `RelativeLayout.LayoutParams` to specify where they should go instead.

For example: `android:layout_verticalCenter` centers the View vertically within the parent. `android:layout_toRightOf` places the View to the right of the View with the given resource id (use an @ reference to refer to the View by its id):

```
<TextView
    android:id="@+id/first"
    android:layout_width="match_parent"
    android:layout_height="wrap_content"
    android:text="FirstString" />
<TextView
    android:id="@+id/second"
    android:layout_height="wrap_content"
    android:layout_below="@id/first"
    android:layout_alignParentLeft="true"
    android:text="SecondString" />
```

(Recall that the @+ syntax defines a *new* View id, like declaring a variable!)

You do not need to specify both `toRightOf` and `toLeftOf`; think about placing one element on the screen, then putting another element relative to what came before. This can be tricky. For this reason the author prefers to use `LinearLayouts`, since you can always produce a Relative positioning using enough `LinearLayouts` (and most layouts end up being linear in some fashion anyway!)

3.3.3 ConstraintLayout

`ConstraintLayout` is a Layout provided as part of an extra support library, and is what is used by Android Studio's "Design" tool (and thus is the default Layout for new layout resources). `ConstraintLayout` works in a manner conceptually similar to `RelativeLayout`, in that you specify the location of Views in relationship to one another. However, `ConstraintLayout` offers a more powerful set of relationships in the form of *constraints*, which can be used to create highly responsive layouts. See the class documentation for more details and examples of constraints you can add.

The main advantage of `ConstraintLayout` is that it supports development through Android Studio's Design tool. However, since this course is focusing on implementing the resource XML files rather than using the specific tool (that may change in a year's time), we will primarily be using other layouts.

3.3.4 Other Layouts

There are many other layouts as well, though we won't go over them all in depth. They all work in similar ways; check the individual class's documentation for details.

- `FrameLayout` is a sort of “placeholder” layout that holds a **single** child `View` (a second child will not be shown). You can think of this layout as a way of adding a simple container to use for padding, etc. It is also highly useful for situations where the framework requires you to specify a `Layout` resource instead of just an individual `View`.
- `GridLayout` arranges `Views` into a `Grid`. It is similar to `LinearLayout`, but places elements into a grid rather than into a line.

Note that this is different than a `Grid_View_`, which is a scrollable, adaptable list (similar to a `ListView`, which is discussed in the next lecture).

- `TableLayout` acts like an HTML table: you define `TableRow` layouts which can be filled with content. This `View` is not commonly used.

3.3.5 Combining and Inflating Layouts

It is possible to combine multiple layout resources. This is useful if you want to dynamically change what `Views` are included, or to refactor parts of a layout into different XML files to improve code organization.

As one option, you can *statically* include XML layouts inside other layouts by using an `<include>` element:

```
<include layout="@layout/sub_layout">
```

But it is also possible to dynamically load views “manually” (e.g., in Java code) using the `LayoutInflater`. This is a class that has the job of “inflating” (rendering) `Views`. The process is called “inflating” based on the idea that it is “unpacking” or “expanding” a compact resource description into a complex Java Object. `LayoutInflater` is implicitly used in the `setContentView()` method, but can also be used independently with the following syntax:

```
LayoutInflater inflater = getLayoutInflater(); //access the inflater (called on the
View myLayout = inflater.inflate(R.layout.my_layout, parentViewGroup, true); //to at
```

Note that we never instantiate the `LayoutInflater`, we just access an object that is defined as part of the Activity.

The `inflate()` method takes a couple of arguments:

- The first parameter is a reference to the resource to inflate (an `int` saved in `R`)
- The second parameter is a `ViewGroup` to act as the “parent” for this `View`—e.g., what layout should the `View` be inflate inside? This can be `null` if there is not yet a layout context; e.g., you wish to inflate the `View` but not show it on the screen yet.
- The third (optional) parameter is whether to actually attach the inflated `View` to that parent (if not, the parent just provides context and layout params to use). If not assigning to parent on inflation, you can later attach

the View using methods in `ViewGroup` (e.g., `addView(View)` similar to what we've done with Swing).

Manually inflating a View works for dynamically loading resources, and we will often see UI implementation patterns that utilize Inflators.

However, for dynamic View creation it tends to be messy and hard to maintain (UI work should be specified entirely in the XML, without needing multiple references to parent and child Views) so it isn't as common in modern development. A much cleaner solution is to use a `ViewStub`⁷. A `ViewStub` is like an “on deck” Layout: it is written into the XML, but isn't actually shown until you choose to reveal it via Java code. With a `ViewStub`, Android inflates the View at runtime, but then removes it from the parent (leaving a “stub” in its place). When you call `inflate()` (or `setVisible(View.VISIBLE)`) on that stub, it is reattached to the View tree and displayed:

```
<!-- XML -->
<ViewStub android:id="@+id/stub"
    android:inflatedId="@+id/subTree"
    android:layout="@layout/mySubTree"
    android:layout_width="wrap_content"
    android:layout_height="wrap_content" />

//Java
ViewStub stub = (ViewStub)findViewById(R.id.stub);
View inflated = stub.inflate();
```

⁷<http://developer.android.com/training/improving-layouts/loading-ondemand.html>

Chapter 4

Interactive Views

This lecture discusses how to use Views to support user interaction and dynamic content, building on the previous lecture as while drawing on concepts introduced in the Threads and HTTP Requests Appendix.

This lecture references code found at <https://github.com/info448-s17/lecture04-inputs-lists>.

4.1 Inputs

The previous lecture discussed **Views** and ViewGroups (**Layouts**), and introduced some basic Views such as `TextView`, `ImageView`, and `Button`.

A `Button` is an example of an Input Control. These are simple (single-purpose; not necessarily lacking complexity) widgets that allow for user input. There are many such widgets in addition to `Button`, mostly found in the `android.widget` package. Many correspond to HTML `<input>` elements, but Android provided additional widgets as well.

Launch the lecture code's `MainActivity` with a content View of `R.id.input_control_layout` to see an example of many widgets (as well as a demonstration of a more complex layout!). These widgets include:

- `Button`, a widget that affords clicking. Buttons can display text, images or both.
- `EditText`, a widget for user text entry. Note that you can use the `android:inputType` property to specify the type of the input similar to an HTML `<input>`.
- `Checkbox`, a widget for selecting an on-off state
- `RadioButton`, a widget for selecting from a set of choices. Put `RadioButton` elements inside a `RadioGroup` element to make the buttons mutually

exclusive.

- `ToggleButton`, another widget for selecting an on-off state.
- `Switch`, yet another widget for selecting an on-off state. This is just a `ToggleButton` with a slider UI. It was introduced in API 14 and is the “modern” way of supporting on-off input.
- `Spinner`, a widget for picking from an array of choices, similar to a drop-down menu. Note that you should define the choices as a resource (e.g., in `strings.xml`).
- `Pickers`: a compound control around some specific input (dates, times, etc). These are typically used in pop-up dialogs, which will be discussed in a future lecture.
- ...and more! See the `android.widget` package for further options.

All these input controls basically work the same way: you define (instantiate) them in the layout resource, then access them in Java in order to define interaction behavior.

There are two ways of interacting with controls (and Views in general) from the Java code:

1. Calling **methods** on the View to manipulate it. This represents “outside to inside” communication (with respect to the View).
2. Listening for **events** produced by the View and responding to them. This represents “inside to outside” communication (with respect to the View).

An example of the second, event-driven approach was introduced in Lecture 2. This involved *registering a listener* for the event (after acquiring a reference to the View with `findViewById()`) and then specifying a **callback method** (by instantiating the Listener interface) that would be “called back to” when the event occurs.

- It is also possible to specify the callback method in the XML resource itself by using e.g., the `android:onClick` attribute. This value of this attribute should be the *name* of the callback method: It is also possible to

```
<Button
    android:layout_width="wrap_content"
    android:layout_height="wrap_content"
    android:onClick="handleButtonClick" />
```

The callback method is declared in the Java code as taking in a `View` parameter (which will be a reference to whatever View caused the event to occur) and returning `void`:

```
public void handleButtonClick(View view) { }
```

- We will utilize a mix of both of these strategies (defining callbacks in both the Java and the XML) in this class.

Author’s Opinion: It is arguable about which approach is “better”. Spec-

ifying the callback method in the Java code helps keep the appearance and behavior separate, and avoids introducing hidden dependencies for resources (the Activity must provide the required callback). However, as buttons are made to be pressed, it isn't unreasonable to give a "name" in the XML resource as to what the button will do, especially as the corresponding Java method may just be a "launcher" method that calls something else. Specifying the callback in the XML resource may often seem faster and easier, and we will use whichever option best supports clarity of our code.

Event callbacks are used to respond to all kind of input control widgets. Check-Boxes use an `onClick` callback, ToggleButtons use `onCheckedChanged`, etc. Other common events can be found in the View documentation, and are handled via listeners such as `OnDragListener` (for drags), `OnHoverListener` (for "hover" events), `OnKeyListener` (for when user types), or `OnLayoutChangeListener` (for when layout changes display).

In addition to listening for events, it is possible to call methods directly on referenced Views to access their state. In addition to generic View methods such as `isVisible()` or `hasFocus()`, it is possible to inquire directly about the state of the input provided. For example, the `isChecked()` method returns whether or not a checkbox is ticked.

This is also a good way of getting access to inputted content from the Java Code. For example, call `getText()` on an `EditText` control in order to fetch the contents of that View.

- For practice, try to log out the contents of the included `EditText` control when the `Button` is pressed!

Between listening for events and querying for state, we can fully interact with input controls. Check the official documentation for more details on how to use specific individual widgets.

4.2 ListViews and Adapters

The remainder of the lecture utilizes the `list_layout` Layout in the lecture code. Modify `MainActivity` so that it uses this resource as its `viewContent`.

Having covered basic controls, this section will now look at some more advanced interactive Views. In particular, it will discuss how to utilize a `ListView`¹, which is a `ViewGroup` that displays a scrollable list of items! A `ListView` is basically a `LinearLayout` inside of a `ScrollView` (which is a `ViewGroup` that can be scrolled). Each element within the `LinearLayout` is another `View` (usually a `Layout`) representing a particular item in a list.

¹<https://developer.android.com/guide/topics/ui/layout/listview.html>

But the `ListView` does extra work beyond just nesting Views: it keeps track of what items are already displayed on the screen, inflating only the visible items (plus a few extra on the top and bottom as buffers). Then as the user scrolls, the `ListView` takes the disappearing views and *recycles* them (altering their content, but not reinflating from scratch) in order to reuse them for the new items that appear. This lets it save memory, provide better performance, and overall work more smoothly. See this tutorial for diagrams and further explanation of this recycling behavior.

- Note that a more advanced and flexible version of this behavior is offered by the `RecyclerView`. See also this guide for more details.

The `ListView` control uses a **Model-View-Controller (MVC)** architecture. This is a design pattern common to UI systems which organizes programs into three parts:

1. The **Model**, which is the data or information in the system
2. The **View**, which is the display or representation of that data
3. The **Controller**, which acts as an intermediary between the Model and View and hooks them together.

The MVC pattern can be found all over Android. At a high level, the resources provide *models* and *views* (separately), while the Java Activities act as *controllers*.

- *Fun fact:* The Model-View-Controller pattern was originally developed as part of the Smalltalk language, which was the first Object-Oriented language!

Thus in order to utilize a `ListView`, we'll have some data to be displayed (the *model*), the *views* (Layouts) to be shown, and the `ListView` itself will connect these together act as the *controller*. Specifically, the `ListView` is a subclass of `AdapterView`, which is a View backed by a data source—the `AdapterView` exists to hook the View and the data together (a controller!)

- There are other `AdapterViews` as well. For example, `GridView` works exactly the same way as a `ListView`, but lays out items in a scrollable grid rather than a scrollable list.

In order to use a `ListView`, we need to get the pieces in place:

1. First we specify the **model**: some raw data. We will start with a simple `String[]`, filling it with placeholder data:

```
String[] data = new String[99];
for(int i=99; i>0; i--){
    data[99-i] = i+ " bottles of beer on the wall";
}
```

While we could define this data as an XML resource, we'll create it dynamically for testing (and to make it changeable later!)

2. Next we specify the **view**: a `View` to show for each datum in the list. Define an XML layout resource for that (`list_item` is a good name and a common idiom).

For simplicity's sake we don't need to specify a full Layout, just a basic `TextView`. Have the width `match_parent` and the height `wrap_content`. *Don't forget an id!*

```
<TextView xmlns:android="http://schemas.android.com/apk/res/android"
    android:id="@+id/txtItem"
    android:layout_width="match_parent"
    android:layout_height="wrap_content" />
```

To make it look better, you can specify `android:minHeight="?android:attr/listPreferredItemHeight"` (using the framework's preferred height for lists), and some `center_vertical` gravity. The `android:lines` property is also useful if you need more space.

3. Finally, we specify the **controller**: the `ListView` itself. Add that item to the Activity's Layout resource (*practice*: what should its dimensions be?)

To finish the controller `ListView`, we need to provide it with an `Adapter`² which will connect the *model* to the *view*. The `Adapter` does the "translation" work between model and view, performing a mapping from data types (e.g., a `String`) and View types (e.g., a `TextView`).

Specifically, we will use an `ArrayAdapter`, which is one of the simplest `Adapters` to use (and because we have an array of data!) An `ArrayAdapter` creates Views by calling `.toString()` on each item in the array, and setting that `String` as the content of a `TextView`!

```
ArrayAdapter<String> adapter = new ArrayAdapter<String>(this,
    R.layout.list_item_layout, R.layout.list_item_txtView, myStringArray);
```

- Note the parameters of the constructor: a `Context`, the item layout resource, the `TextView` resource, and the data array. Also note that this instance utilizes *generics*, since we're using an array of `Strings` (as opposed to an array of `Dogs` or some other type).

We acquire a reference to the `ListView` with `findViewById()`, and call `ListView#setAdapter()` to attach the adapter to that controller.

```
ListView listView = (ListView)findViewById(R.id.listview);
listView.setAdapter(adapter);
```

And that's all that is needed to create a scrollable list of data!

Each item in this list is selectable (can have an `onClick` callback). This allows us to click on any item in order to (for example) view more details about the item.

²<https://developer.android.com/reference/android/widget/Adapter.html>

Utilize the `AdapterView#setOnItemClickListener(OnItemClickListener)` function to register the callback.

- The `position` parameter in the `onItemClick()` callback is the index of the item which was clicked. Use `(Type)parent.getItemAtPosition(position)` to access the data value associated with that View.

Additionally, each item does have an individual layout, so we can customize these appearances (e.g., if our layout also wanted to include pictures). See this tutorial for an example on making a custom adapter to fill in multiple Views with data from a list!

And remember, a `GridView` is basically the same thing (in fact, we can just change over that and have everything work, if we use *polymorphism!*)

4.3 Network Data

In the previous section we created a `ListView` utilizing an adapter to display a list of Strings. But Appendix C provides an implementation for fetching data from the Internet which gave us a list of Strings. Can we combine these? You betchya!

The lecture code provides a `MovieDownloader` class containing the exact same networking code utilized in the Appendix. We can then simply specify that the *model* `String[]` should be the result of the `downloadMovieData()` method, rather than manually created with a loop.

If you test this code, you'll notice that it doesn't work! The program will crash with a `NetworkOnMainThreadException`.

Android apps run by default on the *Main Thread* (also called the *UI Thread*). This thread is in charge of all user interactions—handling button presses, scrolls, drags, etc.—but also UI *output* like drawing and displaying text! See Android Threads for more details.

- A thread is a piece of a program that is independently scheduled by the processor. Computers do exactly one thing at a time, but make it look like they are doing lots of tasks simultaneously by switching between them (i.e., between processes) really fast. Threads are a way that we can break up a single application or process into little “sub-process” that can be run simultaneously—by switching back and forth periodically so everyone has a chance to work

Within a single thread, all method calls are **synchronous**—that is, one has to finish before the next occurs. You can't get to step 4 without finishing step 3. With an event-driven system like Android, each method call is fast enough that this isn't a problem (you're done handling one click by the time the next occurs). But long, drawn-out processes like network access (or processing bitmaps, or

accessing a database), could cause other tasks to have to wait. It's like a traffic jam!

- Tasks such as network access are **blocking** method calls, which stop the Thread from continuing. A blocked *Main Thread* will lead to the infamous “**Application not responding**” (ANR) error!

Thus we need to move the network code *off* the Main Thread, onto a **background thread**, thereby allowing it to run without blocking the user interaction that occurs on the Main Thread. To do this, we will use a class called `AsyncTask`³ to perform a task (such as network access) asynchronously—without waiting for other Threads.

Learning Android Development involves knowing about what classes exist, and can be used to solve problems, but how were we able to learn about the existing of this highly useful (and specialized) `AsyncTask` class? We started from the official API Guide on Processes and Threads Guide⁴, which introduces this class! Thus to learn about new Android options, *read the docs*.

Note that an `AsyncTask` background thread will be *tied to the lifecycle of the Activity*: if we close the Activity, the network connection will die as well. A better but *much* more complex solution would be to use a `Service`—which is covered in a future lecture. But since this example just involves getting a small amount of data, we don't really care if the network connection gets dropped.

`AsyncTask` can be fairly complicated, but is a good candidate to practice learning from the API documentation. Looking at that documentation, the first thing you should notice (or would if the API was a little more readable) is that `AsyncTask` is **abstract**, meaning you'll need to *subclass* it in order to use it. Thus you can subclass it as an *inner* class inside the Activity that will use it (`MovieDownloadTask` is a good name).

You should also notice that `AsyncTask` is a *generic* class with three (3) generic parameters: the type of the Parameter to the task, the type of the Progress measurement reported by the task, and the type of the task's Result. We can fill in what types of Parameter and Result we want from our asynchronous method (e.g., take in a `String` and return a `String[]`), and use the `Void` type for the Progress measurement (since we won't be tracking that).

When we “run” an `AsyncTask`, it will do four (4) things, represented by four methods:

1. `onPreExecute()` is called *on the UI thread* before we run the task. This method can be used to perform any setup for the task.
2. `doInBackground(Params...)` is called *on the background thread* to do the work we want to be performed asynchronously. We **must** override this method (it's **abstract**!) The params and return type for the method need to match the `AsyncTask` generic types.

³<https://developer.android.com/reference/android/os/AsyncTask.html>

⁴<https://developer.android.com/guide/components/processes-and-threads.html>

3. `onProgressUpdate()` can be indirectly called *on the UI thread* if we want to update our progress (e.g., update a progress bar). Note that UI changes can **only** be made on the UI thread!
4. `onPostExecute(Result)` is called *on the UI thread* to process any task results, which are passed as parameters to this method when `doInBackground` is finished.

The `doInBackground()` is what occurs on the background thread (and is the heart of the task), so we put our network accessing method call in there.

We can then *instantiate* a new `AsyncTask` object in the Activity's `onCreate()` callback, and call `AsyncTask#execute(params)` to start the task running on its own thread.

If you test this code, you'll notice that it still doesn't work! The program will crash with a `SecurityException`.

As a security feature, Android apps by default have very limited access to the overall operating system (e.g., to do anything other than show a layout). An app can't use the Internet (which might consume people's data plans!) without explicit permission from the user. This permission is given by the user at *install time*.

In order to get permission, the app needs to ask for it ("Mother may I..."). We do that by declaring that the app uses the Internet in the `Manifest.xml` file (which has all the details of our app!)

```
<uses-permission android:name="android.permission.INTERNET"/>
<!-- put this ABOVE the <application> tag -->
```

Note that Marshmallow introduced a new security model in which users grant permissions at *run-time*, not install time, and can revoke permissions whenever they want. To handle this, you need to add code to request "dangerous" permissions (like Location, Phone, or SMS access; Internet is *not* dangerous) each time you use it.

- For "normal" permissions (e.g., Internet), you declare the permission need in the Manifest.
- For "dangerous" permissions (e.g., Location), you declare the permission need in the Manifest **and** request permission programmatically in code each time you want to use it.

Once we've requested permission (and have been granted that permission by virtue of the user installing our application), we can finally connect to the Internet to download data. We can log out the request results to provide it.

In order to get the downloaded data into a `ListView`, we utilize the `doPostExecute()` method. This method is run on the *UI Thread* so we can use it to update the View (we can *only* change the View on the UI Thread, to avoid collisions). It also gets the results returned by `doInBackground()` passed to it!

We take that passed in `String[]` and put that into the `ListView`. Specifically, we feed it into the `Adapter`, which then works to populate the views.

- First clear out any previous data items in the adapter using `adapter.clear()`.
- Then use `adapter.add()` or `(adapter.addAll())` to add each of the new data items to the Adapter's model.
- You can call `notifyDataSetChanged()` on the Adapter to make sure that the View knows the data has changed, but this method is already called by the `.add()` method so isn't necessary in this situation.

To finalize the app: we can enable the user to search for different movies by copying the `EditText` and `Button` Views from the previous `input_layout` resource, accessing the text from the former when the later is pressed. We can then pass the `EditText` content `String` into the `AsyncTask#execute()` function (since we've declared that the generic `AsyncTask` takes that type as the first Parameter).

- We can actually pass in multiple `String` arguments using the `String... params` spread operator syntax (representing an arbitrary number of items of that type). See [here](#) for details. The value that the `AsyncTask` methods *actually* get is an array of the arguments.

In the end, we are able to download data from the Internet and show an interactive list of that data in the app! We've done a whirl-wind tour of Android in this process: Layouts in the XML, Adapters in the Activity, Threading in a new class, Security in the Manifest... bringing lots of parts together to provide a particular piece of functionality.

Chapter 5

Fragments

This lecture discusses Android **Fragments**. A Fragment is “a behavior or a *portion* of user interface in Activity.” You can think of them as “mini-activities” or “sub-activities”. Fragments are designed to be **reusable** and **composable**, so you can mix and match them within a single screen of a user interface. While XML resource provide reusable and composable *views*, Fragments provide reusable and composable *controllers*. Fragments allow us to make re-usable pieces of Activities that can have their own layouts, data models, event callbacks, etc.

This lecture references code found at <https://github.com/info448-s17/lecture05-fragments>. Note that this code builds upon the example developed in Lecture 4.

Fragments were introduced in API 11 (Honeycomb), which provided the first “tablet” version of Android. Fragments were designed to provide a UI component that would allow for side-by-side activity displays appropriate to larger screens.

Instead of needing to navigate between two related views (particularly for this “master and detail” setup), the user can see both views within the same Activity... but those “views” could also be easily split between two Activities for smaller screens, because their required *controller logic* has been isolated into a Fragment.

Fragments are intended to be **modular**, **reusable** components. They should **not** depend on the Activity they are inside, so that you can be flexible about when and where they are displayed!

Although Fragments are like “mini-Activities”, they are *always* embedded inside an Activity; they cannot exist independently. While it’s possible to have Fragments that are not visible or that don’t have a UI, they still are part of an Activity. Because of this, a Fragment’s lifecycle is directly tied to its containing

¹<https://developer.android.com/images/fundamentals/fragments.png>

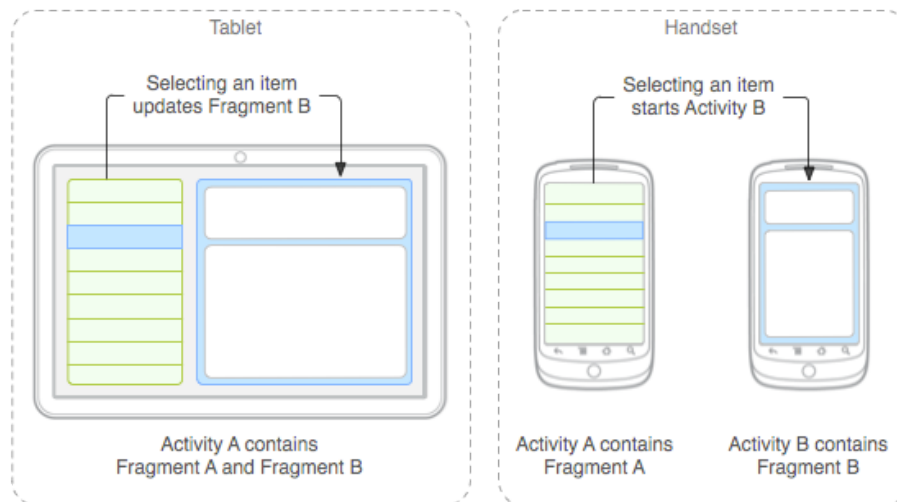


Figure 5.1: Fragment example, from Google¹

Activity's lifecycle. (e.g., if the Activity is paused, the Fragment is too. If the Activity is destroyed, the Fragment is too). However, Fragments also have their own lifecycle with corresponding lifecycle callbacks functions.

The Fragment lifecycle is very similar to the Activity lifecycle, with a couple of additional steps:

- **onAttach():** called when the Fragment is first associated with ("added to") an Activity, and thus gains a **Context**. This callback is generally used for initializing communication between the Fragment and its Activity.

This callback is mirrored by **onDetach()**, for when the Fragment is removed from an Activity.

- **onCreateView():** called when the View (the user interface) is about to be drawn. This callback is used to establish any details dependent on the View (including adding event listeners, etc).

Note that code initializing data models, or anything that needs to be *persisted* across configuration changes, should instead be done in the **onCreate()** callback. **onCreate()** is not called if the fragment is *retained* (see below).

This callback is mirrored by **onDestroyView()**, for when the Fragment's UI View hierarchy is being removed from the screen.

²https://developer.android.com/images/fragment_lifecycle.png

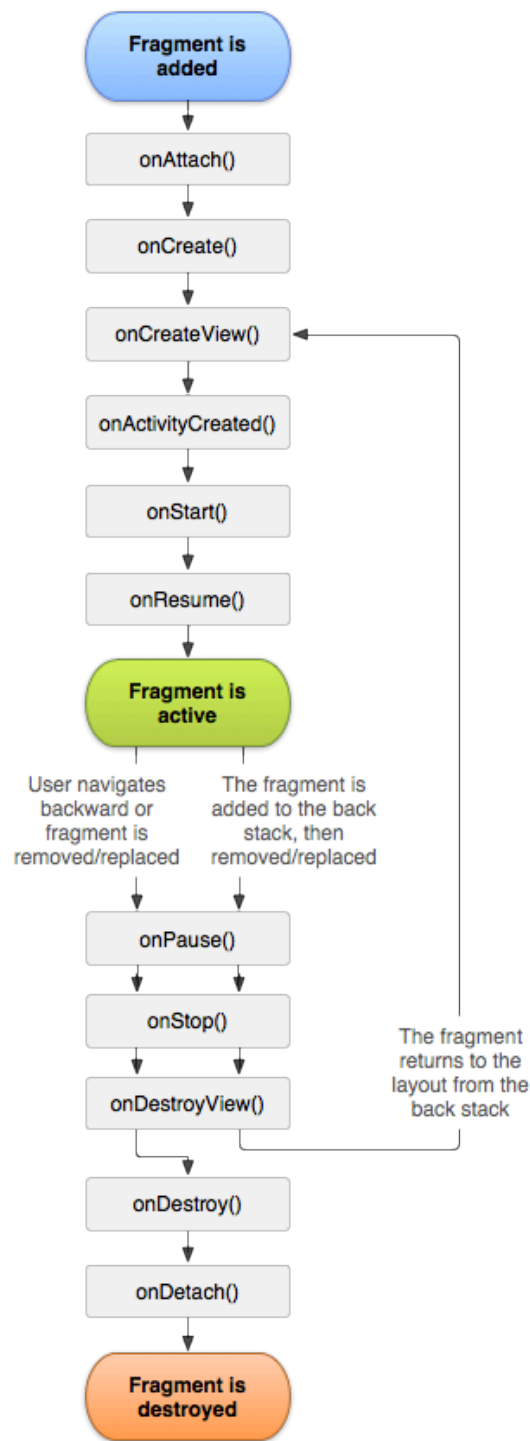


Figure 5.2: Fragment lifecycle state diagram, from Google²

- **onActivityCreated():** called when the *containing Activity's* `onCreate()` method has returned, and thus indicates that the Activity is fully created. This is useful for *retained* Fragments.

This callback has no mirror!

5.1 Creating a Fragment

In order to illustrate how to make a Fragment, we will **refactor** the `MainActivity` to use Fragments for displaying the list of movies. This will help to illustrate the relationship between Activities and Fragments.

To create a Fragment, you subclass the `Fragment` class. Let's make one called `MovieFragment` (in the `MovieFragment.java` file). You can use Android Studio to do this work: via the `File > New > Fragment > Fragment (blank)` menu option. (**DO NOT** select any of the other options for in the wizard for now; they provide template code that can distract from the core principles).

There are two versions of the `Fragment` class: one in the framework's `android.app` package and one in the `android.support.v4` package. The later package refers to the Support Library. These are libraries of classes designed to make Android applications *backwards compatible*: for example, `Fragment` and its related classes came out in API 11 so aren't in the `android.app` package for earlier devices. By including the support library, we can include those classes as well!

- Support libraries *also* include additional convenience and helper classes that are not part of the core Android package. These include interface elements (e.g., `ConstraintLayout`, `RecyclerView`, or `ViewPager`) and accessibility classes. See the features list for details. Thus it is often useful to include and utilize support library versions of classes so that you don't need to "roll your own" versions of these convenience classes.
- The main disadvantage to using support libraries is that they need to be included in your application, so will make the final `.apk` file larger (and may potentially require workarounds for method count limitations). You will also run into problems if you try and mix and match versions of the classes (e.g., from different versions of the support library). But as always, you should *avoid premature optimization*. Thus in this course you should **default** to using the support library version of a class when given a choice!

After we've created the `MovieFragment` Java file, we'll want to specify a layout for that Fragment (so it can be shown on the screen). As part of using the New Fragment Wizard we were provided with a `fragment_movie` layout that we can use.

- Since we want the Movie list to live in that Fragment, we can move (copy) the View definitions from `activity_main` into `fragment_movie`.

- We will then adjust `activity_main` so that it instead contains an empty `FrameLayout`. This will act as a simple “**container**” for our `Fragment` (similar to an empty `<div>` in HTML). *Be sure to give it an `id` so we can refer to it later!*

It is possible to include the `Fragment` directly through the XML, using the XML to instantiate the `Fragment` (the same way that we have the XML instantiate `Buttons`). We do this by specifying a `<fragment>` element, with a `android:name` attribute assigned a reference to the `Fragment` class:

```
<fragment
    android:id="@+id/frag_movie"
    android:name="edu.uw.fragmentdemo.MovieFragment"
    android:layout_width="match_parent"
    android:layout_height="match_parent"/>
```

Defining the `Fragment` in the XML works (and will be fine to start with), but in practice it is *much* more worthwhile to instantiate the `Fragment`s **dynamically** at runtime in the Java code—thereby allowing the `Fragment`s to be dynamically determined and changed. We will start with the XML version to build the `Fragment`, and then shift to the Java version.

We can next begin filling in the Java logic for the `Fragment`. Android Studio provides a little starter code: a constructor and the `onCreateView()` callback—the latter is more relevant since we will use that to set up the layout (similar to in the `onCreate()` function of `MainActivity`). But the `MainActivity#onCreate()` method specifies a layout by calling `setContentView()` and passing a resource id. With `Fragment`s, we can’t just “set” the `View` because the `Fragment` *belongs to* an `Activity`, and so will exist *inside* its `View` hierarchy! Instead, we need to figure out which `ViewGroup` the `Fragment` is inside of, and then **inflate** the `Fragment` inside that `View`.

This “inflated” `View` is referred to as the **root view**: it is the “root” of the `Fragment`’s `View` tree (the `View` that all the `Views` inside the `Fragment`’s layout will be attached to). We access the root view by *inflating* the `fragment`’s layout, and saving a reference to the inflated `View`:

```
View rootView = inflater.inflate(R.layout.fragment_layout, container, false);
```

- Note that the `inflater` object we are calling `inflate()` on is passed as a parameter to the `onCreateView()` callback. The parameters to the `inflate()` method are: the layout to inflate, the `ViewGroup` (`container`) into which the layout should be inflated (also passed as a parameter to the callback), and whether or not to “attach” the inflated layout to the container (`false` in this case because the `Fragment` system already handles the attachment, so the `inflate` method doesn’t need to). The `onCreateView()` callback must return the inflated *root view*, so that the system can perform this attachment.

With the `Fragment`’s layout defined, we can start moving functionality from the

Activity into the Fragment.

- The the background `AsyncTask` can be moved over directly, so that it belongs to the Fragment instead of the Activity.
- The `adapter` declaration will need to be moved as well.
- The UI setup (including initializing the Adapter) will be moved from the Activity's `onCreate()` to the Fragment's `onCreateView()`. However, you will need to make a few changes during this refactoring:
 - The `findViewById()` method is a method of the `Activity` class, and thus can't be called on an implicit `this` inside the Fragment. Instead, the method can be called on the **root view**, searching just that View and its children.
 - The Adapter's constructor requires a `Context` as its first parameter; while an `Activity` is a `Context`, a `Fragment` is not—Fragments operate in the Context of their containing Activity! Fragments can refer to the Activity that they are inside (and the `Context` it represents) by using the `getActivity()` method. Note that this method is used *primarily* for getting a reference to a `Context`, not for arbitrant communication with the Activity (see below for details)

5.1.1 Activity-to-Fragment Communication

The example code intentionally has left the *input controls* (the search field and button) in the Activity, rather than making them part of the Fragment. Apart from being a useful demonstration, this allows the Fragment to have a single purpose (showing the list of movies) and would let us change the search UI independent of the displayed results. But since the the button is in the Activity but the downloading functionality is in the Fragment, we need a way for the Activity to “talk” to the Fragment. We thus need a reference to the contained Fragment—access to the XML similar to that provided by `findViewById`.

We can get a reference to a contained Fragment from an Activity by using a `FragmentManager`. This is an object responsible for (ahem) managing Fragment. It allows us to “look up” Fragments, as well as to manipulate which Fragments are shown. We access this `FragmentManager` by calling the `getSupportFragmentManager()` method on the Activity, and then can use `findFragmentById()` to look up an XML-defined Fragment by its id:

```
//MovieFragment example
```

```
MovieFragment fragment = (MovieFragment)getSupportFragmentManager().findFragmentById
```

- Note that we're using a method to explicit access the **support** `FragmentManager`. The Activity class (API level 15+) is able to work with both the platform and support `FragmentManager` classes. But because these

classes don't have a shared `interface`, the Activity needs to provide different Java methods which can return the correct type.

Once you have a reference to the Fragment, this acts just like an other object—you can call any `public` methods it has! For example, if you give the Fragment a public method (e.g., `searchMovies()`), then this method can be called from the Activity:

```
//called from Activity on the referenced fragment  
fragment.searchMovies(searchTerm)
```

(The parameter to this public method allows the Activity to provide information to the Fragment!)

At this point, the program should be able to be executed... and continue to function in exactly the same way! The program has just been refactored, so that all the movie downloading and listing work is **encapsulated** inside a Fragment that can be used in different Activities.

- In effect, we've created our own “widget” that can be included in any other screen, such as if we always wanted the list of movies to be available alongside some other user interface components.

5.2 Dynamic Fragments

The real benefit from encapsulating behavior in a Fragment is to be able to support multiple Fragments within a single Activity. For example, in the archetypal “master/detail” navigation flow, one screen (Fragment) holds the “master” (list) and another screen (Fragment) holds details about a particular item. This is a very common navigation pattern for Android apps, and can be seen in most email or news apps.

- On large screens, Fragments allow these two screens to be placed side by side!

In this section, we will continue to refine the Movie app so that when the user clicks on a Movie in the list, the app shows a screen (Fragment) with details about the selected movie.

5.2.1 Instantiating Fragments

To do this, we will need to instantiate the Fragments dynamically (in Java code), rather than statically in the XML using the `<fragment>` element. This is because we need to be able to dynamically change which Fragment is currently being shown, which is not possible for Fragments that are “hard-coded” in the XML.

Unlike Activities, Fragments (such as `MovieFragment`) **do** have constructor methods that can be called—in fact, Android *requires* that every Fragment include a default (no-argument) constructor that is called when Fragments are created by the system. While we are able to call this constructor, it is considered best practice to **not** call this constructor directly when you want to instantiate a Fragment, and to in fact leave the method empty. This is because we do not have full control over when the constructor is executed: the Android system may call the no-argument constructor whenever it needs to recreate the Activity (or just the Fragment), which can happen at arbitrary times. Since only this default constructor is called, we can’t add an additional constructor with any arguments we may want the Fragment to have (e.g., the `searchTerm`)... and thus it’s best to not use it at all.

Instead, we specify a **simple factory** method (by convention called `newInstance()`) which is able to “create” an instance of the Fragment for us. This factory method can take as many arguments as we want, and then does the work of passing these arguments into the Fragment instantiated with the default constructor:

```
public static MyFragment newInstance(String argument) {  
    MyFragment fragment = new MyFragment(); //instantiate the Fragment  
    Bundle args = new Bundle(); //an (empty) Bundle for the arguments  
    args.putString(ARG_PARAM_KEY, argument); //add the argument to the Bundle  
    fragment.setArguments(args); //add the Bundle to the Fragment  
    return fragment; //return the Fragment  
}
```

In order to pass the arguments into the new Fragment, we wrap them up in a `Bundle` (an object containing basic *key-value pairs*). Values can be added to a `Bundle` using an appropriate `putType()` method; note that these do need to be primitive types (`int`, `String`, etc.). The `Bundle` of arguments can then be assignment to the Fragment by calling the `setArguments()` method.

- We will be able to access this `Bundle` from inside the Fragment (e.g., in the `onCreateView()` callback) by using the `getArguments()` method (and `getType()` to retrieve the values from it). This allows us to dynamically adjust the content of the Fragment’s Views! For example, we can run the `downloadMovieData()` function using this argument, fetching movie results as soon as the Fragment is created (e.g., on a button press).
- Since the `Bundle` is a set of *key-value* pairs, each value needs to have a particular key. These keys are usually defined as private constants (e.g., `ARG_PARAM_KEY` in the above example) to make storage and retrieval easier.

We will then be able to instantiate the Fragment (e.g., in the Activity class), passing it any arguments we wish:

```
MyFragment fragment = MyFragment.newInstance("My Argument");
```

5.2.2 Transactions

Once we’ve instantiated a `Fragment` in the Java, we need to attach it to the view hierarchy: since we’re no longer using the XML `<fragment>` element, we need some other way to load the `Fragment` into the `<FrameLayout>` container.

We do this loading using a **FragmentTransaction**³. A transaction represents a *change* in the `Fragment` that is being displayed. You can think of this like a bank (or database) transaction: they allow you to add or remove `Fragments` like we would add or remove money from a bank account. We instantiate new transactions representing the change we wish to make, and then “run” that transaction in order to apply the change.

To create a transaction, we utilize the `FragmentManager` again; the `FragmentManager#beginTransaction()` method is used to instantiate a **new** `FragmentTransaction`.

Transactions represent a set of `Fragment` changes that are all “applied” at the same time (similar to depositing and withdrawing money from multiple accounts all at once). We specify these transactions using by calling the `add()`, `remove()`, or `.replace()` methods on the `FragmentTransaction`.

- The `add()` method lets you specify which `View` **container** you want to add a particular `Fragment` to. The `remove()` method lets you remove a `Fragment` you have a reference to. The `replace()` method removes any `Fragments` in a container and then adds the specified `Fragment` instead.
- Each of these methods returns the modified `FragmentTransaction`, so they can be “chained” together.

Finally, we call the `commit()` method on the transaction in order to “submit” it and have all of the changes go into effect.

We can do this work in the `Activity`’s search click handler to add a `Fragment`, rather than specifying the `Fragment` in the XML:

```
FragmentTransaction transaction = getSupportFragmentManager().beginTransaction();
//params: container to add to, Fragment to add, (optional) tag
transaction.add(R.id.container, myFragment, MOVIE_LIST_FRAGMENT_TAG);
transaction.commit();
```

- The third argument for the `add()` method is a “tag” we apply to the `Fragment` being added. This gives it a name that we can use to find a reference to this `Fragment` later if we want (via `FragmentManager#findFragmentByTag(tag)`). Alternatively, we can save a reference

³<https://developer.android.com/reference/android/support/v4/app/FragmentTransaction.html>

to the Fragment as an instance variable; this is faster but more memory intensive (and can cause possible leaks, since the reference keeps the Fragment from being reclaimed by the system).

5.2.3 Inter-Fragment Communication

We can use this structure for instantiating and loading (via transactions) a **second Fragment** (e.g., a “detail” view for a selected Movie). We can add functionality (e.g., in the `onClick()` handler) so that when the user clicks on a movie in the list, we **replace()** the currently displayed Fragment with this new detailed Fragment.

However, remember that Fragments are supposed to be **modular**—each Fragment should be *self-contained*, and not know about any other Fragments that may exist (after all, what if we wanted the master/detail views to be side-by-side on a large screen?)

Using `getActivity()` to reference the Activity and `getSupportFragmentManager()` to access the manager is a violation of the Law of Demeter—don’t do it!

Instead, we have Fragments communicate by passing messages through their contained Activity: the `MovieFragment` should tell its Activity that a particular movie has been selected, and then that Activity can determine what to do about it (e.g., creating a `DetailFragment` to display that information).

The recommended way to provide Fragment-to-Activity communication is to define an **interface**. The Fragment class should specify an **interface** (for one or more public methods) that its containing Activity *must* support—and since the Fragment can only exist within an Activity that implements that interface, it knows the Activity has the specified public methods that it can call to pass information to that Activity.

As an example of this process:

- Create a new **interface** inside the Fragment (e.g., `OnMovieSelectedListener`). This interface needs a public method (e.g., `onMovieSelected(Movie movie)`) that the Fragment can call to give instructions or messages to the Activity.
- In the Fragment’s `onAttach()` callback (called when the Fragment is first associated with an Activity), we can check that the Activity actually implements the interface by trying to *cast* it to that interface. We can also save a reference to this Activity for later:

```
public void onAttach(Context context) {  
    super.onAttach(context);  
  
    try {
```

```

        callback = (OnMovieSelectedListener)context;
    } catch (ClassCastException e) {
        throw new ClassCastException(context.toString() + " must implement OnMovieSelected
    }
}

```

- Then when an action occurs in the Fragment (e.g., a movie is selected), you call the interface's method on the `callback` reference.
- Finally, you will need to make sure that the Activity implements this callback. Remember that a class can implement multiple interfaces!

In the Activity's implementation of the interface, you can handle the information provided. For example, use the `FragmentManager` to create a `replace()` transaction to load a new `DetailFragment` for the appropriate data.

In the end, this will allow you to have one Fragment cause the application to switch to another!

This is not the only way for Fragments to communicate. It is also possible to have a Fragment send an `Intent` to the Activity, who then responds to that as appropriate. But using the Intent system is more resource-intensive than using interfaces.

5.2.4 The Back Stack

But what happens when we hit the “back” button? The Activity exits! *Why?* Because “back” normally says to “leave the Activity”—we only had one Activity, just multiple fragments.

Recall that the Android system may have lots of Activities (even across multiple apps!) with the user moving back and forth between them. As described in lecture2, each new Activity is associated with a “task” and placed on a **stack**⁴. When the “back” button is pressed, that Activity is popped off the stack, and the user is taken to the Activity that is now at the top.

Fragments by default are not part of this “back-stack”, since they are just components of Activities. However, you *can* specify that a transaction should include the Fragment change as part of the stack navigation by calling `FragmentManager#addToBackStack()` as part of your transaction (e.g., right before you `commit()`):

```

getSupportFragmentManager().beginTransaction()
    .add(detailFragment, "detail")
    // Add this transaction to the back stack

```

⁴http://developer.android.com/images/fundamentals/diagram_backstack.png

```
.addToBackStack()  
.commit();
```

Note that the “back” button will cause *the entire transaction* to “reverse”. Thus if you performed a `remove()` then an `add()` (e.g., via a `replace()`), then hitting “back” will cause the the previously added Fragment to be removed *and* the previously removed Fragment to be added.

- `FragmentManager` also includes numerous methods for manually manipulating the back-stack (e.g., “popping” off transactions) if necessary.

Chapter 6

UI Components

This lecture discusses how to include **menus** and **pop-up dialogs** in an Android application as additional navigation and display components. Note that this lecture aims to provide *exposure* rather than *depth* to these concepts; for further details and options, see the official Android documentation.

This lecture references code found at <https://github.com/info448-s17/lecture06-menus-dialogs>.

6.1 The Action Bar

Let's start one of the most prominent visual components in the default app: the **App Bar** or **Action Bar**. This acts as the sort of “header” for your app, providing a dedicated space for navigation and interaction (e.g., through menus). The `ActionBar`¹ is a specific type of `Toolbar` that is most frequently used as the App Bar, offering a particular “look and feel” common to Android applications.

While the `AppCompatActivity` used throughout this course automatically provides an Action Bar for the app, it is also possible to add it directly (such as if you are using a different Activity subclass). To add your own Action Bar, you specify a **theme** that does *not* include an `ActionBar`, and then include an `<android.support.v7.window.Toolbar>` element inside your layout wherever you want the toolbar to go. See Setting up the App Bar for details. This will also allow you to put the `Toolbar` anywhere in the application's layout (e.g., if you want it to be stuck to the bottom).

- To see this in action, change the `android:theme` attribute of the `<application>` element in the `Manifest` to `"@style/Theme.AppCompat.Light.NoActionBar"`. We'll discuss this process in more detail when we talk about Themes and Styles.

¹<http://developer.android.com/reference/android/support/v7/app/ActionBar.html>

From in the Activity's Java code, we can get access to the Action Bar by calling the `getSupportActionBar()` method (for a support Toolbar). We can then call utility methods on this object to interact with it; for example `.hide()` will hide the toolbar!

6.2 Menus

However, the main use for the Action Bar is a place to hold *Menus*. A Menu (specifically, an **options menu**) is a set of items (think: buttons) that appear in the Action Bar. Menus can be specified both in the **Activity** and in a **Fragment**; if declared in both places, they are combined into a single menu in the Action Bar. This allows you to easily make “context-specific” options menus that are only available for an appropriate Fragment, while keeping Fragments modular and self-contained.

- *Fun fact:* before API 11, options menus appeared as buttons at the bottom of the screen!

Menus, like all other user-facing elements, are defined as XML resources, specifically of type **menu**. You can create a new menu resource through Android studio using **File > New > Android resource file** and then choosing the Menu Resource type. This will create an XML file with a main `<menu>` element.

Options can be added to the menu by specifying child XML elements, particularly `<item>` elements. Common `<item>` attributes include:

- **android:id**: a unique id used to refer to the specific option in the Java code
- **android:title** (**required** attribute): the text to display for the option. As user-facing text, the content should ideally be defined as an XML String resource.
- **app:showAsAction**: whether or not the option should be listed in the Action Bar, or collapsed under a “three-dots” button. Note when working with the **appcompat** library, this option uses the **app** namespace (instead of **android**); you will need to include this schema in the `<menu>` with the attribute `xmlns:app="http://schemas.android.com/apk/res-auto"`.
- **android:icon**: an image to use when showing the option as a button on the menu **//CHECK THIS**

You can use one of the many icons built into the Android, referenced as `"@android:drawable/ic_*`". Android Drawables² includes the full list, though not all drawables are publicly available through Android Studio.

- **android:orderInCategory**: used to order the item in the menu (or in a group). This acts as a “priority” (default 0; low comes first). Such

²<http://androiddrawables.com/>

prioritizing can be useful if you want to add suggestions about whether Fragment options should come before or after the Activity options.

See the Menu resources guide³ for the full list of options!

It is possible to include **one level** of sub-menus (a `<menu>` element inside an `<item>` element). Menu items can also be grouped together by placing them inside of a `<group>` element. All items in a group will be shown or hidden together, and can be further ordered within that group. Grouped icons can also be made checkable.

In order to show the menu in the running application, we need to tell the Action Bar which menu resource it should use (there may be a lot of resources). To do this, we override the `onCreateOptionsMenu()` callback in the Activity or Fragment, and then use the component's `MenuInflater` object to expand the menu:

```
public boolean onCreateOptionsMenu(Menu menu) {
    MenuInflater inflater = getMenuInflater();
    inflater.inflate(R.menu.main_menu, menu); //inflate into this menu
    return true;
}
```

- This procedure is similar in concept to how a Fragment's `onViewCreated()` method would inflate the Fragment into the Activity. In this case, the Menu is being inflated into the Action Bar.

We can respond to the menu items being selected by overriding the `onOptionsItemSelected()` callback. By convention, we use a `switch` on the `item.getItemId()` to determine what item was selected, and then act accordingly.

```
public boolean onOptionsItemSelected(MenuItem item) {
    switch(item.getItemId()){
        case R.id.menu_item1 :
            //do thing;
            return true;
        default:
            return super.onOptionsItemSelected(item);
    }
}
```

- On default (if the item selected isn't handled by any cases), we pass the callback up to `super` for "higher-level" components to check. For example, if a menu option isn't handled by the Fragment (because the Fragment didn't add it), the event can be passed up through the Framework for eventually handling by the Activity (who did add it).

³<https://developer.android.com/guide/topics/resources/menu-resource.html>

- This method should return `true` if the selection even has been handled (and thus should not be considered by anyone else). Return `false` if you want other components (e.g., other Fragments) to be able to respond to this option as well.

There are many other menu items that can be placed on Action Bar as well. We can also add Action Views that provide more complex interactions than just clicking buttons (for example, including a search bar). An Action Provider (like `ShareActionProvider`) is an action with its own customized layout, expanding into a separate View when clicked. We will discuss how to utilize these features in a future lecture.

6.2.1 Context Menus

In addition to options menus available in the Action Bar, we can also specify contextual menus that pop up when the user long-presses on an element. This works similarly to using an options menu, but with a different set of callbacks:

- When setting up the View layout (e.g., in an Activity's `onCreate()`), we specify that an element has a context menu using the `registerForContextMenu()` method, passing it the View we want to be able to create the menu for.
- Specify the context menu to use through the `onCreateContextMenu()` callback. This works exactly like setting up an options menu.
- In fact, a context menu can even use *the same menu* as an options menu! This reuse is one of the advantages of defining the user interface as XML.
- And mirroring the options menu, respond to context menu items being selected with the `onContextItemSelected()` callback.

This section has provided a very brief introduction to menus, but there are many more complex interactions that they support. I *highly* recommend that you read through the guide in order to learn what features may be available.

If you ever are using an app and wonder “how did they add this interface feature?”, look it up! There is almost always a documented procedure and example for providing that kind of component.

6.3 Dialogs

While it is simple enough to make menu items that log out some text, logs cannot be seen the user. Instead, we would like to show the message to the user as a kind of “pop-up” message.

A *Dialog*⁴ is a “pop-up” modal (a view which doesn’t fill the screen) that either asks the user to make a decision or provides some additional information. At its most basic, Dialogs are similar to the `window.alert()` function used in JavaScript.

There is a base `Dialog` class, but almost always we use a pre-defined subclass instead (similar to how we’ve use `AppCompatActivity`). `AlertDialog`⁵ is the most common version: a simple message with buttons you can respond with (confirm, cancel, etc).

We don’t actually instantiate an `AlertDialog` directly (in fact, its constructors are *protected* so inaccessible to us). Instead we use a helper *factory* class called an `AlertDialog.Builder`. There are a number of steps to use a builder to create a Dialog:

1. Instantiate a new builder for this particular dialog. The constructor takes in a `Context` under which to create the Dialog. Note that once the builder is initialized, you can create and recreate the same dialog with a single method call—that’s the benefits of using a factory.
2. Call “setter” methods on the builder in order to specify the title, message, etc. for the dialog that will appear. This can be hard-coded text or a reference to an XML String resource (as a user-facing String, the later is more appropriate for published applications). Each setter method will return a reference to the builder, making it easy to chain them.
3. Use appropriate setter methods to specify callbacks (via a `DialogInterface.OnClickListener`) for individual buttons. Note that the “positive” button normally has the text “OK”, but this can be customized.
4. Finally, actually instantiate the `AlertDialog` with the `builder.create()` method, using the `show()` method to make the dialog appear on the screen!

```
AlertDialog.Builder builder = new AlertDialog.Builder(this);
builder.setTitle("Alert!")
    .setMessage("Danger Will Robinson!");
builder.setPositiveButton("I see it!", new DialogInterface.OnClickListener() {
    public void onClick(DialogInterface dialog, int id) {
        // User clicked OK button
    }
});

AlertDialog dialog = builder.create();
dialog.show();
```

An important part of learning to develop Android applications is being able to read the API to discover effective options. For example, can you read the `AlertDialog.Builder` API and determine how to add a “cancel” button to the

⁴<https://developer.android.com/guide/topics/ui/dialogs.html>

⁵<https://developer.android.com/reference/android/support/v7/app/AlertDialog.html>

alert?

While `AlertDialog` is the most common `Dialog`, Android supports other subclasses as well. For example, `DatePickerDialog` and `TimePickerDialog` provide pre-defined user interfaces for picking a date or a time respectively. See the [Pickers](#) guide for details about how to utilize these.

6.3.1 DialogFragments

The process described above will create and show a `Dialog`, but that dialog has a few problems in how it interacts with the rest of the Android framework—namely with the lifecycle of the `Activity` in which it is embedded.

For example, if the device changes configurations (e.g., is rotated from portrait to landscape) then the `Activity` is destroyed and re-created (it's `onCreate()` method will be called again). But if this happens while a `Dialog` is being shown, then a `android.view.WindowLeaked` error will be displayed and the `Dialog` is lost!

To avoid these problems, we need to have a way of giving that `Dialog` its own lifecycle which can interact with the `Activity`'s lifecycle... sort of like making it a *modular* piece of an `Activity`... that's right, we need to make it a `Fragment`! Specifically, we will use a subclass of `Fragment` called `DialogFragment`, which is a `Fragment` that displays as a modal dialog floating above the `Activity` (no extra work needed).

Just like with the `Fragment` examples from the previous lecture, we'll need to create our own subclass of `DialogFragment`. It's often easiest to make this a *nested class* if the `Dialog` won't be doing a lot of work (e.g., shows a simple confirmation).

Rather than specifying a `Fragment` layout through `onCreateView()`, we can instead override the `onCreateDialog()` callback to specify a `Dialog` object that will provide the view hierarchy for the `Fragment`. This `Dialog` can be created with the `AlertDialog.Builder` class as before!

```
public static class MyDialogFragment extends DialogFragment {

    public static HelloDialogFragment newInstance() {
        Bundle args = new Bundle();
        HelloDialogFragment fragment = new HelloDialogFragment();
        fragment.setArguments(args);
        return fragment;
    }

    public Dialog onCreateDialog(Bundle savedInstanceState) {
        AlertDialog.Builder builder = new AlertDialog.Builder(getActivity());
        //...
```

```

        AlertDialog dialog = builder.create();
        return dialog;
    }
}

```

Finally, we can actually show this `DialogFragment` by instantiating it (remember to use a `newInstance()` factory method!) and then calling the `show()` method on it to make it show as a Dialog. The `show()` method takes in a `FragmentManager` used to manage this transaction. By using a `DialogFragment`, it is possible to change the device configuration (rotate the phone) and the Dialog is retained.

Here's the other neat trick: a `DialogFragment` is just a `Fragment`. That means we can use it *anywhere* we normally used Fragments... including embedding them into layouts! For example if you made the `MoviesFragment` subclass `DialogFragment` instead of `Fragment`, it would be able to be used in the exact same as before. It's still a `Fragment`, just with extra features—one of which is a `show()` method that will show it as a Dialog!

- Use `setStyle(DialogFragment.STYLE_NO_TITLE, android.R.style.Theme_Holo_Light_Dialog)` to make the Fragment look a little more like a dialog.

The truth is that Dialogs are not very commonly used in Android (compare to other GU systems). Apps are more likely to just dynamically change the Fragment or Activity being shown, rather than interrupt the user flow by creating a pop-up modal. And 80% of the Dialogs that *are* used are `AlertDialogs`. Nevertheless, it is worth being familiar with this process and the patterns it draws upon!

6.4 Toasts

Dialogs are a powerful way of providing messages and information to users, but they are pretty “heavy” in terms of both their interaction (they stop all other interaction to show the user a message) and the effort required to implement them. Sometimes you just want a “pop-up” message that isn't quite as prominent and doesn't require the user to click “okay” once they've seen it.

A simple, quick way of giving some short visual feedback is to use what is called a **Toast**. This is a tiny little text box that pops up at the bottom of the screen for a moment to quickly display a message.

- It's called a “Toast” because it pops up!

Toasts are pretty simple to implement, as with the following example (from the official documentation):

```

Context context = this; //getApplicationContext(); //use application context to avoid disappea
String text = "Hello toast!";

```

```
int duration = Toast.LENGTH_SHORT;

//use factory method instead of constructor
Toast toast = Toast.makeText(context, text, duration);
toast.show();
```

But since this Activity *is* a Context, and we can just use the Toast anonymously, we can shorten this to a one-liner:

```
Toast.makeText(this, "Hello toast!", Toast.LENGTH_SHORT).show();
```

Boom, a quick visual alert method we can use for proof-of-concept stuff!

Toasts are intended to be a way to provide information to the user (e.g., giving them quick feedback), but they can possibly be useful for testing too (though in the end, Logcat is going to be your best bet for debugging, especially when trying to solve crashes or see more complex output).

Chapter 7

Providers and Loaders

This lecture discusses how to access data from a **Content Provider** using a **Loader**. A *Content Provider* is an abstraction of a data base or other data store, allowing us easily systematically work with that data in Java (rather than in a separate data manipulation language such as SQL). A *Loader* is then used to efficiently perform this data access in the background (off the UI Thread), while also easily connecting that data to Views.

This lecture references code found at <https://github.com/info448-s17/lecture07-loaders>.

7.1 Content Providers

Consider the `WordListFragment` utilized by the example code (though these concepts apply to any `Fragment` or `Activity`). This `Fragment` includes a `ListView` that shows a list of words. Recall that a `ListView` utilizes the **model-view-controller** architecture... and in this case, the “model” (data) is a hard-coded list of array of words. But there are other lists of words as well! Entire databases of words! Previous lectures have discussed how to use *network requests* to access online data APIs, but there are also databases (of words no less) built into your Android phone.

For example, Android keeps track of the list of the spellings of “non-standard” words in what is called the **User Dictionary**. You can view this list on the device at `Settings > Language & Input > Personal Dictionary`. You can even use this Settings interface to add new words to the dictionary (e.g., “em-biggen”, “cromulent”, “fleeek”).

Note that the User Dictionary keeps track of a **database** of words. You can think of this database as being like a single SQL table: it’s a set of *entries*

(rows) each of which have some *values* (columns). The primary key of the table is named (by convention) **ID**.

While you don't need to know SQL to utilize a built-in database like the User Dictionary, it helps to have a passing familiarity with relational databases (e.g., what is taught in the iSchool's INFO 340 course).

Since this data is stored in a (essentially) a simple SQL table, it is possible for us to access and modify it programmatically; moreover, the Android framework allows us to do this without needing to know or write SQL! For example, we can access this list of words in order to show them in the WordFragment's ListView.

- To do this, we'll need to request permission to access the database, just as we asked permission to access the Internet. Include the following in the *Manifest*:

```
<uses-permission android:name="android.permission.READ_USER_DICTIONARY">
```

Although the words are stored in a database, we don't know the *exact* format of this database (e.g., exact table or column names, or even whether it is an SQL database or just a `.csv` file!). We want to avoid having to write code that only works with a specific format, especially as the words may be stored in different kinds of databases on different devices or across different versions of Android. (The Android framework does include support for working directly with a local SQLite database, but it is a lot more work, requires knowing SQL, and produces a more fragile application).

In order to avoid relying on the specific format of how some data is stored, Android offers an *abstraction* in the form of a **Content Provider**. A Content Provider offers an interface to interact with structured data, whether that data is stored in a database, in a file, in *multiple* files, online, or somewhere else. You can thus think of “a Content Provider” as meaning “a data source” (e.g., the source/provider of content)!

- It is possible to create your own Content Providers (described in a later lecture), but this lecture focuses purely on *utilizing* existing Providers.

All Content Providers (data sources) have a **URI** (Universal Resource Identifier, a generalization of a URL used for resources not necessarily on the Internet). It is possible to *query* this URI, similar in concept to how web APIs are accessed via queries to their URI endpoints. In particular, Content Provider URIs utilize the **content://** protocol (instead of **https://**), since their data is accessed as via “content requests” rather than “HTTP requests”.

The URI for the Dictionary's content is defined by the constant `UserDictionary.Words.CONTENT_URI`. We utilize constants to refer to URIs and paths to make it easier to refer to them and to generalize across devices that may have different directory structures.

We are able to access this Content Provider via a `ContentResolver`. This class

provides methods for accessing the data in a provider (represented as a `ContentProvider` object). Each Context has a singleton `ContentResolver`, which is accessed via the `getContentResolver()` method (note that for a Fragment, the Context is the containing Activity). The `ContentResolver`'s methods support the basic CRUD operations: `insert()`, `query()`, `update()`, and `delete()`.

`ContentResolver` methods take multiple parameters, supporting the different options available in a generic SQL query. For example, consider the `query()` method:

```
getContentResolver().query(
    uri,                // The content URI
    projection,         // The an array of columns to return for each row
    selectionClause     // Selection criteria (as an SQL WHERE clause)
    selectionArgs,      // An array of values that can be injected into the selection clause
    sortOrder);        // The sort order for the returned rows (as an SQL ORDER BY clause)
```

- This is basically a wrapper around an SQL `SELECT` statement!

The **projection** is a `String[]` of all the “columns” (attributes) we want to fetch from the data source. This is what you’d put after `SELECT` in SQL. (Note we can pass in `null` to represent `SELECT *`, but that’s inefficient—better to give a list of everything).

- We can see what column names are available for the User Dictionary in `UserDictionary.Words`. Again, these are defined as constants!
- Be sure to always select the `_ID` primary key: it will be needed later!

The other parameters can be used to customize the `SELECT` statement. The “selection” (`WHERE`) clause needs to parameters: the second are values that will be escaped against SQL injection attacks. Passing `null` for any of these parameters will cause the clause to be ignored:

```
ContentResolver resolver = getActivity().getContentResolver();
String[] projection = new String[] { UserDictionary.Words.WORD, UserDictionary.Words._ID };
resolver.query(UserDictionary.Words.CONTENT_URI, projection, null, null, null);
```

So overall, the query is breaking apart the components SQL `SELECT` statement into different pieces as parameters to a method, so you don’t *quite* have to write the selection yourself. Moreover, this method *abstracts* the specific query language, allowing the same queries to be used on different formats of database (SQLite, PostgreSQL, files, etc).

7.2 Cursors

The `ContentResolver#query()` method returns a **Cursor**. A `Cursor` provides an interface to the list of records in a database (e.g., those returned by the query). A `Cursor` also behaves like an `Iterator` in Java: it keeps track of

which record is currently being accessed (e.g., what the `i` would be in a for loop). You can think of it as a “pointer” to a particular record, like the cursor on a screen.

We call methods on the `Cursor` to specify which record we want it to “point” to, as well as to fetch values from the record object at that spot in the list. For example:

```
cursor.moveToFirst(); //move to the first item
String field0 = cursor.getString(0); //get the first field (column you specified) as
String name = cursor.getString(cursor.getColumnIndexOrThrow("word")); //get the "word"
cursor.moveToNext(); //go to the next item
```

The nice thing about `Cursors` though is that they can easily be fed into `AdapterViews` by using a `CursorAdapter` (as opposed to the `ArrayAdapter` we’ve used previously). The **`SimpleCursorAdapter`** is a concrete implementation that is almost as easy to use as an `ArrayAdapter`:

You instantiate a new `SimpleCursorAdapter`, passing it:

1. A `Context` for loading resources
2. A layout resource to inflate for each record
3. A `Cursor` (which can be null)
4. An array of column names to fetch from each entry in the `Cursor` (the **projection**, similar to before)
5. A matching list of View resource `ids` (which should all be `TextViews`) to assign each column’s value to. This is the “mapping” that the Adapter will perform (from projection columns to `TextView` contents).
6. Any additional option flags (0 means no flags, and is the correct option for us).

Then we can use this adapter for the `ListView` in place of the `ArrayAdapter`!

7.3 Loaders

In order to get the `Cursor` to pass into the adapter, we need to `.query()` the database. But we’ll be doing this a lot, and so would like to do it off the UI Thread—database accessing is slow! And every time we do that query (or any other database manipulation), we want to update the `Adapter` so that the changes to the list show up.

In order to easily update your list with new data loaded on a background thread, we’re going to use a class called a **Loader**. This is basically a wrapper around `AsyncTask`, but one that lets you execute a background task repeatedly *whenever the data source changes*. In particular, Android provides a **`CursorLoader`** specifically used to load data from `ContentProviders` through `Cursors`—whenever the content changes, a new `Cursor` is produced which can be “swapped” into the adapter.

To use a `CursorLoader`, we need to specify that our *Fragment* implements the `LoaderManager.LoaderCallback<Cursor>` interface—basically saying that this fragment can react to Loader events.

- Loaders need to work with Fragments, unless the Activity subclasses `FragmentActivity` (as `AppCompatActivity` does) and thereby provides the “Fragment” capabilities needed to use a `Loader`. So we can use Loaders in *our* Activities or Fragments.

We will need to fill in the interfaces callbacks functions in order to use the `CursorLoader`:

- In `onCreateLoader()` we specify what the Loader should *do*. Here we would instantiate and return a new `CursorLoader(...)` that queries the `ContentProvider`. This looks a lot like the `.query()` method we wrote earlier, but will run on a background thread!
- In the `onLoadFinished()` callback, we can `swap()` the `Cursor` into our `SimpleCursorAdapter` in order to feed that model data into our controller (for display in the view). See the guide for more details.
- In the `onLoaderReset()` callback just swap in `null` for our `Cursor`, since there now is no content to show (the loaded data has been “reset”).

Finally, in order to actually *start* our background activity, we’ll use the `getLoaderManager().initLoader(...)` method. This is similar in flavor to the `AsyncTask.execute()` method we’ve used before (using a manager similar to the `FragmentManager`).

```
getLoaderManager().initLoader(0, null, this);
```

The first parameter to the `initLoader()` method is an id number for *which cursor you want to load*, and is passed in as the first param to `onCreateLoader()` (or is accessible via `Loader#getId()`). This allows you to have multiple Loaders using the same callback function (e.g., a Fragment can handle multiple Loaders for multiple data sources). The second param is a `Bundle` of args, and the third is the `LoaderCallbacks` (e.g., who handles the results)!

- Note that you can use the `.restartLoader()` method to “recreate” the `CursorLoader` (without losing other references), such as if you want to change the arguments passed to it.

And with that, we can fetch the words from our database on a background thread—and if we update the words it will automatically change!

7.4 Other Provider Actions

7.4.1 Adding Words

To *insert* a new Word into the ContentProvider, we just call a different method on the ContentResolver:

```
//Example from Google:
ContentValues mNewValues = new ContentValues();
mNewValues.put(UserDictionary.Words.APP_ID, "edu.uw.loaderdemo");
mNewValues.put(UserDictionary.Words.LOCALE, "en_US");
mNewValues.put(UserDictionary.Words.WORD, word);
mNewValues.put(UserDictionary.Words.FREQUENCY, "100");

Uri mNewUri = getContentResolver().insert(
    UserDictionary.Words.CONTENT_URI,    // the user dictionary content URI
    mNewValues                          // the values to insert
);
```

- Note that we specify the “details” of the Word in a ContentValues object, which is a HashMap almost exactly like a Bundle (but only supports values that work with ContentProviders)

Chapter 8

Intents

This lecture discusses how to use **Intents** to communicate between different Activities and Applications. The Intent system allows Activities to communicate, even though they don't have references to each other (and thus we can't just call a method on them).

This lecture references code found at <https://github.com/info448-s17/lecture08-intents>. Note that you will need to have a working camera on your device. To enable the camera in the emulator, use the **Tools > Android > AVD** menu to modify the emulator, and select “webcam” for the front camera option. Confirm that it is enabled by launching the Camera app.

An Intent is a **message** that is sent between app components, allowing them to communicate!

- Most object communication we do is via *direct method call*; you have a reference to an Object and then you call a method on it. We've also seen *event callbacks*, where on an event one of our callbacks gets executed by the system (really just a wrapper around *direct method call* via the Observer pattern)
- Intents step outside of this a little bit: they allow us to create objects that can be “given” to another component (read: Activity), who can then respond upon receiving that. Similar to an event callback, but working at a slightly higher system level.

You can think of Intents as like letters you'd send through the mail: they are addressed to a particular target (e.g., another Activity—more properly a **Context**), and have room for some data called **extras** to go inside (held in a **Bundle**). When the envelope arrives, the recipient can get that data out and do something with it... and possibly sending a response back.

Note that there are couple of different kinds of Intents; we'll go through examples of each.

8.1 Intents for Another Activity (Explicit)

The most basic kind of Intent is an Intent sent to a specific Activity/Context, such as for telling that Activity to open.

An Intent¹ is an object we *can* instantiate: for example, we can create a new Intent in the event handler for when we click the button on MainActivity. The Intent class has a number of different constructors, but the one we'll start with looks like:

```
//           context,           target
Intent intent = new Intent(MainActivity.this, SecondActivity.class);
```

- The first parameter refers to the current **Context** in which the message should be delivered. The second parameter to this constructor is the *class* we want to send the Intent to (the `.class` property fetches a reference to the class type; this is metaprogramming!). Effectively, it is the “address” on the envelop for the message we’re sending.
 - We’re using `MainActivity.this` as the context, because the `this` would refer to the anonymous listener class (for methods in `Main`, we can just use `this`).

After having instantiated the new Intent, we can use that message to start an Activity by calling the `startActivity()` method (inherited from Activity), passing it the Intent:

```
startActivity(intent);
```

This method will “send” the message to the operating system, which will deliver the Intent to the appropriate Activity, telling that Activity to start as soon as it receives the message.

- And we can use the **back** button to go backwards! See the Activities lecture for details.

This is called an **Explicit Intent** because we’re *explicit* about what target we want to receive it. It’s a letter to a specific Activity.

8.1.1 Extras

We can also specify some extra data inside our envelope. These data are referred to as **Extras**. This is a **Bundle** (so a set of primitive key-value pairs) that we can use to pass *limited* information around!

```
intent.putExtra("package.name.key", "value");
```

¹<http://developer.android.com/reference/android/content/Intent.html>

- Docs say that best practice is to include the full package name on keys, so avoid any collisions or misreading of data. There are also some pre-defined values (constants) that you can use in the `Intent` class.

We can then get the extras from the `Intent` in the `Activity` that receives it:

```
//in onCreate();
Bundle extras = getIntent().getExtras(); //All activities are started with an Intent!
String value = extras.getString("key");
```

So we can have `Activities` communicate, and even share information between them! Yay!

8.2 Intents for Another App (Implicit)

We can send `Intents` to our own `Activities`, but we can even address them to other Apps. When calling on other apps, we usually use **Implicit Intents**.

- This is a little bit like letters that have weird addresses², but still get delivered. “For that guy at the end of the block with the red mailbox.”

An `Implicit Intent` includes an **Action** and some **Data**. The **Action** says what the target should *do* upon receiving the intent (a `Command`), and the **Data** gives more detail about what to run that action on.

- **Actions** can be things like `ACTION_VIEW` to view some data, or `ACTION_PICK` to choose an item from a list. See a full list under “Standard Action Activities”.
- `ACTION_MAIN` is the most common (just start the `Activity` as if it were a “main” launching point). So when we don’t specify anything else, this is used!
- **Data** gives detail about what to do with the action (e.g., the `Uri` to `VIEW` or the `Contact` to `DIAL`).
- Extras then support this data!

For example, if we specify a `DIAL` action, then we’re saying that we want our `Intent` to be delivered to an App that is capable of dialing a telephone number. - *If there is more than one app that supports this action, the user will pick one!* This is key: we’re not saying exactly what app to use, just what kind of functionality we need to be supported! It’s a kind of abstraction!

```
Intent intent = new Intent(Intent.ACTION_DIAL);
intent.setData(Uri.parse("tel:206-685-1622"));
if (intent.resolveActivity(getPackageManager()) != null) {
```

²<http://www.theguardian.com/world/2015/jul/18/postman-turns-detective-to-deliver-letter-with-cryptic-address-in-ireland>

```
startActivity(intent);  
}
```

Here we’ve specified the *Action* (`ACTION_DIAL`) for our Intent, as well as some *Data* (a phone number, converted into a Uri). The `resolveActivity()` method looks up what Activity is going to receive our action—we check that it’s not null before trying to start it up.

- This should allow us to “dial out” !

Note that we can open up all sorts of apps. See Common Intents³ for a list of common implicit events (with examples!).

8.3 Intents for a Response

We’ve been using intents to start Activities, but what if we’d like to get a result *back* from the Activity? That is, what if we want to look up a Contact or take a Picture, and then be able to use the Contact or show the Picture?

To do this, we’re going to create Intents in the same way, but use a different method to launch them: `startActivityForResult()`. This will launch the resolved Activity. But once that Action is finished, the launched Activity will send *another* Intent back to us, which we can then react to in order to handle the result.

- This is a bit like including an “RSVP” note in a letter!

For fun, let’s do it with the Camera—we’ll launch the Camera to take a picture, and then get the picture and show it in an `ImageView` we have.

- Note that your Emulator will need to have Camera emulation on!
- See Taking Photos Simply for walkthrough.

In the activity, we can specify an intent that uses the `MediaStore.ACTION_IMAGE_CAPTURE` action (the action for “take a still picture and return it”).

- The “request code” is used to distinguish this intent from others we may send (kind of like a “tag”).
- Note that we could pass an Extra for where we want to save the large picture file to. However, we’re going to leave that off and just work with the thumbnail for this demonstration. See the guide⁴ for details; if time we can walk through it!

```
static final int REQUEST_IMAGE_CAPTURE = 1;  
  
private void dispatchTakePictureIntent() {
```

³<http://developer.android.com/guide/components/intents-common.html>

⁴<http://developer.android.com/training/camera/photobasics.html#TaskPath>

```
Intent takePictureIntent = new Intent(MediaStore.ACTION_IMAGE_CAPTURE);  
if (takePictureIntent.resolveActivity(getPackageManager()) != null) {  
    startActivityForResult(takePictureIntent, REQUEST_IMAGE_CAPTURE);  
}  
}
```

In order to handle the “response” Intent, we need to provide a callback that will get executed when that Intent arrives. Called `onActivityResult()`.

- We can get information about the Intent we’re receiving from the params. And we can get access to the returned data (e.g., the image) by getting the “data” field from the extras.
- Note that this is a `Bitmap`, which is the Android class representing a raster image. We’ll play with Bitmaps more in a couple weeks, because I like graphics.

```
@Override  
protected void onActivityResult(int requestCode, int resultCode, Intent data) {  
    if (requestCode == REQUEST_IMAGE_CAPTURE && resultCode == RESULT_OK) {  
        Bundle extras = data.getExtras();  
        Bitmap imageBitmap = (Bitmap) extras.get("data");  
        mImageView.setImageBitmap(imageBitmap);  
    }  
}
```

8.4 Listening for Intents

We’re able to send implicit Intents that can be heard by other Apps, but what if we wanted to receive implicit Intents ourselves? What if *we* want to be able to handle phone dialing?!

In order to receive an implicit Intent, we need to declare that our Activity is able to handle that request. Since we’re specifying an aspect of our application, we’ll do this in the `Manifest` using what is called an `<intent-filter>`.

- The idea is that we’re “hearing” all the intents, and we’re “filtering” for the ones that are relevant to us. Like sorting out the junk mail.

An `<intent-filter>` tag is nested inside the element that it applies to (e.g., the `<activity>`). In fact, you can see there is already one there: that responds to the `MAIN` action sent with the `LAUNCHER` category (meaning that it responds to intents from the app launcher).

Similarly, we can specify three “parts” of the filter:

- a `<action android:name="action">` filter, which describes the Action we can respond to.

- a `<data ...>` filter, which specifies aspects of the data we accept (e.g., only respond to Uri's that look like telephone numbers)
- a `<category android:name="category">` filter, which is basically a “more information” piece. You can see the “Standard Categories” in the documentation.
- Note that you *must* include the `DEFAULT` category to receive implicit intents. This is the category used by `startActivity()` and `startActivityForResult`.

Note that you can include multiple actions, data, and category tags. You just need to make sure that you can handle all possible combinations selected from each type (they are “or” not “and” filters!)

Responding to that dial command:

```
<activity android:name="SecondActivity">
  <intent-filter>
    <action android:name="android.intent.action.DIAL"/>
    <category android:name="android.intent.category.DEFAULT" />
    <data android:scheme="tel" />
  </intent-filter>
</activity>
```

You can see many more examples in the `Intent` documentation.

8.5 Broadcasts and Receivers

There is one other kind of Intent I want to talk about: **Broadcasts**. A broadcast is a message that *any* app can receive. Unlike Explicit and Implicit Intents, broadcasts are heard by the entire system—anything you “shout” with a broadcast is publicly available (security concerns!)

- Mass mailings question mark?

Other than who receives them, broadcasts work the same as normal implicit intents! We create an `Intent` with an Action and Data (and Category and Extras...). But instead of using the `startActivity()` method, we use the `sendBroadcast()` method. That intent can now be heard by all `Activities` on the phone,

- We'll skip a demo for time and motivation... we'll generate broadcasts later in the course.

But more common than sending broadcasts will be *receiving* broadcasts; that is, we want to listen and respond to System broadcasts that are produced (things like power events, wifi status, etc). Or more germane to this week's homework—to incoming text messages!!

We can receive broadcasts by using a `BroadcastReceiver`. This is a base class that is used by an class that can receive broadcast Intents. We **subclass** it and implement the `onReceive(Context, Intent)` callback in order to handle when broadcasts are received.

```
public void onReceive(Context context, Intent intent)
{
    Log.v("TAG", "received! "+intent.toString());
    else if(intent.getAction() == Intent.ACTION_BATTERY_LOW){
        Toast.makeText(context, "Battery is low!", Toast.LENGTH_SHORT).show();
    }
}
```

But in order to **register** our receiver (so that intents go past its desk), we also need to specify it in the Manifest. We do this by including a `<receiver>` attribute inside our `<application>`. Note that this is *not* an Activity, but a separate component! We can put an `<intent-filter>` inside of this to filter for broadcasts we care about.

```
<receiver android:name=".MyReceiver">
    <intent-filter>
        <action android:name="android.intent.action.ACTION_POWER_CONNECTED" />
        <action android:name="android.intent.action.ACTION_POWER_DISCONNECTED" />
        <action android:name="android.intent.action.BATTERY_CHANGED" />
        <action android:name="android.intent.action.BATTERY_OKAY" />
        <!-- no category because not for an activity! -->
    </intent-filter>
</receiver>
```

We can test these power events easily using the latest version of the emulator. In the “extra options” button (the three dots at the bottom) in the emulator’s toolbar, we can get to the **Battery** tab where we can effectively change the battery status of the device (which our app can respond to!)

- Note that there is a Phone tab where you can send Text Messages to the emulator... you’ll need this for your homework this week.

We can also *register* these receivers in code (rather than in the manifest). This is good for if we only want to temporarily listen for some kind of events, or if we want to determine the `intent-filter` on the fly.

```
IntentFilter batteryFilter = new IntentFilter();
batteryFilter.addAction(Intent.ACTION_BATTERY_LOW);
batteryFilter.addAction(Intent.ACTION_BATTERY_OKAY);
batteryFilter.addAction(Intent.ACTION_POWER_CONNECTED);
batteryFilter.addAction(Intent.ACTION_POWER_DISCONNECTED);
this.registerReceiver(new MyReceiver(), batteryFilter);
```

- We’re dynamically declaring an intent-filter as well! This can be used not

just for `BroadcastReceivers`, but `Activities` too.

8.6 An Example: SMS

One specific use of `Intents` is when working with text messages (SMS, Short Messaging Service, the most popular form of data communication in the world). While it is possible to fetch a list of messages using a `ContentProvider`, it is also possible to send SMS as well. This will also let us show off one more type of `Intent`.

- *Important note:* the SMS APIs changed *drastically* in KitKat (API 19). So we're going to make sure that is our minimum so we can get all the helpful methods and support newer stuff (check gradle to confirm!).

The main thing to note about sending SMS is that as of KitKat, each system has a *default* messaging client—who is the only one who can actually send messages. Luckily, the API lets you get access to that messaging client's services in order to send a message *through* it:

```
SmsManager smsManager = SmsManager.getDefault();
smsManager.sendTextMessage("5554", null, "This is a test message!", null, null);
//                                     target,         message
```

We will need permission: `<uses-permission android:name="android.permission.SEND_SMS" />`

If we look at the documentation for this method⁵, you can see that this works by looking at the inbox in the Messages app... but there is another way as well. Those last two parameters are for `PendingIntents`: one for when messages are sent and one for when messages are delivered.

- What's a `PendingIntent`? The details are not *super* readable... It's basically a wrapper around an `Intent` that we give to **another** class. Then when that class receives our `PendingIntent` and reacts to it, it can run the `Intent` (command) we sent it with as if that `Activity` was us (whew).
- Basically we're saying "when I call you, you can come pick me up using my car" kind of thing.
- Or like if you gave a stamped envelope to someone to put your letter or recommendation inside (do this!)
- So the idea is we specify what `Intent` should be delivered when the message is finished being sent (that `Intent` becomes "pending"). Effectively, this lets us send `Intents` in response to some other kind of event.

Let's go ahead and set one up:

⁵<https://developer.android.com/reference/android/telephony/SmsManager.html>

```
public static final String ACTION_SMS_STATUS = "edu.uw.intentdemo.ACTION_SMS_STATUS";
...
Intent intent = new Intent(ACTION_SMS_STATUS);
PendingIntent pendingIntent = PendingIntent.getBroadcast(MainActivity.this, 0, intent, 0);

smsManager.sendTextMessage("5554", null, "This is a test message!", pendingIntent, null);
```

We're doing a couple of steps here:

- We're defining our own custom Action. It's just a `String`, but name-spaced to avoid conflicts
- We then create an **implicit intent** for this action
- And then create a `PendingIntent`. We're using the `getBroadcast()` method to specify that the intent should be sent via a Broadcast (c.f. `getActivity()` for `startActivity()`).
- First param is `content` that should send the intent, then a request code (e.g., for result callbacks if we wanted), then the `Intent`, and finally any extra flags (none for now).

We can then have our `BroadcastReceiver` respond to this `Intent` just like any other one!

```
if(intent.getAction() == MainActivity.ACTION_SMS_STATUS) {
    if (getResultCode() == Activity.RESULT_OK) {
        Toast.makeText(context, "Message sent!", Toast.LENGTH_SHORT).show();
    }
    else {
        Toast.makeText(context, "Error sending message", Toast.LENGTH_SHORT).show();
    }
}
```

- **Don't forget** to add our custom intent to the `<intent-filter>`!

We'll see more with `PendingIntents` in the next chapter when we talk about notifications.

8.7 ShareActionProvider

But wait there's more we can do with Intents! One of the other things we can add to menus are Action Views that are expandable widgets in the action bar (e.g., search example). Or, to play around with Intents more, we can add an Action Provider (like `ShareActionProvider`), which gives us a bunch of interaction built into the menu! This is the "quick share with these social media sites" button that we see commonly.

- We'd want to look at class documentation for how to set this up (it's much clearer than the training docs).

How to use it:

- We're going to add another item to our menu's XML. This will look like most items, except it will have an extra field `app:actionProviderClass`

```
<item
    android:id="@+id/menu_item_share"
    android:title="Share"
    app:showAsAction="ifRoom"
    app:actionProviderClass="android.support.v7.widget.ShareActionProvider"
/>
```

- We'll then add the item to our menu in `onCreateOptionsMenu()`

```
MenuItem item = menu.findItem(R.id.menu_item_share);
mShareActionProvider = (ShareActionProvider) MenuItemCompat.getActionProvider(item);

Intent intent = new Intent(Intent.ACTION_DIAL);
intent.setData(Uri.parse("tel:206-685-1622"));

mShareActionProvider.setShareIntent(intent);
```

- We get access to the item using `findItem()`, and then cast it to a `ShareActionProvider` (make sure you're using the support version!)
- We can then specify an *implicit Intent* that we want that "Share Button" to be able to perform. This would commonly use the `ACTION_SEND` action (like for sharing a picture or text), but we'll use the `DIAL` action because we have a couple of dialers but don't actually have many `SEND` responders on the emulator.

The Menu item will then list a dropdown with all of the different Activities that `resolve` to handling that implicit intent!

Chapter 9

UI Components II

This lecture discusses how to include additional user interface components in an Android application: namely **Notifications**¹ and **Settings Menus**. As before, this lecture aims to provide *exposure* rather than complete coverage to these concepts; for more options and examples, see the official Android documentation.

This lecture references code found at <https://github.com/info448-s17/lecture09-notifications-settings>.

9.1 Notifications

We have previously covered how to let the user know what’s going on by popping up a toast or even an `AlertDialog`, but often we want to notify the user of something outside of the normal Activity UI (e.g., when the app isn’t running, or without getting in the way of other interactions). To do this, we can use Notifications. These are specialized views that show up in the **notification area** (the icons at the top of the operating system display) and in the system’s **notification drawer**, which the user can get to at any point—even when outside the app—by swiping down on the screen.

Android’s documentation for UI components is overall quite thorough and usable (after all, Google wants to make sure that developers can build effective apps, thereby making the platform worthwhile). And because there are so many different UI elements and they change all the time, in order to do real-world Android development you need to be able to read, synthesize, and apply this documentation. As such, this lecture will demonstrate how to utilize that documentation and apply it to create notifications. We will utilize this documentation in order to add a feature that when we click on the appropriate *menu*

¹<https://developer.android.com/guide/topics/ui/notifiers/notifications.html>

button, a notification will appear that reports how many times we've selected that option.

- To follow along this, open up the **Notifications** documentation.
- Looking at the documentation we see an overview to start. There is also a link to the Notification Design Guide, which is a good place to go to figure out how to design *effective* notifications.
- There is a lot of text about how to make a Notification... I personally prefer to work off of sample code, modifying it until I have something that does what I want, so I'm going to scroll down **slowly** until I find an example I can copy/paste in, or at least reference. Then we can scroll back up later to get more detail about how that code works.
- Eventually you'll find a subsection "Creating a Simple Notification", which sounds like a great place to start!

The first part of this Notification is using `NotificationCompat.Builder` (use the v4 support version). We have previously seen this kind of Builder class with `AlertBuilder`, and the same concept applies here: it is a class used to construct the Notification for us. We call setters to specify the properties of the Notification

- I don't have a drawable resource to use for an icon, which makes me want to not include the icon specification. However, scrolling back up will reveal that a notification icon is required, so we will need to make one.

We can produce a new Image Asset for the notification icon (`File > New > Image Asset`), just as we did previously with launcher icons. Specify the "type" as `Notification`, give it an appropriate name, and pick a clipart of your choosing.

The next line makes an `Intent`. We've done that too... but why create an `Intent` for a Notification? If we scroll up and look where `Intent` is referenced, we can find out about Notification Actions, which specify what happens when the user clicks on the Notification. Usually this opens the relevant application, and since `Intents` are messages to open Activities, it makes sense that clicking a Notification would send an `Intent`.

- Notice that the `Intent` will actually be wrapped in a `PendingIntent`. Thus we will give the Notification a `PendingIntent`, which contains an "RSVP" (to open the Activity) that it can send to the system when someone clicks on it. (the `Intent` is "pending" delivery/activation by another service).

In particular, we use a `PendingIntent` in order to make sure that the Activity who will be executing it (the "notification service" component) will have permission to send the contained `Intent`. The `Intent` the notification service sends is to wake up our Activity, run with our permissions. It is as if we had sent the `Intent` ourselves!

The example Notification is also using the a `TaskStackBuilder` to construct an “artificial” backstack. This is used to specify, for example, that if the user clicks on the Notification and jumps to a “detail” view (say), they can still hit the back button to return to the “master” view, as if they had navigated to the “detail” view following a normal application phone.

- We build this backstack not just with methods, but by integrating with the “parent-child” relationship we’ve otherwise set up between Activities. In the `Manifest`, we had specified that `SecondActivity`’s parent is `MainActivity`. This is what gave us the nice back button in the `ActionBar`. These sequence of `parentActivityName` attributes form a hierarchy that will be the “back navigation hierarchy.” We add the “endpoint” of the hierarchy to the builder using `addParentStack(MyResultActivity.class)`, and then finally put the `Intent` we actually want to use “on top” of the stack with `addNextIntent(resultIntent)`.

The `resultIntent` is *not* the `PendingIntent`... yet. While we could define a `PendingIntent` manually, the example uses the `TaskStackBuilder#getPendingIntent()` method to build an appropriate `PendingIntent` object.

- Pass it an *ID* to refer to that request (like we’ve done when sending `Intents` for Results), and a flag `PendingIntent.FLAG_CURRENT_UPDATE` so that if we re-issue the `PendingIntent` it update instead of replace the pending `Intent`.
- We can then assign that `PendingIntent` to the *Notification* builder (with `setContentIntent()`).

Finally, we can use the `NotificationManager` (similar to the `FragmentManager`, `SmsManager`, etc.) to fetch the *notification service* (the “application” that handles all the notifications for the OS). We tell this manager to actually issue the built `Notification` object.

- We also pass the `notify()` method an *ID* number to refer to the particular Notification (not the `PendingIntent`, but the `Notification`). Again, this will allow us to refer to and update that Notification.

This allows us to have working Notifications! We can click the button to launch a Notification, and then click on the Notification to be taken to our app, which has a working back stack!

We can also **update** this notification later, and it’s really straightforward: we simply re-issue a Notification with the same **ID** number, and it will “replace” the previous one!

- For example, we can have our text be based on some instance variable, and have the Notification track the number of clicks!

You may notice that this notification doesn’t “pop up” in a way we might expect. This is because its priority isn’t high enough (it needs to be `NotificationCompat.PRIORITY_HIGH` or higher) **and** because it doesn’t use either sound or

vibration (it needs to be *really important* to get a heads-up pop).

- We can make the Notification vibrate by using the `setVibrate()` method, passing it an array of times (in milliseconds) at which to turn vibration on and off.
- Pattern is `[delay, vibrate, sleep, vibrate, sleep, ...]`
- We can also assign a default sound with (e.g.,) `builder.setSound(Settings.System.DEFAULT_NOTIFICATION_SOUND)`
- See the design guide for best practices on priority.

As always, there are a number of other pieces/details we can specify, but I leave those to you to look up in the documentation.

As a focus on development, this lecture references but does **not** discuss the UI Design guidelines: e.g., what kind of text should you put in your Notification? *When* should you choose to use a notification? Android has lots of guidance on these questions in their “design” documentation, and further HCI and Mobile Design guidelines apply here just as well. In general, this course will leave the UI design up to you. But major guidelines apply (e.g., make actions obvious, give feedback, avoid irreversible actions, etc.).

9.2 Settings

The second topic of this lecture is to support letting the user decide whether clicking the button should create notifications or not. For example, maybe sometimes the user just want to see Toasts! The cleanest way to support this kind of user preference is to create some Settings using **Preferences**.

9.2.1 SharedPreferences

Shared Preferences² are another way that we can **persist** data in application (besides putting it into a database via a ContentProvider, or using the file system as described in the next lecture). SharedPreferences store *key-value pairs* of primitives (Strings, ints, etc), similar to what we’ve been putting in Bundles. This data will be stored across application sessions: if I save some data to the Preferences and close the app, it will be there when I come back.

- Preferences are stored in an **XML File** in the file system. Basically we save in lists of key-value pairs as a basic XML tree in a plain-text file. Note that this is *not a resource*, rather a file that happens to be structured as XML.
- This is not great for intricate or extensive structured data (since it only stores key-value pairs, and only primitives at that). Use other options for more complex data persistence.

²<https://developer.android.com/guide/topics/data/data-storage.html#pref>

Even though they are *called* “Preferences”, they not just for “user preferences”. We can persist any small bits of primitive data in a Preferences file.

We can get access to this SharedPreferences file using the `.getSharedPreferences(String, int)` method. The first parameter `String` is the name of the Preference File we want to access (we can have multiple XML files; just use `getPreferences()` to use a single default). The second parameter `int` is a flag about whether other apps should have access to that file. `MODE_PRIVATE` (0) is the default, `MODE_WORLD_READABLE` and `MODE_WORLD_WRITEABLE` are the other options.

We can edit this XML file by calling `.edit()` on the `SharedPreferences` object to get a `SharedPreferences.Editor`, which is a Bundle-esque object we can put values into.

- We need to call `.commit()` on the editor to save our changes to the file system!

Finally, we can just call `get()` methods on the `SharedPreferences` object in order to fetch data out of it! The second parameter of these methods is a default value for if a preference doesn’t exist yet, making it easy to avoid `null` errors.

For practice, try saving the notification count in the Activity’s `onStop()` function, and retrieving it in `onCreate()`. This will allow you to persist the count even when the Activity is destroyed.

9.2.2 Preference Settings

While `SharedPreferences` acts a generic data store, it is called Shared *Preferences* because it’s most commonly used for “user preferences”—e.g., the “Settings” for an app.

The “Preference Menu” is a user-facing element, so we’ll want to define it as an XML resource. But we’re not going to try and create our own layout and interaction: instead we’re just going to define the list of `Preferences`³ themselves as a resource!

- We can create a new resource using Android Studio’s New Resource wizard. The “type” for this is actually just XML (generic), though our “root element” will be a `PreferenceScreen` (thanks intelligent defaults!). By convention, the preferences resource is named `preferences.xml`

Inside the `PreferenceScreen`, we add more elements: one to represent each preference we want to let the user adjust (or each “line” of the screen Settings window). We can define different types of `Preference` objects, such as `<CheckBoxPreference>`, `<EditTextPreference>`, `<SwitchPreference>`, or `<ListPreference>` (for a dialog of radio buttons). There are a couple of other options as well; see the `Preference` base class.

³<https://developer.android.com/reference/android/preference/Preference.html>

- These elements should include the following XML attributes (among others):
 - `android:key` the key to store the preference in the `SharedPreferences` file
 - `android:title` a user-visible name
 - `android:defaultValue` a default value for the preference (use `true` or `false` for checkboxes).
 - More options can be found in the `Preference` documentation.
- We can further divide these Preferences to organize them: we can place them inside a `PreferenceCategory` tag (with its own `title` and `key`) in order to group them together.
- Finally we can specify that our Preferences have multiple screens by nesting `PreferenceScreen` elements. This produces “subscreens” (like submenus): when we click on the item it will take us to the next screen.

Note that a cleaner (but more labor-intensive) way to do this if you have *lots* of settings is to use `preference-headers` which allows for better multi-pane layouts... but since we’re not making any apps with that many settings this process is left as exercise for the reader.

Once we have the Preferences all defined in XML: we just need to show them in our application! To do this, we’re going to use the `PreferenceFragment` class (a specialized `Fragment` for showing lists of `Preference` objects).

- We don’t need to specify an `onCreateView()` method, instead we’re just going to load that `Preference` resource in the `onCreate()` method using `addPreferencesFromResource(R.xml.preferences)`. This will cause the `PreferenceFragment` to create the appropriate layout!

We’ll put this `Fragment` inside a plain `Activity`, which just loads that `Fragment` via a `FragmentManager`:

```
getFragmentManager().beginTransaction()
    .replace(android.R.id.content, new SettingsFragment())
    .commit();
```

- The `Activity` doesn’t even need to load a layout: just specify a transaction! But if we want to include other stuff (e.g., an `ActionBar`), we’d need to structure the `Activity` and its layout in more detail.
- Note that `android.R.id.content` refers to the “root element” of the current `View`—basically what `setContentView()` is normally inflating into.
- There is a `PreferenceActivity` class as well, but the official recommendation is **do not use it**. Many of its methods are deprecated, and since we’re using `Fragments` via the support library, we should stick with the `Fragment` process.

Finally, how do we interact with these settings? Here's the trick: a `preferences` XML resource is **automatically** associated with a `SharedPreferences` file. And in fact, every time we adjust a setting in the `PreferenceFragment`, the values in that file are edited as well! We never need to write to the file, just read from it (similar to any other `SharedPreferences` file).

The `preference` XML corresponds to the “default” `SharedPreferences` file, which we'll access via:

```
SharedPreferences sharedPref = PreferenceManager.getDefaultSharedPreferences(this);
```

- And then we have this object we can fetch data from with `getString()`, `getBoolean()`, etc.

This will allow us to check the preferences before we show a notification!

That's the basics of using Settings. For more details see the documentation, as well as the design guide for best practices on how to organize your Settings.

Chapter 10

Files and Permissions

This lecture discusses how to working with files in Android. Using the file system allows us to have persistant data storage in a more expansive and flexible manner than using the `SharedPreferences` discussed in the previous lecture (and as a supplement to `ContentProvider` databases).

This lecture references code found at <https://github.com/info448-s17/lecture10-files-permissions>.

In order to demonstrate all of the features discussed in this lecture, your device or emulator will need to be running **API 23 (6.0 Marshmallow)** or later.

10.1 File Storage Locations

Android devices split file storage into two types: **Internal storage** and **External storage**. These names come from when devices had built-in memory as well as external SD cards, each of which may have had different interactions. However, with modern systems the “external storage” can refer to a section of a phone’s built-in memory as well; the distinctions are instead used for specifying *access* rather than physical data location.

- **Internal storage** is always accessible, and by default files saved internally are *only* accessible to your app. Similarly, when the user uninstalls your app, the internal files are deleted. This is usually the best place for “private” file data, or files that will only be used by your application.
- **External storage** is not always accessible (e.g., if the physical storage is removed), and is usually (but not always) *world-readable*. Normally files stored in External storage persist even if an app is uninstalled, unless certain options are used. This is usually used for “public” files that may be shared between applications.

When do we use each? Basically, you should use *Internal* storage for “private” files that you don’t want to be available outside of the app, and use *External* storage otherwise.

- Note however that there are publicly-**hidden** *External* files—the big distinction between the storage locations is less visibility and more about *access*.

In addition, both of these storage systems also have a “**cache**” location (i.e., an *Internal Cache* and an *External Cache*). A cache is “(secret) storage for the future”, but in computing tends to refer to “temporary storage”. The Caches are different from other file storage, in that Android has the ability to automatically delete cached files if storage space is getting low... However, you can’t rely on the operating system to do that on its own in an efficient way, so you should still delete your own Cache files when you’re done with them! In short, use the Caches for temporary files, and try to keep them *small* (less than 1MB recommended).

- The user can easily clear an application’s cache as well.

In code, using all of these storage locations involve working with the `File` class. This class represents a “file” (or a “directory”) object, and is the same class you may be familiar with from Java SE.

- We can instantiate a `File` by passing it a directory (which is another `File`) and a filename (a `String`). Instantiating the file will create the file on disk (but empty, size 0) if it doesn’t already exist.
- We can test if a `File` is a folder with the `.isDirectory()` method, and create new directories by taking a `File` and calling `.mkdir()` on it. We can get a list of `Files` inside the directory with the `listFiles()` method. See more API documentation for more details and options.

The difference between saving files to Internal and External storage, *in practice*, simply involves which directory you put the file in! This lecture will focus on working with **External storage**, since that code ends up being a kind of “superset” of implementation details needed for the file system in general. We will indicate what changes need to be made for interacting with Internal storage.

- This lecture will walk through implementing an application that will save whatever the user types into a text field to a file.

Because a device’s External storage may be on removable media, in order to interact with it in any way we first need to check whether it is available (e.g., that the SD card is mounted). This can be done with the following check (written as a helper method so it can be reused):

```
public static boolean isExternalStorageWritable() {
    String state = Environment.getExternalStorageState();
    if (Environment.MEDIA_MOUNTED.equals(state)) {
        return true;
    }
}
```

```
    return false;  
}
```

10.2 Permissions

Directly accessing the file system of any computer can be a significant security risk, so there are substantial protections in place to make sure that a malicious app doesn't run roughshod over a user's data. So in order to work with the file system, we first need to discuss how Android handles permissions in more detail.

One of the most important aspect of the Android operating system's design is the idea of **sandboxing**: each application gets its own "sandbox" to play in (where all its toys are kept), but isn't able to go outside the box and play with someone else's toys. The "toys" (components) parts that are outside of the sandbox are things that would be *impactful* to the user, such as network or file access. Apps are not 100% locked into their sandbox, but we need to do extra work to step outside.

- Sandboxing also occurs at a package level, where packages (applications) are isolated from packages *from other developers*; you can use certificate signing (which occurs as part of our build process automatically) to mark two packages as from the same developer if we want them to interact.
- Additionally, Android's underlying OS is Linux-based, so it actually uses Linux's permission system under the hood (with user and group ids that grant access to particular files or processes).

In order for an app to go outside of its sandbox (and use different components), it needs to request permission to leave. We ask for this permission ("Mother may I?") by declaring out-of-sandbox usages explicitly in the **Manifest**, as we've done before with getting permission to access the Internet or send SMS messages.

Android permissions we can ask for are divided into two categories: normal and dangerous:

- **Normal permissions** are those that may impact the user (so require permission), but don't pose any serious risk. They are granted by the user at *install time*; if the user chooses to install the app, permission is granted to that app. See this list for examples of normal permissions. **INTERNET** is a normal permission.
- **Dangerous permissions**, on the other hand, have the risk of violating a user's privacy, or otherwise messing with the user's device or other apps. These permissions *also* need to be granted at install time. But **IN ADDITION**, starting from Android 6.0 Marshmallow (API 23), users

additionally need to grant dangerous permission access **at runtime**, when the app tries to actually invoke the “permitted” dangerous action.

- The user grants permission via a system-generated pop-up dialog. Note that permissions are granted in “groups”, so if the user agrees to give you `RECEIVE_SMS` permission, you get `SEND_SMS` permission as well. See the list of permission groups.
- When the user grant permission at runtime, that permission stays granted as long as the app is installed. But the big caveat is that the user can choose to **revoke** or deny privileges at *any* time (they do this though System settings)! Thus you have to check *each time you want to access the feature* if the user has granted the privileges or not—you don’t know if the user has *currently* given you permission, even if they had i

Writing to external storage is a *dangerous* permission, and thus we will need to do extra work to support the Marshmallow runtime permission system.

- In order to support runtime permissions, we need to specify our app’s **target SDK** to be 23 or higher AND execute the app on a device running Android 6.0 (Marshmallow) or higher. Runtime permissions are only considered if the OS supports *and* the app is targeted that high. For lower-API devices or apps, permission is only granted at install time.

First we *still* need to request permission in the `Manifest`; if we haven’t announced that we might ask for permission, we won’t be allowed to ask in the future. In particular, saving files to External storage requires `android.permission.WRITE_EXTERNAL_STORAGE` permission (which will also grant us `READ_EXTERNAL_STORAGE` access).

Before we perform a dangerous action, we can check that we currently have permission:

```
int permissionCheck = ContextCompat.checkSelfPermission(activity, Manifest.permission.WRITE_EXTERNAL_STORAGE);
```

- This function basically “looks up” whether we’ve been granted a particular permission or not. It will return either `PackageManager.PERMISSION_GRANTED` or `PackageManager.PERMISSION_DENIED`.

If permission has been granted, great! We can go about our business (e.g., saving a file to external storage). But if permission has NOT been explicitly granted (at runtime), then we have to ask for it. We do this by calling:

```
ActivityCompat.requestPermissions(activity, new String[]{Manifest.permission.WRITE_EXTERNAL_STORAGE}, 1);
```

- This method takes a context and then an *array* of permissions that we need access to (in case we need more than one). We also provide a request code (an `int`), which we can use to identify that particular request for permission in a callback that will be executed when the user chooses whether to give us access or not. This is the same pattern as when we sent

an Intent for a *result*; asking for permission is conceptually like sending an Intent to the permission system!

We can then provide the callback that will be executed when the user decides whether to grant us permission or not:

```
public void onRequestPermissionsResult(int requestCode, String permissions[], int[] grantResults) {
    switch (requestCode) {
        case REQUEST_CODE:
            if (grantResults.length > 0 && grantResults[0] == PackageManager.PERMISSION_GRANTED) {
                //have permission! Do stuff!
            }
            default:
                super.onRequestPermissionsResult(requestCode, permissions, grantResults);
    }
}
```

We check which request we’re hearing the results for, what permissions were granted (if any—the user can piece-wise grant permissions), and then we can react if everything is good... like by finally saving our file!

- Note that if the user deny us permission once, we might want to try and explain *why* we’re asking permission (see best practices) and ask again. Google offers a utility method (`ActivityCompat#shouldShowRequestPermissionRationale()`) which we can use to show a rationale dialog if they’ve denied us once. And if that’s true, we might show a Dialog or something to explain ourselves—and if they OK that dialog, then we can ask again.

10.3 External Storage

Once we have permission to write to external file, we can actually do so! Since we’ve verified that the External storage is available, we now need to pick what directory in that storage to save the file in. With External storage, we have two options:

- We can save the file **publicly**. We use the `getExternalStoragePublicDirectory()` method to access a public directory, passing in what type of directory we want (e.g., `DIRECTORY_MUSIC`, `DIRECTORY_PICTURES`, `DIRECTORY_DOWNLOADS` etc). This basically drops files into the same folders that every other app is using, and is great for shared data and common formats like pictures, music, etc.. Files in the public directories can be easily accessed by other apps (assuming the app has permission to read/write from External storage!)
- Alternatively starting from API 18, we save the file **privately**, but still on External storage (these files *are* world-readable, but are hidden from the user as media, so they don’t “look” like public files). We access this

directory with the `getExternalFilesDir()` method, again passing it a *type* (since we're basically making our own version of the public folders). We can also use `null` for the type, giving us the root directory.

Since API 19 (4.4 KitKat), you don't need permission to write to *private* External storage. So you can specify that you only need permission for versions lower than that:

```
xml    <uses-permission android:name="android.permission.WRITE_EXTERNAL_STORAGE"
android:maxSdkVersion="18" />
```

We can actually look at the emulator's file-system and see our files by created using `adb`. Connect to the emulator from the terminal using `adb -s emulator-5554 shell` (note: `adb` needs to be on your PATH). **Public** external files can usually be found in `/storage/sdcard/Folder`, while **private** external files can be found in `/storage/sdcard/Android/data/package.name/files` (these paths may vary on different devices).

Once we've opened up the file, we can write content to it by using the same IO classes we've used in Java:

- The “low-level” way to do this is to create a `FileOutputStream` object (or a `FileInputStream` for reading). We just pass this constructor the `File` to write to. We write `bytes` to this stream... but can write a `String` by calling `myString.getBytes()`. For reading, we'll need to read in *all* the lines/characters, and probably build a `String` out of them to show. This is actually the same loop we used when reading data from an HTTP request!
- However, we can also use the same *decorators* as in Java (e.g., `BufferedReader`, `PrintWriter`, etc.) if we want those capabilities; it makes reading and writing to file a little easier
- In either case, **remember to `.close()` the stream when done** (to avoid memory leaks)!

```
//writing
try {
    //saving in public Documents directory
    File dir = getExternalStoragePublicDirectory(Environment.DIRECTORY_DOCUMENTS);
    if (!dir.exists()) { dir.mkdirs(); } //make dir if doesn't otherwise exist
    File file = new File(dir, FILE_NAME);
    Log.v(TAG, "Saving to " + file.getAbsolutePath());

    PrintWriter out = new PrintWriter(new FileWriter(file, true));
    out.println(textEntry.getText().toString());
    out.close();
} catch (IOException ioe) {
    Log.d(TAG, Log.getStackTraceString(ioe));
}
```

```
//reading
try {
    File dir = getExternalStoragePublicDirectory(Environment.DIRECTORY_DOCUMENTS);
    File file = new File(dir, FILE_NAME);
    BufferedReader reader = new BufferedReader(new FileReader(file));
    StringBuilder text = new StringBuilder();

    //read the file
    String line = reader.readLine();
    while (line != null) {
        text.append(line + "\n");
        line = reader.readLine();
    }

    textDisplay.setText(text.toString());
    reader.close();
} catch (IOException ioe) {
    Log.d(TAG, Log.getStackTraceString(ioe));
}
```

This will allow us to have our “save” button write the message to the file, and have our “read” button load the message from the file (and display it on the screen)!

10.4 Internal Storage & Cache

Internal storage works pretty much the same way as External storage. Remember that Internal storage is always *private* to the app. We also don’t need permission to access Internal storage!

For Internal storage, we can use the `getFilesDir()` method to access to the files directory (just like we did with External storage). This method normally returns the folder at `/data/data/package.name/files`.

Alternatively, we can use `Context#openFileOutput()` (or `Context#openFileInput()`) and pass it the *name* of the file to open. This gives us back the `Stream` object for that file in the Internal storage file directory, without us needing to do any extra work (cutting out the middle-man!)

- These methods take a second parameter: `MODE_PRIVATE` will create the file (or *replace* a file of the same name). Other modes available are: `MODE_APPEND` (which adds to the end of the file if it exists instead of erasing). `MODE_WORLD_READABLE`, and `MODE_WORLD_WRITEABLE` are deprecated.

- Note that you can wrap a `FileInputStream` in a `InputStreamReader` in a `BufferedReader`.

We can access the Internal Cache directory with `getCacheDir()` (and same read/write process), or the External Cache directory with `getExternalCacheDir()`. We almost always use the Internal Cache, because why would you want temporary files to be world-readable (other than maybe temporary images...)

And again, once you have the file, you use the same process for reading and writing as External storage.

For practice make the provided toggle support reading and writing to an Internal file as well. This will of course be *different* file than that used with the External switch. Ideally this code could be refactored to avoid duplication, but it gets tricky with the need for checked exception handling.

10.5 Example: Saving Pictures

As another example of how we might use the storage system, consider the “take a selfie” system from lecture 8. The code for taking a picture can be found in a separate `PhotoActivity` (which is accessible via the options menu).

To review: we sent an `Intent` with the `MediaStore.ACTION_IMAGE_CAPTURE` action, and the *result* of that `Intent` included an *Extra* that was a `Bitmap` of a low-quality thumbnail for the image. But if we want to save a higher resolution version of that picture, we’ll need to store that image in the file system!

To do this, we’re actually going to modify the `Intent` we *send* so it includes an additional *Extra*: a file in which the picture data can be saved. Effectively, we’ll have *our Activity* allocate some memory for the picture, and then tell the Camera where it can put the picture data that it captures. (Intent envelopes are too small to carry entire photos around!)

Before we send the `Intent`, we’re going to go ahead and create an (empty) file:

```
File file = null;
try {
    String timestamp = new SimpleDateFormat("yyyyMMdd_HH:mm:ss").format(new Date()); //
    //ideally should check for permission here, skipping for time
    File dir = Environment.getExternalStoragePublicDirectory(Environment.DIRECTORY_P
    file = new File(dir, "PIC_"+timestamp+".jpg");
    boolean created = file.createNewFile(); //actually make the file!
    Log.v(TAG, "File created: "+created);
} catch (IOException ioe) {
```



```
Log.d(TAG, Log.getStackTraceString(ioe));
}
```

We will then specify an additional Extra to give that file's location to the camera: if we use `MediaStore.EXTRA_OUTPUT` as our Extra's *key*, the camera will know what to do with that! However, the extra won't actually be the `File` but a `Uri` (recall: the "url" or location of a file). We're not sending the file itself, but the *location* of that file (because it's smaller data to fit in the Intent envelope).

- We can get this Uri with the `Uri.fromFile(File)` method:

```
//save as instance variable to access later when picture comes back
pictureFileUri = Uri.fromFile(file);
```

- Then when we get the picture result back from the Camera (in our `onActivityResult` callback), we can access that file at the saved Uri and use it to display the image! The `ImageView.setImageUri()` is a fast way of showing an image file.

Note that when working with images, we can very quickly run out of memory (because images can be huge). So we'll often want to "scale down" the images as we load them into memory. Additionally, image processing can take a while so we'd like to do it off the main thread (e.g., in an `AsyncTask`). This can become complicated; the recommended solution is to use a third-party library such as Glide, Picasso, or Fresco.

10.6 Sharing Files

Once we have a file storing the image, we can also save that image with other apps!

As always, in order to interact with other apps, we use an Intent. We can craft an *implicit intent* for `ACTION_SEND`, sending a message to any apps that are able to send (share) pictures. We'll set the data type as `image/*` to mark this as an image. We will also attach the file as an extra (specifically an `EXTRA_STREAM`). Again note that we don't actually put the *file* in the extra, but rather the `Uri` for the file!

Since multiple activities may support this action, we can wrap the intent in a "chooser" to force the user to pick which Activity to use:

```
Intent chooser = Intent.createChooser(shareIntent, "Share Picture");
//check that there is at least one option
if (shareIntent.resolveActivity(getPackageManager()) != null) {
    startActivity(chooser);
}
```

There is one complication though: because we're saving files in External storage, the app who is executing the `ACTION_SEND` will need to have permission to read the file (e.g., to access External storage). The Messenger app on the emulator appears to lack this permission by default, though we need to take a slightly different approach:

Rather than putting the `file://` Uri in the Intent's extra, we'll need to create a `content://` Uri for a *ContentProvider* who is able to provide files to anyone who requests them regardless of permissions (the provider grants permission to access its content). Luckily, each image stored in the public directories is automatically tracked by a ContentProvider known as the `MediaStore`. It's easy to fetch a `content://` Uri for a particular image file from this provider:

```
MediaScannerConnection.scanFile(this, new String[] {file.toString()}, null,
    new MediaScannerConnection.OnScanCompletedListener() {
        public void onScanCompleted(String path, Uri uri) {
            mediaStoreUri = uri; //save the content:// Uri for later
            Log.v(TAG, "MediaStore Uri: "+uri);
        }
    });
```

This provides a Uri that can be given to the Intent, and that the Messenger app will be able to access! We can generate this Uri as soon as we have a file for the image to be saved in.

10.6.1 Bonus: Sharing with a `FileProvider`

This section has not been edited for formatting or content.

What happens if we try and share an Internal file? You'll get an error (actually notified the user!), because the other (email) app doesn't have permission to read that file!

- There is a way around this though, and it's by using a `ContentProvider` (haha!) A `ContentProvider` explicitly is about making content available outside of a package (that's why we declared it in the `Manifest`). Specifically, a `ContentProvider` can convert a set of `Files` into a set of data contents (e.g., accessible with the `content://` protocol) that can be used and returned and understood by other apps!
 - Kind of like a "File Server"
- Android includes a `FileProvider` class in the support library that does exactly this work.

Setting up a `FileProvider` is luckily not too complex, though it has a couple of steps. You will need to declare the `<provider>` inside your `Manifest` (see the guide link for an example).

```

<provider
    android:name="android.support.v4.content.FileProvider"
    android:authorities="edu.uw.mapdemo.fileprovider"
    android:exported="false"
    android:grantUriPermissions="true">
    <meta-data
        android:name="android.support.FILE_PROVIDER_PATHS"
        android:resource="@xml/fileprovider" />
</provider>

```

The attributes you will need to specify are:

- `android:authority` should be your package name followed by `.fileprovider` (e.g., `edu.uw.myapp.fileprovider`). This says what source/domain is granting permission for others to use the file.
- The child `<meta-data>` tag includes an `android:resource` attribute that should point to an XML resource, of type `xml` (the same as used for your `SharedPreferences`). *You will need to create this file!* The contents of this file will be a list of what *subdirectories* you want the `FileProvider` to be able to provide. It will look something like:

```

<?xml version="1.0" encoding="utf-8"?>
<paths xmlns:android="http://schemas.android.com/apk/res/android">
    <files-path name="my_maps" path="maps/" />
</paths>

```

The `<files-path>` entry refers to a subdirectory inside the Internal Storage files (the same place that `.getFilesDir()` points to), with the `path` specifying the name of the subdirectory (see why we made one called `maps/`?)

Once you have the provider specified, you can use it to get a `Uri` to the “shared” version of the file using:

```
Uri fileUri = FileProvider.getUriForFile(context, "edu.uw.myapp.fileprovider", fileToShare);
```

(note that the second parameter is the “authority” you specified in your `<provider>` in the Manifest). You can then use this `Uri` as the `EXTRA_STREAM` extra in the Intent that you want to share!

Chapter 11

Location

This lecture discusses **localization**: the process for determining *location*. This is particularly important for Android, which is primarily intended as an operating system for *mobile* devices. What makes phones and tablets special, and different from desktops, is that they can and do move around. And this mobility makes means that a device's position and location can matter *significantly* for how they are used; it's a major part of what separates the functionality of Android apps from any other computer application. Indeed: localization gives apps the ability to create new kinds of user experiences, and to adjust their functionality to fit the user's *context*, supporting context-aware applications.

- The classic example of context-awareness is having software determine if you are at home, in the office, or on a bus, and change its usage accordingly.
 - In fact, one of the winners of the *first* Android Developer Challenge (2008) was Ecorio, an app that figured out whether you were driving, walking, or busing and calculated your carbon footprint from that.
- Note that the emphasis on context-awareness comes out of Ubiquitous Computing, a discipline that considers technology that is *ubiquitous* or everywhere, to the point that it “blends into the surroundings.” That’s the author’s take on why phone development is important; so that you can compute without thinking about it.

I highly recommend you read Mark Weiser’s original 1991 Scientific American article. It’s a neat vision and is foundational for a lot of modern research into mobile systems. It marks the “official” start of the field of Ubicomp.

In short: localization can let us know about the user’s situation (though mobile phone location is not necessarily a proxy for user location).

11.1 Localization Techniques

Ubicomp researchers have been developing localization systems for *years*. A classical reference is a survey paper by Jeff Hightower (who was getting his PhD in the CSE department at UW!)

- As an early example: the *Active Badge* (AT&T) system had a name-badge emit an infrared message, that was picked up by sensors in a room to determine where the wearer was! This is room-level precision, but improvements and *triangulation* (calculating angles to what you see) got it down to about *10cm* precision. However, this system required a lot of infrastructure to be built into a particular room.

With Android, we're usually interested in more general-purpose localization. Mobile devices use a couple of different kinds of localization (either independently or together).

11.1.1 GPS

GPS is the most common, and what most people think of when they think of localization. GPS stands for “Global Position System”—and yes, it can work anywhere on the globe.

GPS's functionality depends on satellites: 24 satellites in high orbit (not geosynchronous) around the Earth. Satellites are distributed so that 4 to 12 are visible from any point on Earth at any time, and their locations are known with high precision. These satellites are each equipped with an atomic, synchronized clock that “ticks” every nanosecond. At every tick, the satellite broadcasts its current time and position. You can almost think of them as *really* loud alarm clocks.

The thing in your phone (or your car, or your watch) that you call a “GPS” or a “GPS device” is actually a *GPS receiver*. It is able to listen for the messages broadcast by these satellites, and determine its position based on that information.

First, the receiver calculates the *time of arrival* (TOA) based on its own clock and comparing time-codes from the satellites. It then uses the announced *time of transmission* (TOT; what the satellite was shouting) to calculate the time of flight, or how long it took for the satellite's message to reach the receiver. Because these messages are sent at (basically) the speed of light, the [time of flight] is equivalent to the distance from the satellite!

- There is some other synchronization work that is done to make sure clocks are all the same, but we won't go into that here.

And once it has distances from the satellites, the receiver can use trilateration to determine its position based on the satellites it “sees”. (Trilateration is like Triangulation, but relies on measuring distances rather than measuring angles.

Basically, you construct three spheres of given radii, and then look to see where they intersect).

GPS precision is generally about 5 meters (15 feet); however, by repeatedly calculating the receiver's position (since the satellites tick every nanosecond), we can use *differential positioning* to extrapolate position with even higher precision, increasing precision to less than 1 meter! This is in part how Google can determine where you're walking.

While GPS is ubiquitous, scalable, and appropriately accurate, it does have some limitations. The biggest problem with GPS is that you need to be able to see the satellites! This means that GPS frequently doesn't work indoors, as many building walls block the signals. Similarly, in highly urban areas (think downtown Seattle), the buildings can bounce the signal around and throw off the TOF calculations, making it harder to pinpoint position accurately.

- Additionally, receivers requires a lot of energy to constantly listen for the satellite messages. This means that utilizing the GPS can lead to a big hit on device battery life—which is of particular importance for mobile devices!

11.1.2 Cell Tower Localization

But your phone can also give you a rough estimate of your location even *without* GPS. It does this through a couple of techniques, such as relying on the cell phone towers that provide the phone network service. This is also known as **GSM localization** (Global System for Mobile Communications; the standard for cell phone communication used by many service providers). The location of these towers are known, so we can determine location based off them in a couple of ways:

- If you're connected to a tower, you must be within range of it. So that gives you some measure of localization right off the bat. This would not be a very accurate measure though (you might be *anywhere* within that range).
- If you can see multiple towers (which important for "handoff" purposes, so your call doesn't drop as you move), you can trilaterate the position between them (e.g., finding the possible overlapping area and picking a location in the middle of that). This can give accuracy within 50m in urban areas, with more towers producing better precision.

11.1.3 WiFi Localization

But wait there's more! What other kinds of communication antennas do you have in your phone? **WiFi**! As WiFi has become more popular, efforts have

been made to identify the *location* of WiFi hotspots so that they too can be used for trilateration and localization.

This is often done through crowdsourced databases, with information gathered via war driving. War driving involves driving around with a GPS receiver and a laptop, and simply recording what WiFi routers you see at what locations. This then all gets compiled into a database that can be queried—given that you see *these* routers, where must you be?

- Google got in hot water for doing this as it was driving around to capture Street-View images.

WiFi localization can then be combined with Cell Tower localization to produce a pretty good estimate of your location, even without GPS.

And in fact, Google provides the ability to automatically use all of these different techniques, abstracted into a single method call!

I want to flag that just like the old *Active Badge* systems, all of these localizations systems rely on some kind of existing infrastructure: GPS requires satellites; GSM requires cell towers, and WiFi needs the database of routers. All these systems require and react to the world around them, making localization influenced by the actual location as well, as well as both social and computational systems!

11.1.4 Representing Location

So once we have a location, how do we represent it?

First, note that there is a philosophical difference between a “place” and a “space.” A **space** is a location, but without any social connotations. For example, GPS coordinates, or Cartesian xy-coordinates will all indicate a “space.” A **place** on the other hand is somewhere that has social meaning: Mary Gates Hall; the University of Washington; my kitchen. Space is a computational construct; place is a human construct. When we talk about localization with a mobile device, we’ll be mostly talking about *space*. But often *place* is what we’re really interested in, and we may have to convert between the two (Google does provide a few ways to convert between the two, such as with its Places API).

Our space locations will generally be reported as two coordinates: **Latitude** and **Longitude**. (**Altitude** or height can also be reported, but that isn’t very relevant for us).

- **Latitude** (“lat”) is the *angle* between the equatorial plane and a line that passes through a point and the center of the Earth—the angle you have to go up the earth’s surface from the equator. Effectively, it’s a measure of “north/south”. Latitude is usually measured in *degrees north*, so going south of the equator gives a negative latitude (though this can be expressed positively as “degrees south”).

- **Longitude** (“lng”) is the *angle* between the prime meridian plane and a line that passes through a point and the center of the Earth—the angle you have to go across the earth’s surface from the meridian. Effectively, it’s a measure of “east/west”. Latitude is measured in *degrees east*, so going east of the meridian. That mean that the western hemisphere has “negative longitude” (though this can be expressed as positive “degrees west”).

As an example: UW’s GPS Coordinates¹ are N/W, so this would be expressed as N (positive) and E (negative).

The distance between degrees and miles depends on where you you are (particularly for longitude—the curvature of the earth means that each degree has less space between it as you get closer to their “joining” at the poles). However, for a very rough sense of scale, in the American Northwest, .01 degrees corresponds with a distance of *about* a mile (again: this is not an accurate conversion, and is intended only for a sense of the “units”).

11.2 Android Location

The remainder of the lecture will discuss how to implement an app that is able to access the device’s location. This location will simply be displayed for now; connecting the location to a visual display (e.g., a map) is left as an exercise to the reader.

This lecture references code found at <https://github.com/info448-s17/lecture11-location>.

11.2.1 Google Play Services

In order to effectively access location, we first need to make sure we include the Google Play Services. These are a special set of libraries (similar to the support libraries) that provide additional functionality to Android. That functionality will include the location and mapping tools we’re interested in. (Much of this functionality was originally built into core Android, but Google has since been moving it into a separate app that can be more easily distributed and updated!)

There are a few steps to including the Play Services library:

1. Make sure you’ve downloaded the proper library. Go to `Tools > Android > SDK Manager` to open up the manager for the various versions of Android installed. Under `SDK Tools`, select `Google Play Service` and `Google Play Repository` to download those.

¹<https://www.google.com/search?q=uw+gps+coordinates>

2. Make sure the device supports these services (e.g., that it's a Google device and not an Amazon device). For the emulator, go to the **AVD Manager**, and confirm the *target* platform includes the **Google APIs**.
3. Modify your **build.gradle** file so that you can get access to the Location classes. In the *module-level* **build.gradle** file, under **dependencies** add

```
compile 'com.google.android.gms:play-services-location:10.2.4'
```

This will load in the location services (but not the other play services, which take up extra space and may require additional API keys). Note that you can specify a different version of the services, as long as it is greater than 8.3.0.

Additionally, you'll need to request permission to access the device's location. There are two permission levels we can ask for: **ACCESS_COARSE_LOCATION** (for GSM/WiFi level precision), and **ACCESS_FINE_LOCATION** (for GPS level precision). We'll use the later because we want GPS-level precision.

This is a **dangerous** permission, so in Marshmallow we need to make sure to ask for permission at run-time! See the lecture on permissions for details.

We're going to use Google Play Services to access the device's location. The Google APIs provide a nice set of methods for accessing location (without us needing to specify the source of that localization, GPS or GSM), and is the recommended API to use.

- There is a built-in **android.location** API (e.g., for non-Google based Android devices), but it's not recommended practice and is harder to use.

The first thing we need to do is get access to the API; we do this with a **GoogleApiClient** object. We construct this object in the **onCreate()** callback, using a **GoogleApiClient.Builder**:

```
if (mGoogleApiClient == null) {
    mGoogleApiClient = new GoogleApiClient.Builder(this)
        .addConnectionCallbacks(this)
        .addOnConnectionFailedListener(this)
        .addApi(LocationServices.API)
        .build();
}
```

This builder requires us to specify what are called the *Connection Callbacks*: callbacks that will occur when we connect to the Google Play Services (a *Service* or separate application managing all of Google's API work). We do this by implementing the **GoogleApiClient.ConnectionCallbacks** and **GoogleApiClient.OnConnectionFailedListener** interfaces. Each require methods that we must fill in; in particular, the **onConnected()** method is where we can "start" our API usage (like asking for location!)

- `onSuspended` and `onFailed` are for when the connection is stopped (similar to `onStop()`) or if we fail to connect. See Accessing Google APIs for details.

Note we also specify that we want to access the `LocationServices` API in the builder.

Finally, we need to actually connect to the client. We do this in the Activity's `onStart()` method (and disconnect in `onStop()`):

```
protected void onStart() {  
    mGoogleApiClient.connect();  
    super.onStart();  
}
```

This of course, will lead to our `onConnected()` callback being executed once the connection to the service is established.

11.2.2 Accessing Location

Once we have the the client connected to the service, we can start getting the location!

To access the location, we're going to use a class called the `FusedLocationApi`². This is a “unified” interface for accessing location. It fuses together all of the different ways of getting location, providing which-ever one best suits our specified needs. You can think of it as a “wrapper” around more detailed location services.

- It will let us specify at a high level whether we want to trade accuracy for power consumption, rather than us needing to be explicit about that. And it will make decisions about what how best to fetch location given our stated needs and other contextual information.

We're going to specify this “high level” requirement using a `LocationRequest`³ object, which represents the details of our request (e.g., how we want to have our phone search for it's location).

```
LocationRequest request = new LocationRequest();  
request.setInterval(10000);  
request.setFastestInterval(5000);  
request.setPriority(LocationRequest.PRIORITY_HIGH_ACCURACY);
```

- We create the object, then specify the “interval” that we want to check for updates. We can also specify the “fastest” interval, which is the maximum

²<https://developers.google.com/android/reference/com/google/android/gms/location/FusedLocationProviderApi>

³<https://developers.google.com/android/reference/com/google/android/gms/location/LocationRequest>

rate we want updates (assuming they are available). It's a bit like a minimum and maximum. 5 to 10 seconds is good for real-time navigation.

- We also specify the priority, which is the indicator to the FusedLocationApi about what kind of precision we want. `HIGH_ACCURACY` basically means GPS (trade power for accuracy!)

Before actually sending the request, check for run-time permissions! This will introduce *another* layout of callbacks: first you wait for the GoogleApiClient to connect in one callback, then you wait for permission to be granted in another!

Once we have this request in place, we can send it off through the FusedLocationApi:

```
LocationServices.FusedLocationApi.requestLocationUpdates(mGoogleApiClient, request,
```

- The first parameter is going to be the `GoogleApiClient` object, and the second will be the request we just made. The third parameter for the `requestLocationUpdates()` method is a `LocationListener`—an object with a callback that can be executed when the location is updated (i.e., when we move). To provide this listener, we'll make the *Activity* into one by implementing the interface and filling in the `onLocationChanged()` method.
 - Yes, this is a *third* asynchronous callback after the `GoogleApiClient` connection has been established and permission has been granted *and* a location has been received!
 - This listener's callback will be handed a `Location` object, which contains the latitude/longitude of the location. We can then use that location (such as display it). We can access the latitude and longitude with getters:

```
textLat.setText("" + location.getLatitude());
textLng.setText("" + location.getLongitude());
```

It is possible to test this out (even when indoors) by using the emulator. Although the emulator doesn't actually have a GPS receiver, it is possible to give it a "fake" location using the emulator's options sidebar (where we previously sent SMS messages from). This allows us to "send" the phone a location, almost as if we as humans were the GPS receiver!

- You can test by giving the emulator UW's coordinates (47.6550 N, -122.3080 E), and you can watch it update!
 - Note that you may need to start up the Maps application to make sure the device's location settings are enabled and correct. See here for how we can prompt for that ourselves (it's a lot of repetitious code, so leaving it as exercise to the reader).
- The `FusedLocationApi` class also has a `setMockLocation()` method, which can allow you to programmatically define locations (e.g., you can

make a button that changes your location). This can be useful for testing and debugging.

To review the process:

- We start by creating and connecting to a `GoogleApiClient`, which is going to let us talk to the Play Services application running in the background of our phone.
- This may not be able to connect (or may take a moment), so we have a *asynchronous* callback for when it does.
- Once it connects (in that callback), we check to make sure we have permission to get location, asking for it if we don't. This requires the user to make a decision, which may take some time, so we have *another* asynchronous callback for when we finally get permission.
- Once we have permission, we start up a repeated request for location updates. These updates may take some time to arrive, so we have *yet another* asynchronous callback for when they do!
- And when we get a location update, we finally update our View.

That's pretty much what is involved in working with location. Lots of pieces (because callbacks all over the place!), but this does the work of tracking location.

Chapter 12

Sensors

This lecture discusses how to access and utilize hardware **sensors** built into Android devices. These sensors can be used to detect changes to the device (such as its *motion* via the **accelerometer**) or its surrounding environment (such as the weather via a **thermometer** or **barameter**). Additionally, the system is structured so you can develop and connect your own sensor hardware if needed—such as connecting to a medical device or some other kind of tricorder.

This lecture references code found at <https://github.com/info448-s17/lecture12-sensors>.

12.1 Motion Sensors

To continue to emphasize to *mobility* of Android devices (they can be picked up and moved, shook around, tossed in the air, etc.), this lecture will demonstrate how to use **motion sensors** to detect how an Android device is able to measure its movement. Nevertheless, Android does provide a general *framework* for interacting with any arbitrary sensor (whether built into the device or external to it); motion sensors are just one example.

- There are many different sensor types¹ defined by the Android framework. The interfaces for these sensors are defined by the Android Alliance rather than Google, since the interface needs to exist between hardware and software (so multiple stakeholders are involved).

In particular, we'll focus on using the **accelerometer**, which is used to detect *acceleration force* (e.g., how fast the device is moving in some direction). This sensor is found on most devices, and has the added benefit of being a relatively

¹<https://source.android.com/devices/sensors/sensor-types.html>

“low-powered” sensor—its ubiquity and low cost of usage makes it ideal for detecting motions!

The accelerometer is an example of a *motion sensor*, which are used to detect how the device *moves* in space: tilting, shaking, rotating, or swinging. Motion sensors are related to but different from *position sensors* which determine where the device *is* in space: for example, the device’s current rotation, facing, or proximity to another object (e.g., someone’s face). Position sensors different from location sensors (like GPS), in that they measure position relative to the device rather than relative to the world.

- It is also possible to detect motion using a *gravity sensor* (which measures the direction of gravity relative to the device), a *gyroscope* (measures the rate of spin of the device), or a number of other sensors. However, the accelerometer is the most common and can be used in combination with other sensors as needed.

We do not need any special permissions to access the accelerometer. But because our app will rely on a certain piece of hardware that—while common—may not be present on every device, we will want to make sure that anyone installing our app (e.g., from the Play Store) has that hardware. We can specify this requirement in the **Manifest** with a `<uses-feature>` element:

```
<uses-feature android:name="android.hardware.sensor.accelerometer"
              android:required="true" />
```

- This declaration doesn’t actually prevent the user from installing the app, though it will cause the Play Store to list it as “incompatible”. Effectively, it’s just an extra note.

12.1.1 Accessing Sensors

In Android, we start working with sensors by using the `SensorManager`² class, which will tell us information about what sensors are available, as well as let us register listeners to record sensor readings. The class is actually a *service* (an application that runs in the background) which manages all of the external sensors—very similar to the `NotificationManager` used to track all of the system notifications. We can get a reference to the `SensorManager` object using:

```
mSensorManager = (SensorManager) getSystemService(Context.SENSOR_SERVICE);
```

- Just like how we accessed the Notification Service, we ask the Android System to “get” us a reference to the Sensor Service, which *is* a `SensorManager`.

The `SensorManager` class provides a number of useful methods. For example, the `SensorManager#getSensorList(type)` method will return a list of

²<https://developer.android.com/reference/android/hardware/SensorManager.html>

sensors available to the device (the argument is the “type” of sensor to list; use `Sensor.TYPE_ALL` to see all sensors). The sensors are returned as a `List<Sensor>`—each `Sensor`³ object represents a particular sensor. The `Sensor` class includes information like the sensor type (which is *not* represented via subclassing, because otherwise we couldn’t easily add our own types! Composition over inheritance).

Devices may have multiple sensors of the same type; in order to access the “main” sensor, we use the `SensorManager#getDefaultSensor(type)` method. This method will return `null` if there is no sensor of that type (allowing us to check if the sensor even exists), or the “default” `Sensor` object of that type (as determined by the OS and manufacturer).

- If no valid sensor is available, we can have the Activity close on its own by calling `finish()` on it.

In order to get readings from the sensor, we need to *register a listener* for the event that occurs when a sensor sample is available. We can do this using the `SensorManager`:

```
mSensorManager.registerListener(this, mSensor, SensorManager.SENSOR_DELAY_NORMAL);
```

- The first parameter is a `SensorEventListener`, which will handle the callbacks when a `SensorEvent` (a reading) is produced. It is common to make the containing Activity the listener, and thus have it implement the interface and its two callbacks (described below).
- The second parameter is the sensor to listen to, and the third parameter is a flag indicating how often to sample the environment. `SENSOR_DELAY_NORMAL` corresponds to a 200,000 microsecond (200ms) delay between samples; use `SENSOR_DELAY_GAME` for a faster 20ms delay (e.g., if making a motion-based game).
- **Important** be sure to *unregister* the listener in the Activity’s `onPause()` callback in order to “turn off” the sensor when it is not directly being used. Sensors can cause significant battery drain (even though the accelerometer is on the low end of that), so it is best to minimize that. Equivalently, you can register the sensor in the `onResume()` function to have it start back up.

We can utilize the sampled sensor information by filling in the `onSensorChanged(event)` callback. This callback is executed *whenever* a new sensor reading occurs (so possibly 50 times a second)! The `onAccuracyChanged()` method is used to handle when the sensor switches modes in some way; we will leave that blank for now.

In the `onSensorChanged()` method, sensor readings are stored in the `event.values` variable. This variable is an array of `floats`, but the size of the array and the meaning/range of the values in that array are entirely depending

³<http://developer.android.com/reference/android/hardware/Sensor.html>

on the sensor type that produced the event (which can be determined via the `event.sensor.getType()` method).

When working with the **accelerometer**, each element in the `float[]` is the acceleration force (in m/s^2) along each of the three Cartesian *axes* (x, y, and z in order):

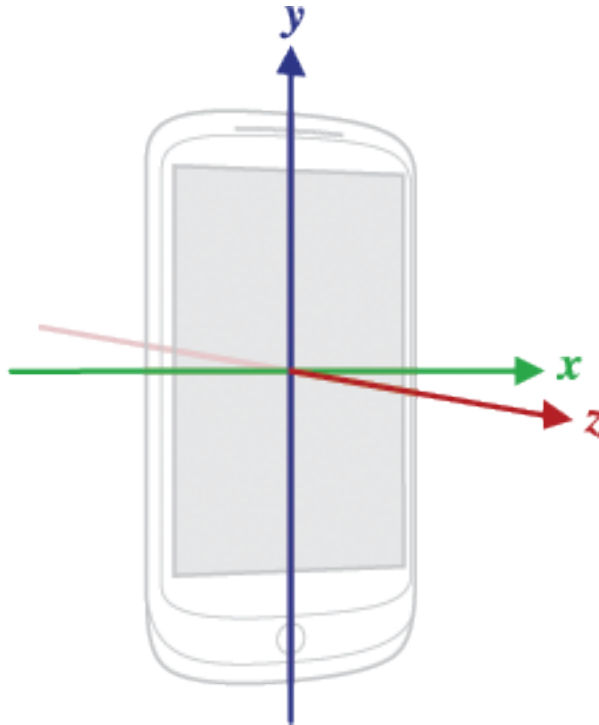


Figure 12.1: Coordinate system (relative to a mobile device). Image from [source.android.com](https://developer.android.com/images/axis_device.png)⁵.

12.1.2 Composite Sensors

If you Log out these coordinates while the phone sitting flat on a table (not moving), you will notice that the numbers are not all `0.0`. This is because *gravity* is always exerting an accelerating force, even when the device is at rest! Thus in order to determine the actual acceleration, we would need to “factor out” the force due to gravity. This requires a little bit of linear algebra; the Android documentation has an example of the math (and an additional version can be found in the sample app).

⁵https://developer.android.com/images/axis_device.png

However, an easier solution is to utilize a *second* sensor. For example, we can read the current force due to gravity from a *magnetometer* or a *gyroscope*, and then do some math to subtract that reading from the accelerometer.

We can effectively combine these two sets of readings by listening not to the *accelerometer*, but to the **Linear acceleration** sensor instead. This is an example of a **composite sensor**, a “virtual” sensor that combines readings from multiple pieces of hardware to produce useful results. Composite sensors allow us to query a single sensor for a set of data, even if that data is being synthesized from multiple other sensor components (similar to how the `FusedLocationApi` allows us to get location from multiple receivers). For example, the *linear acceleration* sensor uses the *accelerometer* in combination with the *gyroscope*, or the *magnetometer* if there is no gyroscope. This sensor is thus able to sample the acceleration independent of the gravity automatically.

- It is theoretically possible for a device to provide dedicated hardware for a composite sensor, but no distinction is made by the Android software.
- Note that not all devices will have a *linear acceleration* sensor!

Android provides many such compound sensors, and they are incredibly useful for simplifying sensor interactions.

12.2 Rotation

Acceleration is all good and well, but it only detects motion when the phone is *moving*. If we tilt the phone to one side, it will measure that movement... but then the acceleration goes back to 0 since the phone has stopped moving. What if we want to detect something like the **tilt** of the device?

The *gravity sensor* (`TYPE_GRAVITY`) can give this information indirectly, but it is a bit hard to parse out. So a better option is to use a **Rotation Vector Sensor**. This is another **composite** (virtual) sensor that is used to determine the current rotation (angle) of the device by combining readings from the *accelerometer*, *magnetometer*, and *gyroscope*.

After registering a listener for this sensor, we can see that the `onSensorChanged(event)` callback once again provides three `float` values from the sensed event. These values represent the phone’s rotation in quaternions. This is a lovely but complex coordinate system (literally complex: it uses imaginary numbers to measure angles). Instead, we’d like to convert this into rotation values that we understand, such as the degrees of device roll, pitch, and yaw.

- Our approach will be somewhat round-about, but it is useful for understanding how the device measures and understands its motion.

In computer systems, rotations are almost always stored as **matrices** (a mathematical structure that looks like a table of numbers). Matrices can be used to multiply **vectors** to produce a *new*, transformed vector—the matrix represents a

(linear) mapping. Because a “direction” (e.g., the phone’s facing) is represented by a vector, that direction can be multiplied by a matrix to represent a “change” in the direction. A matrix that happens to correspond with a transformation that rotates a vector by some angle is called a **rotation matrix**.

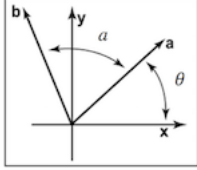
$$\begin{aligned}
 x &= r \cos(\theta) \\
 y &= r \sin(\theta) \\
 x' &= r \cos(a + \theta) \\
 y' &= r \sin(a + \theta) \\
 \sin(A + B) &= \sin(A)\cos(B) + \cos(A)\sin(B) \\
 \cos(A + B) &= \cos(A)\cos(B) - \sin(A)\sin(B) \\
 x' &= r \sin(a + \theta) = r \sin(a)\cos(\theta) + r \cos(a)\sin(\theta) \\
 y' &= r \cos(a + \theta) = r \cos(a)\cos(\theta) - r \sin(a)\sin(\theta) \\
 x' &= x \cos(\theta) - y \sin(\theta) \\
 y' &= x \sin(\theta) + y \cos(\theta)
 \end{aligned}
 \quad
 \begin{bmatrix} \cos(\theta) & -\sin(\theta) \\ \sin(\theta) & \cos(\theta) \end{bmatrix}
 \begin{bmatrix} x \\ y \end{bmatrix}
 =
 \begin{bmatrix} x' \\ y' \end{bmatrix}$$


Figure 12.2: Derivation of a 2D rotation matrix.

- You can actually use matrices to represent *any* affine transformation (including movement, skewing, scaling, etc)... and these transformations can be specified for things like animation. 30% of doing 3D Computer Graphics is simply understanding and working with these transformations.

Luckily, we don’t actually need to know any of the math for deriving rotation matrices, as Android has a built-in method that will automatically produce a rotation matrix from a the rotation quaternion produces by the *rotation vector* sensor: `SensorManager.getRotationMatrixFromVector(targetMatrix, vector)`

- This method takes in a `float[16]`, representing a 4x4 matrix (one dimensions for each axis x, y, and z, plus one dimension to represent the “origin” in the coordinate system. These are known as homogenous coordinates. This array will be filled with the resulting values of the rotation matrix. The method doesn’t produce a `new` array because allocating memory is time-intensive—so you need to provide your own (ideally reused) array.

A 4x4 rotation matrix may not *seem* like much of an improvement towards getting human-readable orientation angles. So as a second step we can use the `SensorManager.getOrientation(matrix, targetArray)` method to convert that that rotation matrix into a set of *radian* values that are the angles the phone is rotated around each axis—thereby telling us the orientation. Note this method also takes a (reusable) `float[3]` as a parameter to contain the resulting angles.

- The resulting angles can be converted to degrees and outputted using some

basic Math and String functions:

```
String.format("%.3f",Math.toDegrees(orientation[0]))+"\u00B0" //include the degree symbol.
```

The *rotation vector* sensor works well enough, but another potential option in API 18+ is the **Game rotation vector** sensor. This **compound** sensor is almost exactly the same as the `ROTATION_VECTOR` sensor, but it does *not* use the magnetometer so is not influenced by magnetic fields. This means that rather than having “0” rotation be based on compass directions North and East, “0” rotation can be based on some other starting angle (determined by the gyroscope). This can be useful in certain situations where magnetic fields may introduce errors, but can also involve gyroscope-based sampling drift over time.

- We can easily swap this in, without changing most of our code. We can use even check the API version dynamically in Java using:

```
if (Build.VERSION.SDK_INT >= Build.VERSION_CODES.JELLY_BEAN_MR2) {
    //... API 18+
}
```

This strategy is useful for any API dependent options, including external storage access and SMS support!

12.2.1 Coordinates

As illustrated above, motion sensors use a standard 3D Cartesian coordinate system, with the x and y axes matching what you expect on the screen (with the “origin” at the center of the phone), and the z coming *out* of the front of the device (following the right-hand rule as a proper coordinate system should). However, there are a few “gotchas” to consider.

For example, note that the values returned by the `getOrientation()` method are *not* in x,y,z order (but instead in z, x, y order)—and in fact rotates around the -x and -z axes. This is detailed in the documentation, and can be confirmed through testing. Thus you need to be careful about exactly what units you’re working with when accessing a particular sensor!

Moreover, the coordinate system used by the sensors is based on the *device’s frame of reference*, not on the Activity or the software configuration! The x axis always goes across the “natural” orientation of the device (portrait mode for most devices, though landscape mode for some tablets), and rotating the device (e.g., into landscape mode) won’t actually change the coordinate system. This is because the sensors are responding to the *hardware’s* orientation, and not considering the software-based configuration.

- One solution to dealing with multiple configurations is to use the `SensorManager#remapCoordinateSystem()` method to “remap” the rotation matrix. With this method, you specify *which* axes should be

transformed into which other axes (e.g., which axes will become the new x and y), and then pass in a rotation matrix to adjust. You can then fetch the orientation from this rotation matrix as before. You can determine the the device's current orientation with `Display#getRotation()` method:

```
Display display = ((WindowManager) getSystemService(Context.WINDOW_SERVICE)).get  
display.getRotation();
```

- It is also common for some motion-based applications (such as games or other graphical systems) to be restricted to a single configuration, so that you wouldn't need to dynamically handle coordinate systems within a single device.

Chapter 13

Services

This lecture discusses a component of Android development that is **not** immediately visible to users: **Services**¹.

Services are sort of like Activities that don't have a user interface or user interaction directly tied to them. Services can be launched by Activities or Applications, but then do their own thing in the background *even after the starting component is closed* (this is distinct from `AsyncTask`, which had its lifecycle tied to that of its containing Activity). Once a Service is started, it keeps running until it is explicitly stopped (Services can be destroyed by the OS to save memory, similar to an Activity, but Services have higher “priority” and so aren't killed as readily).

Some common uses for a Service include:

- Downloading or uploading data from/to a network in the background even if the app is closed
- Saving data to a database without crashing if the user leaves the app
- Running some other kind of long-running, “background” task even after the app is closed, such as playing music!

An important thing to note about Services: a Service is **not** a separate process; it runs in the same process as the app that starts it (unless otherwise specified). Similarly, a Service is **not** a Thread, and in fact doesn't need to run outside the UI thread! However, we quite often *do* want to run the service outside of the UI Thread, and so often have it spawn and run a new `Runnable` Thread. When we say a Service runs “in the background”, we mean from a user's perspective rather than necessarily on a background thread.

This lecture references code found at <https://github.com/info448-s17/lecture13-services>.

¹<https://developer.android.com/guide/components/services.html>

13.1 IntentServices

To create a Service, we're going to subclass `Service` and override some *lifecycle callbacks*, just like we've done with `Activity`, `Fragment`, `BroadcastReceiver`, and most other Android components. In this sense, Services are in fact implemented like Activities that run without a user interface ("in the background").

Because Services will be performing extra background computation, it's important to also create a separate background thread so that we don't block the Main Thread. Since making a Service that does some (specific) task in a background thread is so common, Android includes a `Service` subclass we can use to do exactly this work. This class is called `IntentService`—a service that responds to `Intents` and does some work in response to them.

- An `IntentService` does similar work to `AsyncTask`, but with the advantage that it will keep doing that work even if the Activity is destroyed!
- `IntentService` will listen to any incoming "requests" (`Intents`) and "queue" them up, handling each one at a time. Once the service is out of tasks to do, the service will shut itself down to save memory (though it will restart if more `Intents` are sent to it). Basically, it handles a lot of the setup and cleanup involved in `Service` on its own!
- (This lecture will start with `IntentService` because it's simpler, and then move into the more generic, complex version of Services).

We create an `IntentService` by defining a new class (e.g., `CountingService`) that subclasses `IntentService`.

- Implement a default *constructor* that can call `super(String nameForDebugging)`. This allows the class to be instantiated (by the Android framework; again, like an Activity).
- Also implement the `onHandleIntent(Intent)` method. Incoming `Intents` will wait their turn in line, and then each is delivered to this method in turn. Note that all this work (delivery and execution) will happen in a **background thread** supplied by `IntentService`.

For example, we can have the Service (when started) log out a count, pausing for a few seconds between. This will represent "expensive" logic to perform, like accessing a network or a database.

```
for(int count=0; count<=10; count++){
    Log.v(TAG, "Count: "+count);
    try {
        Thread.sleep(5000); //sleep for 5 seconds
    } catch (InterruptedException e) {
        Thread.currentThread().interrupt();
    }
}
```


Just like with Activities, we also need to declare the `<service>` in the Manifest, as a child of the `<application>`:

```
<service android:name=".CountingService" />
```

Finally, we can send an `Intent` to the Service by using the `startService()` method. This is similar to `startActivity()`, but is for services! We can use explicit intents just like with Activities, and could even include Extras if we wanted to label and track the specific Intents sent to the service.

- When the Service starts, we can see it start counting (but without blocking the UI Thread). We can also destroy the Activity and see that the Service keeps running.

If we want to have the Service to interact with the user interface, such as displaying a Toast, we will need to make sure that occurs on the UI Thread (you cannot change the UI on a separate thread). This requires *inter-thread communication*: we need to get a message (a function call) from the background thread to the UI Thread. We can perform this communication using a `Handler`, which is an object used to pass messages between Threads—it “handles” the messages!

- We instantiate a new `Handler()` object (e.g., in the Service’s `onCreate()` callback), calling a method on that object when we want to “send” a message. The easiest way to send a message is to use the `post()` function, which takes a `Runnable()` method which will be executed *on the Main Thread*:

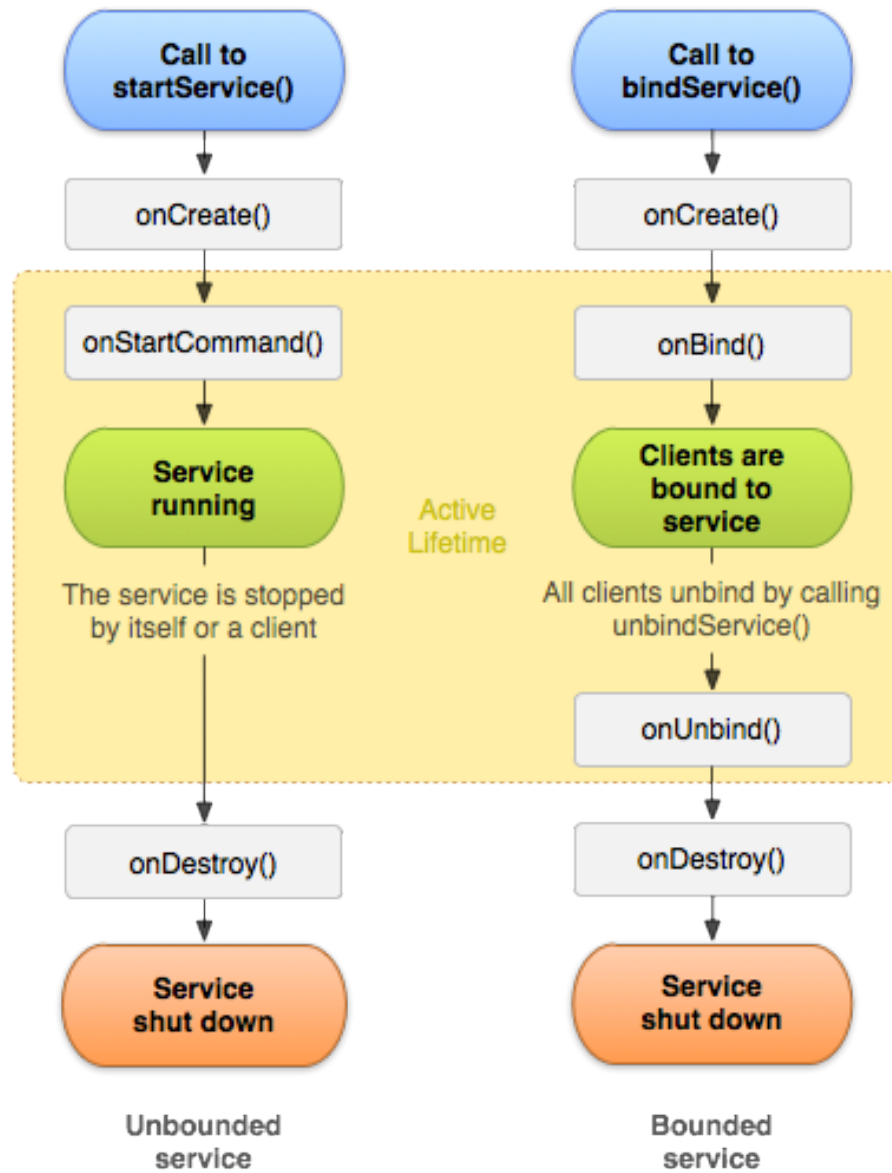
```
mHandler.post(new Runnable() {
    @Override
    public void run() {
        Toast.makeText(CountingService.this, "Count: " + count, Toast.LENGTH_SHORT).show();
    }
});
```

13.1.1 The Service Lifecycle

Having demonstrated the basic usage of a service, consider what is going on “under the hood”—starting with the Service lifecycle. There are actually two different “types” of Services, with different variations of the lifecycle. **Started Services** (or “unbound” Services) are those that are initiated via the `startService()` function, as in the above example. The other option, **Bound Services**, are Services that have “client” Activities bound to them to interact with; see below for details.

- Just like with Activities, Services have an `onCreate()` method that is called when the Service is first created. Since Services don’t have a user interface to set up, so we don’t often do a lot in here.

²https://developer.android.com/images/service_lifecycle.png

Figure 13.1: Service lifecycle diagram, from Google²

- IntentService already overrides this in order to set up a “message queue” so that it can queue up Intents (tasks) to run one at a time.
- The most important callback for a *Started Service* is called `onStartCommand()`. This method is called when the Service is **sent a command** by another component (via an Intent). Importantly, `onStartCommand()` is not only called when the Service is started for the first time, but whenever the Service receives an Intent to start (even if the Service was already running)! These Intents are those sent via `startService()`.
 - Note that when working with an *IntentService* specifically, `onStartCommand()` will “queue” any incoming Intents. When it is the specific Intent’s turn to be “run”, that Intent is automatically passed to the `onHandleIntent()` method, which executes on a *background thread* (similar to `AsyncTask#doInBackground()`). This callback is not part of the normal Service lifecycle, but is a special helper method used by *IntentService*—similar to how `onCreateDialog()` is a special method used by *DialogFragments*.
- The `onBind()` and `onUnbind()` callbacks are used for bound services, and are discussed below.
 - *IntentService* does have a default `onBind()` implementation that returns `null`.
- Finally, Services have an `onDestroy()` callback, which is again equivalent to the Activity callback.
 - In general, Services have to be manually told to **stop**. We stop a Service by using `stopService(Intent)` to send that Service a “stop” Intent. The Service can also stop itself by calling `stopSelf()`.
 - *Important:* When told to stop, an *IntentService* will finish up handling any Intents that are currently “running”, but any other Intents that are “queued” will be removed. Once there are no more queued Intents, an *IntentService* will call `stopSelf()`, thereby causing the `onDestroy()` callback to be executed.

Practice: fill in the callback functions with Log or Toast messages to see how and when they are executed. For example:

```
public int onStartCommand(Intent intent, int flags, int startId) {
    Toast.makeText(this, "Intent received", Toast.LENGTH_SHORT).show();
    return super.onStartCommand(intent, flags, startId);
}
```

As a last point to note about the Service lifecycle consider the `int` that is returned by `onStartCommand()`. This `int` is a flag that indicates how the Service should behave³ when it is “restarted” after having been destroyed:

³<https://developer.android.com/guide/components/services.html#ExtendingService>

- `START_NOT_STICKY` indicates that if the Service is destroyed by the system, it should not be recreated. This is the “safest option” to avoid extraneous service executions; instead, just have the application restart the Service.
- `START_STICKY` indicates that if the Service is destroyed by the system, it should be recreated when possible. At that point, `onStartCommand()` will be called with delivered a `null` Intent (unless there were other start Intents waiting to be delivered, in which case those are used). This option works well for media players or similar services that are running indefinitely (rather than executing specific commands).
- `START_REDELIVER_INTENT` indicates that if the Service is destroyed by the system, it should be recreated when possible. At that point, `onStartCommand()` will be called with the *last* Intent that was delivered to the Service (and any other Intents are delivered in turn). This option is good for Services that actively perform jobs that need to be resumed, such as downloading a file.

In other words: services may get killed, but we can specify how they get resurrected! And of course, we can and should return different values for different starting commands (Intents): so the Intent to download a music file might return `START_REDELIVER_INTENT`, but the Intent to play the music file might return `START_STICKY`.

13.2 Example: A Music Service

One of the classic uses for a background service is to play music, so we will use that as an example. It is possible to play music directly from an Activity, and the music will even keep playing as long as the Activity is alive. But remember that Activities are fragile, and can be destroyed at any moment (whether by us or by the system to save resources). So in order to keep our music playing even as we go about other tasks, we should use a Service. Services have higher “priority” in the eyes of the Android system, and so don’t get sacrificed for resources as readily as normal Activities.

13.2.1 MediaPlayer

In order to make a music service, we need to briefly explain how to play music with `MediaPlayer`. This is the main API for playing sound and video (e.g., if you want to play `.mp3` files).

Android actually has a toad of three (3) audio APIs! The `SoundPool` API is great for short sound effects that play simultaneously (though you need to do extra work to load those clips ahead of time), as with simple games. The `AudioTrack` API allows you to play audio at a very low level (e.g., by “pushing” bytes to a

stream). This is useful for generated Audio (like MIDI music) or if you're trying to do some other kind of low-level stuff.

`MediaPlayer` is very simple to use, particularly when playing a locally defined resource (e.g., something in `res/raw/`). You simply use a factory to make a new `MediaPlayer` object, and then call `.play()` on it:

```
MediaPlayer mediaPlayer = MediaPlayer.create(context, R.raw.my_sound_file);
mediaPlayer.start(); // no need to call prepare(); create() does that for you
```

We can also call `.pause()` to pause the music, `.seekTo()` to jump to a particular millisecond, and `.stop()` to stop the music.

- Note that when we `stop()`, we also need to release any resources used by the `MediaPlayer` (to free up memory):

```
mediaPlayer.release();
mediaPlayer = null;
```

We can also implement and register a `MediaPlayer.OnCompletionListener` to handle when a song finishes playing.

Finally, it is possible to use `MediaPlayer` to play files from a `ContentProvider` or even off the Internet!

```
String url = "http://....."; // your URL here
MediaPlayer mediaPlayer = new MediaPlayer();
mediaPlayer.setAudioStreamType(AudioManager.STREAM_MUSIC);
mediaPlayer.setDataSource(url);
mediaPlayer.prepareAsync(); //prepare media in the background (buffering, etc)
                             //prepare() for synchronous buffering
mediaPlayer.setOnPreparedListener(this); //handle when file is buffered
mediaPlayer.start();
```

13.2.2 Creating a Service

In order to make our music service, we are going to subclass the `Service` class itself (*don't forget to include the `Service` in the `Manifest`*) and manually set up all the pieces. Specifically, we will fill in the lifecycle callbacks:

- `onCreate()` we can include, though it doesn't need to do anything.
- `onStartCommand()` should create and start our `MediaPlayer`. We can return `START_NOT_STICKY` so the music doesn't start up again randomly if the system needs to destroy the `Service` (since it won't get recreated).

Important: Normally with a `Service` we would create a background thread to handle any extraneous work (such as preparing the music to play, as done with the `create()` method). However, this may not be necessary for `MediaPlayer` when loading resources.

- `onDestroy()` can stop, release, and clean-up the `MediaPlayer`. We can implement this in a separate helper function for reuse.
 - If we want to handle pausing, we can specify that in the Intent we send to the service (e.g., via a custom ACTION or an Extra). But a more effective approach is to use Service Binding; see below for details.

We can now have our Activity `startService()` and `stopService()` in order to play our music in the “background”, even if we leave and return to the Activity!

13.3 Foreground Services

Services are normally “background” tasks, that run without any user interface and that the user isn’t aware of (e.g., for downloading or uploading data, etc). But music playing is definitely something that the user *is* aware of, and in fact may want to interact with it! So we’d like the Service to have some kind of user interface, but we’d like to still keep that Service separated from an Activity (so that it can run with the Activity being active).

To do this, we use what is called a **Foreground Service**. Foreground Services represent Services that are divorced from Activities (they *are* Services after all), but the user is aware of them—and accordingly, have an even higher survival priority if the OS gets low on memory!

Foreground services require a **Notification** in the status bar, similar to the Notifications we’ve created before. This Notification will effectively act as the “user interface” for the Service, and let the user see and be aware of its execution!

We create this Notification inside the Service’s `onStartCommand()` method, then pass it to the `startForeground()` method in order to put our Service in the foreground:

```
String songName = "The Entertainer";

PendingIntent pendingIntent = PendingIntent.getActivity(getApplicationContext(), 0,
    new Intent(getApplicationContext(), MainActivity.class), PendingIntent.FLAG_

Notification notification = new NotificationCompat.Builder(this)
    .setSmallIcon(android.R.drawable.ic_media_play)
    .setContentTitle("Music Player")
    .setContentText("Now playing: "+songName)
    .setContentIntent(pendingIntent)
    .setOngoing(true) //cannot be dismissed by the user
    .build();
startForeground(NOTIFICATION_ID, notification); //make this a foreground service!
```

Some details about this Notification:

- We build and set the icon, title, and text as in the previous lecture.
- We give the Notification a `PendingIntent` to run when selected. This `PendingIntent` can just open up our `MainActivity`, allowing us to control the Player. (Alternatively, we could use Notification Actions to control the music directly).
- We set the Notification to be *ongoing*, in order to enforce that it cannot be dismissed by the user.

Importantly, once we are done doing foreground work (e.g., playing music), we should call `stopForeground(true)` to get rid of the foreground service. This is a good thing to do in our `stopMusic()` helper (called from `onDestroy()`).

There are a couple of other details that you should handle if you’re making a full-blown music player app, including: keeping the phone from going to sleep, playing other audio at the same time (e.g., notification sounds; ringtones), switching to external speakers, etc. See the guide for more details.

13.4 Bound Services

As mentioned above, there are two “types” of Services: **Started Services** (Services launched with `startService()`) and **Bound Services**. A Bound Service is a Service that acts as the “server” in a client-server setup: it allows for client Activities to “connect” to it (*bind it*) and then exchange messages with—primarily by calling methods on the Service. These messages can even be *across processes*, allowing for interprocess communication! This is useful when you want interact with the Service from an Activity in some way (e.g., if we want to `pause()` our music), or if we want to make the service’s capabilities available to other applications.

We make a Bound Service by having the Service implement and utilize the **onBind()** callback. This method returns an `IBinder` object (the **I** indicates that it’s an *Interface*, following a Java convention common in enterprise software). When Activities connect to this Service (using the `bindService()` method), this `IBinder` object is passed to them, and they can use it to get access to the Service process to call methods on it. Effectively, the binding process produces an *object* that represents that Service, so Activities can call methods on the Service without needing to send it Intents!

As an example, let’s add the ability to “pause” the music being played as a bound service:

The first thing we need to do is have our Service implement the `onBind()` method. To do this, we will need an `IBinder` object to return (that is: an object of a class that implements the `IBinder` interface). For “local services” (e.g., Services that are run *in the same process*), the easiest way to get an `IBinder` is to extend the `Binder` class:

```
private final IBinder mBinder = new LocalBinder(); //singleton instance variable

public class LocalBinder extends Binder { //implements IBinder
    //binder class methods will go here!
}
```

- Our local version starts “empty” for now; we’ll add details below.
- We will just return this object from `onBind()`.

Because the Activity is given a copy of this `LocalBinder` object, that class can be designed to support the Activity communicating with the Service in a couple of different ways:

1. The `IBinder` can provide public methods for the Activity to call. These methods can then access instance variables of the Service (since the `LocalBinder` is a nested class). This causes the `IBinder` to literally act as the “public interface” for the Service!

```
//in LocalBinder
public String getSongName() {
    return songName; //access Service instance variable
}
```

2. The `IBinder` can provide access to the Service itself (via a getter that returns the Service object). The Activity can then call any public methods provided by that Service class.

```
//in LocalBinder
public MusicService getService() {
    // Return this instance of this Service so clients can call public methods
    return MusicService.this;
}
```

3. The `IBinder` can provide access to some other object “owned” by the Service, which the Activity can then call methods on (e.g., the `MediaPlayer`). This is somewhat like a compromise between the first two options: you don’t need to implement a specific public interface on the `IBinder`, but you also don’t have to provide full access to your Service object! This is good for only exposing part of the Service.

In the Activity, we need to do a bit more work in order to interact with the bound Service. We bind to a Service using `bindService(Intent, ServiceConnection, flag)`. We can do this whenever we want the Service to be available (`onStart()` is a good option, so it is available when the Activity is active).

- The `Intent` parameter should be addressed to the Service we want to bind.
- The `ServiceConnection` parameter is a reference to an object that implements the `ServiceConnection` interface, providing callbacks that can

be executed when the Activity connects to the Service. We can have the Activity implement the interface, or create a separate anonymous class:

```
/** Defines callbacks for service binding, passed to bindService() */
private ServiceConnection mConnection = new ServiceConnection() {
    public void onServiceConnected(ComponentName className, IBinder service) {
        // We've bound to LocalService, cast the IBinder and get LocalService instance
        LocalBinder binder = (LocalBinder) service;
        mService = binder.getService();
        mBound = true;
    }
    public void onServiceDisconnected(ComponentName arg0) {
        mBound = false;
    }
};
```

The `onServiceConnected()` callback handles the actual connection, and is where we get access to that `IBinder`. We can use that `IBinder` to fetch the Service object to call methods on, saving that as an instance variable to do stuff to it! We'll also track whether or not the Service has been bound to avoid any null errors.

- Finally, the `flag` parameter indicates some options for how the Service should be bound (e.g., for specifying survival priority). `Context.BIND_AUTO_CREATE` is a good default, specifying that the binding should create the Service object if needed.

Once a Service is bound, we can call methods on that Service (which must exist!)—allowing us to support the “pause” button.

We should also call `unbindService()` when the Activity stops, in order to free up resources:

```
protected void onStop() {
    if (mBound) {
        unbindService(this);
    }
    super.onStop();
}
```

Keep in mind that binding a Service **DOES NOT** call `onStartCommand()`, but simply creates the Service and gives us access to it! Bound Services are not by default considered “started”, and are generally kept around by the OS as long as they are bound. If we do “start” a Bound Service (e.g., with `startService()`), we will need to remember to stop it later!

This example is just for *local services* (that are accessed within the same process—within the same Application). If we want the Service to be available to other processes (i.e., other Applications), we need to do more work. Specifically, we use `Handler` and `Messenger` objects to pass messages between these

processes (similar to the example we did for passing messages between threads); for more details, see the example in the guide, as well as the complete sample classes `MessengerService` and `MessengerServiceActivities`.

Chapter 14

Material Design

This lecture discusses Material design: the *design language* created by Google to support mobile user interfaces. The design language focuses on mobile designs (e.g., for Android), but can also be used across platforms (e.g., on the web through css frameworks).

This lecture references code found at <https://github.com/info448-s17/lecture14-material>.

This lecture is under development and will be added later.

14.1 Resources:

Some links and resources as a placeholder

- <https://developer.android.com/design/material/index.html>
- <https://material.io/guidelines/material-design/introduction.html#introduction-principles>
- <https://material.io/guidelines/material-design/material-properties.html>
- <https://material.io/guidelines/material-design/elevation-shadows.html#elevation-shadows-elevation-android>
- <http://saulmm.github.io/mastering-coordinator>
- <https://lab.getbase.com/introduction-to-coordinator-layout-on-android/>

Chapter 15

Animation and Graphics

This lecture discusses some different ways to add “visual motion” (graphical animation) to Android applications. It covers 2D drawing with custom Views, Property Animations (also used in Material effects), and how to handle touch-based gestures.

This lecture references code found at <https://github.com/info448-s17/lecture15-animation>.

15.1 Drawing Graphics

Android provides a 2D Graphics API similar in both spirit and usage to the HTML5 Canvas API: it provides an *interface* by which the developer can *programmatically* generate 2D, raster-based images. This API can be used for drawing graphs, showing manipulated images, and even performing animations!

As in HTML5, in Android this API is available via the `Canvas`¹ class. Similar to the HTML5 `<canvas>` element or the Java SE `Graphics2D` class, the Android `Canvas` provides a graphical “context” upon which the developer can “draw” rectangles, circles, and even images (`Bitmaps`) to be shown on the screen.

15.1.1 Custom Views

In order to draw pictures, we need to have a View to draw on (which will provide the `Canvas` context). The easiest way to get this View is to create it ourselves: define a **custom View** which we can specify as having a “drawn” appearance. We can make our own special View by subclassing it (remember: `Buttons` and

¹<https://developer.android.com/reference/android/graphics/Canvas.html>

`EditTexts` are just subclasses of `View`!), and then filling in a callback function (`onDraw()`) that specifies how that `View` is rendered on the screen.

The word *render* in this case means to “bring into being”, meaning to generate a graphical image and putting it on the screen.

Customizing a `View` isn’t too hard, but to save time a complete example is provided in the lecture code in the form of the `DrawingView` class. Notes about this classes implementation are below:

- The class `extends View` to subclass the base `View` class.
- `View` has a number of different of constructors. We override them all, since each one is used by a different piece of the Android system (and thus we need to provide custom implementations for each). However, we’ll have each call the “last” one in order to actually do any setup.
 - In the constructor we set up a `Paint`, which represents *how* we want to draw: color, stroke width, font-size, anti-aliasing options, etc. We’ll mostly use `Paint` objects for color.
- We override the `onSizeChanged()` callback, will get executed when the `View` changes size. This occurs on inflation (which happens as part of an Activity’s `onCreate`, meaning the callback will be called on rotation). This callback can act a little bit like a `Fragment`’s `onCreateView()`, in that we can do work that is based on the created `View` at this point.
- We should also override the `onMeasure()` callback, as recommend by the Android guides. This callback is used to specify how the `View` should be sized in response to its width or height being set as `wrap_content`. This is particularly important for making things like custom `Buttons`. However, our example will skip this for time and space, since the `DrawingView` is intended to always take up the entire screen.
- Finally, we override `onDraw()`, which is where the magic happens. This method gets called whenever the `View` needs to be displayed (like `paintComponent()` in the Swing framework). This callback is passed a `Canvas` object as a parameter, providing the context we can draw on!
 - Like all other lifecycle callbacks: **we never call `onDraw()`!!** The Android UI system calls it for us!

The provided `Canvas` can be drawn on in a couple of ways:

- We can call methods like `drawColor()` (to fill the background), `drawCircle()`, or `drawText()` to draw specific shapes or entities on it. These methods are similar in usage to the HTML5 `Canvas`.
- We can also draw a `Bitmap`, which represents a graphics raster (e.g., a 2D array of pixels). If we have a `Bitmap`, we can set the colors of individual pixels (using `setPixel(x,y,color)`), and then draw the `Bitmap` onto the `Canvas` (thereby double-buffering!). This is useful for pixel-level drawing, or when you want to make more complex graphics or artwork.

- If you’ve used MS Paint, it’s the difference between the shape drawing options and the “zoomed in” pixel coloring.

Note that we cause the `Canvas` to be “redrawn” (so our `onDraw()` method to be called) by calling `invalidate()` on the `View`: this causes Android to need to recreate it, thereby redrawing it. By repeatedly calling `invalidate()` we can do something approximating animation!

- We can do this via a recursive loop by calling `invalidate()` at the end of `onDraw()`. This lets us “request” that Android cause `onDraw()` to be called again once it is finished, but **we don’t call it**.
- As a demo, we can make the `Ball` slide off the screen by changing it’s position slightly:

```
ball.cx += ball.dx;
ball.cy += ball.dy;
```

We can also add in wall collisions:

```
if(ball.cx + ball.radius > viewWidth) { //left bound
    ball.cx = viewWidth - ball.radius;
    ball.dx *= -1;
}
else if(ball.cx - ball.radius < 0) { //right bound
    ball.cx = ball.radius;
    ball.dx *= -1;
}
else if(ball.cy + ball.radius > viewHeight) { //bottom bound
    ball.cy = viewHeight - ball.radius;
    ball.dy *= -1;
}
else if(ball.cy - ball.radius < 0) { //top bound
    ball.cy = ball.radius;
    ball.dy *= -1;
}
```

Animation is the process of “imparting life” (from the Latin “*anima*”). We tend to mean giving something **motion**—making an object appear to move over time. Consider what that means for how people understand “life”.

Video animation involves showing a sequences of images over time. If the images go fast enough, then the human brain interprets them as being part of the same successive motion, and any objects in those images will be considered to be “moving”. Each image in this sequence is called a “frame”. Film tends to be 24 frames per second (**fps**), video is 29.97fps, and video games aim at 60fps. Any video running at at least 16fps will be perceived as mostly smooth motion.

Hitting that 16fps can actually be pretty difficult, since determining *what* to draw is computationally expensive! If we’re calculating every pixel on a 600x800

display, that's half a million pixels we have to calculate! At 60fps, that's 28 million pixels per second. For scale, a 1Ghz processor can do 1 billion operations per second—so if each pixel requires 5 operations, we're at 15% of our processor. This is part of why most graphical systems utilize a dedicated GPU (graphical processing unit)—it provides massive parallelization to speed up this process.

15.1.2 SurfaceViews

Since all this calculation (at pixel-level detail) can take some time, we want to be careful it doesn't block the UI thread! We'd like to instead do the drawing in the background. The rendering itself needs to occur on the UI Thread, but we want all of the *drawing logic* to occur on the background thread, so that the UI work is as fast as possible (think: hanging up a pre-printed poster rather than needing to print it entirely).

- However, an `AsyncTask` isn't appropriate, because we want to do this repeatedly. Similarly, an `IntentService` may not be able to respond fast enough if we need to wait for the system to deliver Intents.

Android provides a class that is specially designed for being “drawn” on a background thread: the **SurfaceView**. Unlike basic `Views` that are somewhat ephemeral, a `SurfaceView` includes a dedicated drawing surface that we can interact with in a separate thread. It is designed to support this threading work without requiring *too* much synchronizatoin code.

These take even more work to setup, so a complete example (`DrawingSurfaceView`) is again provided in the lecture code:

- This class extends `SurfaceView` and *implements* `SurfaceHolder.Callback`. A `SurfaceHolder` is an object that “holds” (contains) the underlying drawable surface; somewhat similar to the `ViewHolder` pattern utilized with an `Adapter`. We interact with the `SurfaceView` through the holder to make sure that we're *thread-safe*: that only one thread is interacting with the surface at a time.
 - In general there will be two threads trading off use of the holder: our background thread that is drawing on the surface (“printing the poster”), and then UI thread that is showing the surface to the user (“hanging the printed poster”). You can think of the holder *as* the poster in this metaphor!
- We register the holder in the constructor with the provided `getHolder()` method, and register ourselves for callbacks when the holder changes. We also instantiate a new `Runnable`, which will represent the callback executed in a separate (background) thread to do the drawing.
- The `SurfaceHolder.Callback` interface requires methods about when the surface changes, and so we fill those in:

- `onSurfaceCreated()` starts our background thread (because the surface has now been created)
- `onSurfaceChanged()` ends up acting a lot like `onSizeChanged()` from the basic `DrawingView`
- `onSurfaceDestroyed()` stops the background thread in a “safe” way (code adapted from Google)
- If we look at the `Runnable`, it’s basically an infinite loop:
 1. Grab the Surface’s `Canvas`, “locking” it so only used in this (background) thread.
 2. Draw on it.
 3. Then “push” the `Canvas` back out to the rest of the world, basically saying “we’re done drawing, you can show it to the user now”.

Overall, this process will cause the Surface to “redraw” as fast as possible, all without blocking the UI thread! This is great for animation, which can be controlled and timed (e.g., in the `update()` helper method by only updating variables at a particular rate). Moreover, it provides a drawable surface that can be interacted with!

And that gives us a drawable surface that we can interact with in the same way, using the same kind of movement/interaction logic.

- This demonstrates one way to create low-level game and animation logic using basic Java work; no specific game engines are required (though those exist as well).

15.2 Touch and Gestures

As this point we have some simple animation and movement, but we would like to make it more interactive. Our `View` takes up the entire screen so we don’t want to add buttons, but there are other options available.

In particular, we can add Touch Gestures. Touch screens are a huge part of Android devices (and mobile devices in general, especially since the first iPhone) that are incredibly familiar to most users. We’ve already indirectly used the touch interface, with how we’ve had users click on buttons (theoretically using the touch screen). But here we’re interested in more than just button clicks, which really could come from anywhere: instead, how we can react to *where* the user might touch the screen and even the different ways the user might *caress* the screen: flings, drags, multi-touch, etc.

Android devices automatically detect various touching interactions (that’s how buttons work); we can respond to these **touch events** by overriding the `onTouchEvent()` callback, which is executed whenever there something happens that involves the touch screen

- For example, we can log out the event to see the kind of details it includes.

There are *lots* of things that can cause `TouchEvents`, so much of our work involves trying to determine what *semantic* “gesture” the user made. Luckily, Android provides a number of utility methods and classes to help with this.

The most basic is `MotionEventCompat.getActionMasked(event)`, which extracts the “action type” of the event from the motion that was recorded:

```
int action = MotionEventCompat.getActionMasked(event); //get action constant
float x = event.getX(); //get location of event
float y = event.getY() - getSupportActionBar().getHeight(); //closer to center...

switch(action) {
    case (MotionEvent.ACTION_DOWN) : //put finger down
        //e.g., move ball
        view.ball.cx = x;
        view.ball.cy = y;
        return true;
    case (MotionEvent.ACTION_MOVE) : //move finger
        //e.g., move ball
        view.ball.cx = x;
        view.ball.cy = y;
        return true;
    case (MotionEvent.ACTION_UP) : //lift finger up
    case (MotionEvent.ACTION_CANCEL) : //aborted gesture
    case (MotionEvent.ACTION_OUTSIDE) : //outside bounds
    default :
        return super.onTouchEvent(event);
}
```

This lets us react to basic touching. For example, we can make it so that taps (`ACTION_DOWN`) will “teleport” the ball to where we click! We can also use the `ACTION_MOVE` events to let us drag the ball around.

15.2.1 Advanced Gestures

We can also detect and react to more complex gestures: long presses, double-taps, or “flings” (a flick or swipe on the screen). As these gestures, the Material Design specification details some specific patterns that you should consider when utilizing these interactions

Android provides a `GestureDetector` class that can be used to identify these actions. The easiest way to use this class—particularly when we’re interested in a particular gesture (like fling)—is to *extend* `GestureDetector.SimpleOnGestureListener` to make our own “listener” for gestures. We can then override the callbacks for the gestures we’re interested in responding to: e.g., `onFling()`.

- Note that the official documentation says we should also override the `onDown()` method and have it return `true` to indicate that we’ve “con-

sumed” (handled) the event—similar to what we’ve done with Options-Menus. If we return false from this method, then *“the system assumes that you want to ignore the rest of the gesture, and the other methods of GestureDetector.OnGestureListener never get called.”* However, in my testing the gesture detection works either way, but we’ll follow the spec for now.

We can instantiate a `GestureDetector` by passing in our listener into a `GestureDetectorCompat` constructor:

```
mDetector = new GestureDetectorCompat(this, new MyGestureListener());
```

Then in the Activity’s `onTouchEvent()` callback, we can pass the event into the `GestureDetector` to process:

```
boolean gesture = this.mDetector.onTouchEvent(event); //check gestures first!
if(gesture){
    return true;
}
```

- Since the detector’s `onTouchEvent()` returns a `boolean` for whether or not a gesture was detected, we can check for whether we should otherwise handle the gesture ourselves.

This gives us the ability to “fling” the Ball by taking the detecting fling *velocity* and assigning that as the Ball’s velocity. Note that we need to negate the velocities since they are registered as “backwards” from the coordinates our drawing system is utilizing expect (though this doesn’t match the documented examples). Scaling down the velocity to 3% produce a reasonable Ball movement speed. work okay for me. We can also have the Ball slow down by 1% on each update so it drifts to a stop!

15.3 Property Animation

We’ve seen how we can create animations simply by adjusting the drawing we do on each frame. This is great for games or other complex animations if we want to have *a lot* of control over our graphical layout... but sometimes we want to have some simpler, platform-specific effects (that run smoother!) Android actually involves a number of different animation systems that can be used within and *across* Views:

- We’ve previously talked about some Material Animations built into the Material Design support library; in particular we discussed creating Activity transition. Android also includes a robust framework for Scene Transitions even outside of Material; see Adding Animations for more details.

- Android also supports OpenGL Animations for doing 3D animated systems. This requires knowing the OpenGL API.

In this section, we will discuss how to use **Property Animation**. This is a general animation framework in which you specify a start state for an Object *property* (attribute), an end state for that property, and a duration for the animation; the Android systems then changes the property from the start state to the end over that length of time—thereby producing animation!

- The change in property state over time (that is, at any given “frame”) is calculated using **interpolation**. This is basically a “weighted average” between the the start and end states, where the weight is determined by how close you are to the “start” or “end”. While we often use *linear interpolation* (so that being 70% across means the end gets 70% of the weight), it is also possible to use *non-linear interpolation* (e.g., you need to get 70% across in for the end to have 50% of the weight).

The main engine for doing this kind of interpolated animation in Android is the `ValueAnimator`² class. This class lets you specify the start state, end state, and animation duration. It will then be able to run through and calculate all of the “intermediate” values throughout the interpolated animation. The `ValueAnimator` class provides a number of static methods (e.g., `.ofInt()`, `.ofFloat()`, `.ofArgb()`) which creates “animators” for interpolating different *value types*. For example:

```
ValueAnimator animation = ValueAnimator.ofFloat(0f, 1f); //interpolate between 0 and 1
animation.setDuration(1000); //over 1000ms (1 second)
animation.start(); //run the animation
```

Of course, just performing this interpolation over time doesn’t produce any visible result—it’s changing the numbers, but those numbers don’t correspond to anything.

We can access the interpolated values by registering a listener and overriding the callback we’re interested in observing (e.g., `onAnimationUpdate()` from `ValueAnimator.AnimatorUpdateListener`). But more commonly, we want to have our interpolated animation change the *property* of some object—for example, the color of a `View`, the position of an `Button`, or the instance variables of an object such as a `Ball`.

We can do this easily using the `ObjectAnimator`³ subclass. This subclass runs an animation just like the `ValueAnimator`, but has the built-in functionality to change a property of an object on each interpolated step. It does this by calling a **setter** for that property—thus the object needs to have a setter method for the property we want to animate:

²<http://developer.android.com/guide/topics/graphics/prop-animation.html#value-animator>

³<http://developer.android.com/guide/topics/graphics/prop-animation.html#object-animator>

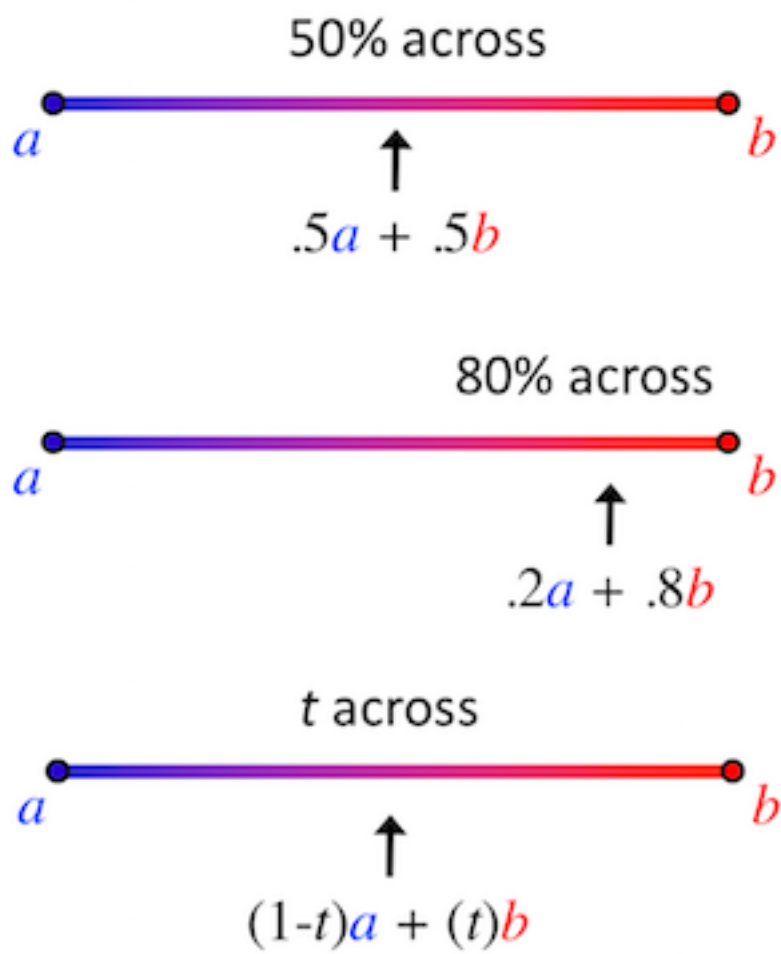


Figure 15.1: Linearly interpolating colors

```
//change the "alpha" property of foo: will call `foo.setAlpha(float)`
ObjectAnimator anim = ObjectAnimator.ofFloat(foo, "alpha", 0f, 1f);
anim.setDuration(1000);
anim.start();
```

- This example will mutate the object by calling the `setAlpha()` method (the name of the method is generated from the property name following normal CamelCasing style).
- If the object lacks such a setter, such as because we are using a class provided by someone else, we can either make a “wrapper” which will call the appropriate mutating function, or just utilize a `ValueAnimator` with an appropriate listener.

For example, we can use this approach to change the Ball’s radius or position using an interpolated animation (make it “pulse”).

- Note that we’re just changing the object property; the only reason we see the changed display is because the `SurfaceView` is refreshing continuously.

The `ObjectAnimator` interpolator methods support a number of variations as well: - As long as the object has an appropriate **getter**, it is possible to only pass the Animator an ending value (indicating that the animation should interpolate “from current state to specified end state”) - We can use `.setRepeatCount(ObjectAnimator.INFINITE)` and `.setRepeatMode(ObjectAnimator.REVERSE)` to cause it to repeat back and forth.

If we want to include multiple animations in sequence, we can use an `AnimatorSet`, which gives us methods used to specify the ordering:

```
//example from docs
ObjectAnimator animX = ObjectAnimator.ofFloat(obj, "x", 50f);
ObjectAnimator animY = ObjectAnimator.ofFloat(obj, "y", 100f);
AnimatorSet animSetXY = new AnimatorSet();
animSetXY.playTogether(animX, animY);
animSetXY.start();
```

`AnimatorSet` animations can get complicated, and we may want to reuse them. Thus best practice is to instead define them in XML as resources. Animation resources are put inside the `/res/animator` directory (**not** the `/res/anim/` folder, which is for View Animations).

```
<set android:ordering="together"> <!-- together is default -->
  <objectAnimator
    android:propertyName="x"
    android:duration="500"
    android:valueTo="400"
    android:valueType="intType"/>
```

```
<!-- ... -->
</set>
```

- See Property Animation Resources⁴ for the full XML schema.
- Note that by defining animations as resources, it also means that we can easily have different device configurations use different animations (e.g., perhaps objects move faster on larger displays).

In order to utilize the XML, we will need to **inflate** the Animator resource, just as we have done with Layouts:

```
ObjectAnimator anim = (ObjectAnimator)AnimatorInflater.loadAnimator(context, R.anim.my_animation);
anim.setTarget(myObject);
anim.start();
```

Note that we can also use this same framework to animate changes to **Views**: Buttons, Images, etc. Views are objects and have properties (along with appropriate *getter* and *setter* methods), so we can use just an **ObjectAnimator**! See Animating Views for a list of properties we can change (a list that includes `x`, `y`, `rotation`, `alpha`, `scaleX`, `scaleY`, and others)

To make this process even simpler, Android also provides a **ViewPropertyAnimator** class. This Animator is able to easily animate multiple properties together (at the same time), and does so in a much more efficient way. We can access this Animator via the `View#animate()` method. We then call relevant shortcut methods on this Animator to “add in” additional property animations to the animation set:

```
//animate x (to 100) and y (to 300) together!
myView.animate().x(100).y(300);
```

This allows you to easily specify moderately complex property animations for **View** objects.

- But really, if you want to animate layout changes on a modern device, you should use transitions, such as the ones we used with Material design.

There are many more ways to customize exactly what you want your animation to be. You can also look at official demos for more examples of different styles of animation.

⁴<http://developer.android.com/guide/topics/resources/animation-resource.html#Property>

Chapter 16

Databases and Providers

This lecture provides an in-depth discussion of working with **Databases** and **Content Providers** in Android. *Accessing* Content Providers (via a Loader) was discussed in a previous lecture. This lecture will instead talk about how to make your own database and a provider for it.

Databases are appropriate when you want to store data *locally* on the device (e.g., not on the cloud, which may require expensive network transactions as well as user accounts), but that data has greater scale or complexity than is appropriate for a SharedPreferences XML file—that is, you need to store more than just key-value pairs.

This lecture references code found at <https://github.com/info448-s17/lecture17-databases>.

Note that the initial version of this program accesses the device’s User Dictionary, which is only available to on API 22 (Lollipop) *or earlier*. The tutorial does support all versions of Android.

16.1 Review: Providers and Loaders

As discussed previously, a **Content Provider** is an abstraction for a source of structured data (like a database, but also possibly files, internet resources, etc). It acts as an interface for interacting with that data, supporting the developing in reading, adding to, updating, or deleting data from the source (e.g., the basic CRUD operations).

The lecture reference code demonstrates again how to access and modify structured data—specifically the User Dictionary—via a Content Provider using a Loader. You can read this example to review how to utilize an existing Provider:

- The application displays a `ListView`, which is backed by a `SimpleCursorAdapter`. This adapter takes a “cursor” (think: a “pointer” or an `Iterator`—also a list of data that has been loaded *into memory*) and connects each item to a `View` on the screen. This `View` shows the word (`WORD`) and the “frequency”/prominence (`FREQUENCY`) of that word.
- In order to get this list of items into memory from data store itself (to perform the **read** operation), we set up a `Loader`. The `Loader` fetches 3 “columns” (attributes) from the data store: `_ID`, `WORD`, and `FREQUENCY`; the `_ID` field is *not* shown on the `View`, but the `Loader` needs that to keep track of the displayed items). We do not utilize any selection or sorting criteria, though we could add them in if we wanted.

The loader fetches (*queries*) data from the data store to load it into memory. It then tells the `Adapter` to take that loaded data and display it in the `View`. By using a `Loader` for this process, we gain two benefits: (1) the data is loaded into memory *on a background thread* (not the `UI Thread`), and (2) the data is *automatically reloaded* when the data store’s content changes.

- The example also supports the **create** operation: by clicking the “Add Word” button, we can *insert* a new entry into the data store represented by the `Content Provider`. We construct a `ContentValues` object (similar to a `Bundle`, but for `Content Providers`) that contains the attribute values for the new provider entry. We then use the `ContentResolver` to `insert()` this item into the `Provider` (indicated by its `URI`).
- Finally, the example supports the **update** operation: by clicking the on an item in the list, we can *update* that entry in the data store (increasing the word’s frequency). We get the `Cursor` containing the items from the `AdapterView`, with the “pointer” of that `iterator` set to the item that was clicked on. We then again use the `ContentResolver` to `update()` the item with the a `ContentValues` bundle of the fields we wish to change.
 - Note that we make sure to update only that particular item by specifying the *URI of that item*. We do this by constructing a new `URI` representing/identifying that item, effectively by appending `"/:id"` to the `URI`. This means that we don’t need to use the selection criteria (though we could do that as well).

To review: the `Content Provider` acts as the data store, abstracting information at some location (e.g., in a database). The `Loader` grabs a bunch of rows and columns from that database, and hands it to the `Adapter`. The `Adapter` takes a subset of those rows and columns and puts them in the `ListView` so that they display to the user. User interaction allows us to add or modify the data in that database.

16.2 SQLite Databases

Content Providers can abstract all kinds of data stores (files, urls, etc.). They abstract these as a *structured information* similar to a database... and in fact the most common kind of store they represent is a relational database (specifically, an SQLite database). Android comes with an API for creating and querying a database; these databases are stored on *internal storage* meaning that each application can have its own private database (or multiple databases, in fact)!

If you have worked with SQL or another relational database system (e.g., in the iSchool's INFO 340 course), this interaction will seem familiar. If you've never worked with a database, the simplest explanation is to think of them as a spreadsheet (like in an Excel file) where you manipulate *rows* of data given a set of pre-defined *columns*. SQL (Structured Query Language) is its own command language for working with these spreadsheets; we'll see some samples of those queries in this lecture. SQLite is a "flavor" (version) of SQL; the full SQLite spec can be found [here](#). A short tutorial (borrowed from Google) is also available in the code repository.

In this lecture, we will build our own database of words (separate from the User Dictionary—and so which will work on API 23+) that we can access through a Content Provider. We will simply change *which* "data store" is being accessed; the rest of the application's interface will remain the same. This will let us demonstrate how to put together a Content Provider from scratch. We will start by setting up the database, and then implementing the `ContentProvider` that abstracts it.

- Setting up a database is somewhat wordy and round-about, though it does not involve many new concepts.

The step to effectively utilizing a database in Android is to create a class (e.g., `WordDatabase`) to act as a "namespace" for the various pieces of our database. This class will not be instantiated (and so could even have a `private` default constructor).

The `WordDatabase` class will contain a number of *constants*:

- `DATABASE_NAME` to refer to the name of the database file stored on the device (e.g., `words.db`)
- `DATABASE_VERSION` to refer to the current version number of our database's schema. This is used more for supporting migrations like if we want to update our database later.

We're then going to specify constants that define the database's **schema** or **contract**. This is so that other classes (e.g., the `ContentProvider` and the `MainActivity`) can refer to column names consistently without having to remember or even know the specific text we utilize in the database. This is similar to how we used the variable `UserDictionary.Words.WORD` rather than the `String` value `"word"`. By convention, we define this schema as a separate

static nested class (e.g., `WordEntry`), to keep things organized. This class contains the constants to hold the column names:

```
static class WordEntry implements BaseColumns {
    //class cannot be instantiated
    private WordEntry(){}

    public static final String TABLE_NAME = "words";
    public static final String COL_WORD = "word";
    public static final String COL_COUNT = "count";
}
```

- The class implements `BaseColumns`, which lets it inherit a few framework specific constants for free—in particular, the `_ID` variable which Content Providers rely on the database to have.
- We create a different nested class for each table in the database (sheet in a spreadsheet). This allows us to use Java-style namespacing (dot notation) to refer to different tables in a single database.

Once we have defined the schema, we are ready to create and work with the database. In order to help us do this, we're going to use a class called `SQLiteOpenHelper`. This class offers a set of methods to help manage the database being created and upgraded (e.g., for migrations). Specifically, we will *subclass* `SQLiteOpenHelper`, creating another nested class that represents the specific helper for our database.

The subclass has a constructor that takes in a `Context`, and then “passes up” the database name and version to the parent class.

```
public DatabaseHelper(Context context){
    super(context, DATABASE_NAME, null, DATABASE_VERSION);
}
```

`SQLiteOpenHelper` also has two abstract methods (event callbacks) that we need to implement: what happens when the database is *created*, and what happens when the database is *upgraded*.

When the database is first created, we'll need to actually create the table to hold our words. This involves sending it an SQL command to create the table! We'll write this out as yet another constant for readability.

```
private static final String CREATE_TASKS_TABLE =
    "CREATE TABLE " + WordEntry.TABLE_NAME + "(" +
        WordEntry._ID + " INTEGER PRIMARY KEY AUTOINCREMENT" + ", " +
        WordEntry.COL_WORD + " TEXT" + ", " +
        WordEntry.COL_COUNT + " INTEGER" +
    ")";

private static final String DROP_TASKS_TABLE =
```

```
"DROP TABLE IF EXISTS "+ WordEntry.TABLE_NAME;
```

- We can do the same for dropping (deleting) the table as well.
- This is the only SQL we will write in this tutorial.

We can run these SQL statements by using the `execSQL()` method, called on the `SQLiteDatabase` object that is passed to these callbacks. Note that this runs a “raw” SQL query (that doesn’t return anything, so not `SELECT`), without any kind of checks against SQL injection attacks. But since we’re hard-coding the information to run, it’s not a problem. Aside from this situation, you should *never* use this method.

- We can also use the `insert()` method to add some sample words to the database (similar to how we used the Content Provider), for clarity when testing:

```
ContentValues sample1 = new ContentValues();
sample1.put(WordEntry.COL_WORD, "Embiggen");
sample1.put(WordEntry.COL_COUNT, 0);
db.insert(WordEntry.TABLE_NAME, null, sample1);
```

- In the `onUpdate()` callback, we’ll just “drop” the table and recreate it (by calling `onCreate()`).

If we want to interact with this database in `MainActivity`, we can initialize the `DatabaseHelper` object (which will create the database *if needed*) and then use that helper to fetch the database we want to query (using `getReadableDatabase()`).

- Note that querying a database could take a long time, and so we should *not* be doing it on the UI Thread... this example is simply for testing.

We can check that our database is set up correctly in one of two ways:

- We can directly explore the SQLite database that is on your device by using `adb` and the `sqlite3` tool. See this link for more details.

```
$ adb -s emulator-5554 shell
# sqlite3 /data/data/edu.uw.package.name/databases/words.db
# sqlite> select * from words;
# sqlite> .exit
```

- We can call a `query()` method on our `SQLiteDatabase`, and log out the results. A `SQLiteQueryBuilder` can offer some help if our query was going to be complex (e.g., with `JOIN`):

```
SQLiteQueryBuilder builder = new SQLiteQueryBuilder();
builder.setTables(WordDatabase.WordEntry.TABLE_NAME); //set the table to use

Cursor results = builder.query(
    db,
```

```

        new String[] {WordDatabase.WordEntry.COL_WORD, WordDatabase.WordEntry.COL_FREQ,
            null, null, null, null, null}); //5 nulls!

while(results.moveToNext()) {
    String word = results.getString(results.getColumnIndexOrThrow(WordDatabase.WordEntry.COL_WORD));
    int freq = results.getInt(results.getColumnIndexOrThrow(WordDatabase.WordEntry.COL_FREQ));
    Log.v(TAG, ""+word+" ("+"freq+"");
}

```

- This is the exact same Cursor processing work used when logging out the clicked item, but using our column names instead!
- We could even remove the Loader call and just pass in this query directly to the Adapter, if we wanted to display our database in the list.

Voila, we have a database that we can call methods on to access!

16.3 Implementing ContentProvider

We don't want to do this database creation and querying on the main thread (because it may take a while). And since we also want to easily let our `ListView` update when the database changes, we like to be able to use a Loader to access this database. In order to use a Loader, we need to wrap the database in a `ContentProvider`.

There are a lot of steps and a lot of code involved in making a `ContentProvider`, and most of them are “boilerplate” for most databases. So much so that there is thorough example code in the Google documentation, which you can copy-and-paste from as needed.

We'll start by creating another class that extends `ContentProvider` (*can you understand why?*). Since this will have a lot of abstract methods we'll need to fill in, so we can actually use one of Android Studio's generators via **New > Other > Content Provider** to help us along (I normally say not to use these, but with the `ContentProvider` it's not too messy).

We will have to specify an **authority** for the Provider. This acts as a unique, Android-internal “name” for the database (to indicate which it is, or who “owns” it). This is the “name” by which others will be able to refer to our particular Provider. This is thus sort of like a package name—and in fact, we usually use the package name with an extra `.provider` attached as the authority name.

Also notice that an entry for this `<provider>` has been added to the `Manifest`, including the authority name. `android:enabled` means the Provider can be instantiated, and `android:exported` means it is available to other applications.

16.3.1 URIs and Types

The most important piece of a `ContentProvider` (that makes it more than just helper methods for a database) is how it can be accessed at a particular **URI**. So the first thing we need to do is specify this URI for our provider.

- We'll actually want to specify *multiple* URIs. This is because each piece of content we provide (each record in the database!) is itself a distinct *resource*, and thus should have its own URI. Thus we need to design a **schema** for the URIs so that we know how to refer to each kind of content offered by our provider.

Designing a URI schema is like designing a URL structure for a website; this will feel familiar to specifying *routes* for a web application.

The most common URI approach for Content Providers is to give each resource we provide a URI of the format:

```
content://authority/resource/id
```

- This URI indicates that it is a identifier for a particular provider (the *authority*), which has a particular *resource* type (think: which database table of information), which may have a particular resource *id* (think: the ID of the record in the table)
- Leaving off the *id* would refer to the entire table, or rather the “list” of resources. So really we have two different “categories” of URIs: the whole list, and an individual resource within that list. Both have the same “base”, but will need to be handled slightly differently.
- See designing content URIs for more discussion on how to structure these.

We will define these URIs piece-wise using constants (of course). One for the *authority*, one for the *resource type* (which happens to be the name of the database table, but doesn't need to be), and finally the overall Content URI (parsed into a `Uri` object):

```
public static final Uri CONTENT_URI =
    Uri.parse("content://" + AUTHORITY + "/" + WORD_RESOURCE);
```

But we also need to handle both types of resources: the “list” of words, and the individual words themselves. To enable this, we're going to use a class called a `UriMatcher`. This class provides a *mapping* between URIs and the actual “type” of data we're interested in (either lists or word objects). This will help us do “routing” work, without needing to parse the path of the URI ourselves.

- We'll represent the “type” or “kind” with `int` constants, allowing us to easily refer to “which” kind of resource we're talking about.

```
//integer values representing each supported resource Uri
private static final int WORD_LIST_URI = 1; // /words
private static final int WORD_SINGLE_URI = 2; // /words/:id
```

- So if you give me a `/words` URI, I can tell you that you’re interested in “resource kind #1”

We want to make a `static UriMatcher` object (like a constant) that we can use to do the mapping... but because it takes more than one line to set this up (we add an entry for each mapping), we need to put it inside a `static` block so that all this code is run together:

```
private static final UriMatcher sUriMatcher; //for handling Uri requests
static {
    //setup mapping between URIs and IDs
    sUriMatcher = new UriMatcher(UriMatcher.NO_MATCH);
    sUriMatcher.addURI(AUTHORITY, WORD_RESOURCE, WORD_LIST_URI);
    sUriMatcher.addURI(AUTHORITY, WORD_RESOURCE + "/#", WORD_SINGLE_URI);
}
```

- Note the wildcard `#`, meaning “any number” (after the slash) will “match” this URI.

We can then figure out which “kind” of task by using the `UriMatcher#match(uri)` method, which will return the “kind” `int` that matches the given Uri.

As an example of this, let’s fill in the `getType()` method. The purpose of this method is to allow the ContentProvider to let whoever queries it know the MIME Type (media type) of the resource a URI is accessing. This lets the program specify whether the content provided by the Content Provider is an image, text, music, or some other type.

- The type we’re going to give back is a `Cursor` (list of rows in a table), so we’ll specify MIME Types for that:

```
public String getType(Uri uri) {
    switch(sUriMatcher.match(uri)){
        case WORD_LIST_URI:
            return "vnd.android.cursor.dir/"+AUTHORITY+"."+WORD_RESOURCE;
        case WORD_SINGLE_URI:
            return "vnd.android.cursor.item/"+AUTHORITY+"."+WORD_RESOURCE;
        default:
            throw new IllegalArgumentException("Unknown URI "+uri);
    }
}
```

- `vnd` stands for “vendor specific”—in this case, a format specific to Android.

16.3.2 Query Methods

Once all of the URIs are specified, we can start responding to requests for content at those URIs. Specifically, when a request for content at a URI comes

in, we're going to fetch data from the *database* we made earlier and then return that data. We handle these “requests” through 4 different methods: `query()`, `insert()`, `update()`, and `delete()` (mirroring the CRUD operations, drawing on standard SQL query names). We will fill in those methods to have them fetch and return the database data.

First, we need to get access to the database (through a helper), just as we did in the `MainActivity`. We'll instantiate the `DatabaseHelper` in the `ContentProvider#onCreate()` callback, saving that helper as an instance variable to reference later. Then in the CRUD methods (which will be executed *in a background thread*), we can call `getWritableDatabase()` to get access to that database.

We will start with implementing the `query()` method. Basically, we need to do the same query we used in `MainActivity`—though can pass in the extra query parameters (e.g., `projection`, `selection`, `sortOrder`) instead of always having them be `null` or defined manually.

However, we also need to be able to handle both types of resources that our Provider serves (lists or single words). We can use the `UriMatcher` to determine how to adjust our query: for example, by using the `UriBuilder#appendWhere()` method to add a “selection” argument:

```
switch(sUriMatcher.match(uri)){
    case WORD_LIST_URI: //all words
        break; //no change
    case WORD_SINGLE_URI: //single word
        builder.appendWhere(WordDatabase.WordEntry._ID + "=" + uri.getLastPathSegment()); //rest
    default:
        throw new IllegalArgumentException("Unknown URI "+uri);
}
```

We'll then just return the `Cursor` that we get as a result of the query.

But there is also one more piece. We want to make sure that the Loader that is reading from our Content Provider (that loaded this `Cursor` object) is notified of any changes to the results of its query. This will allow the Loader to “automatically” query for new content if any of the data *at that URI* changes.

```
cursor.setNotificationUri(getContext().getContentResolver(), uri);
```

With this step in place, we can go back to our `MainActivity` and swap all the column names and URIs for our own custom `WordProvider`! Rerun the app... and voila, we see our own list of words!

We can do basically the same thing to support `insert()` and `update()` to enable all of our use cases.

- Use the `UriMatcher` to make to only respond to proper Uris—you can't insert into a single record, and you can't update the entire list.

```

if(sUriMatcher.match(uri) != WORD_LIST_URI) {
    throw new IllegalArgumentException("Unknown URI "+uri);
}

```

- For insert(), it is also possible to make sure that no “empty” entries are added to the database, and to return the result if the insertion is successful:

```

if(!values.containsKey(WordDatabase.WordEntry.COL_WORD)){
    values.put(WordDatabase.WordEntry.COL_WORD, "");
}
if(!values.containsKey(WordDatabase.WordEntry.COL_COUNT)){
    values.put(WordDatabase.WordEntry.COL_COUNT, 0);
}

long rowId = db.insert(WordDatabase.WordEntry.TABLE_NAME, null, values);
if (rowId > 0) { //if successful
    Uri wordUri = ContentUris.withAppendedId(CONTENT_URI, rowId);
    getContext().getContentResolver().notifyChange(wordUri, null);
    return wordUri; //return the URI for the entry
}
throw new SQLException("Failed to insert row into " + uri);

```

- The update() method can be somewhat awkward because we need to basically add our id restriction to the user-given selection args:

```

int count;
switch (sUriMatcher.match(uri)) {
    case WORD_LIST_URI:
        count = db.update(WordDatabase.WordEntry.TABLE_NAME, values, selection, selectionArgs);
        break;
    case WORD_SINGLE_URI:
        String wordId = uri.getLastPathSegment();
        count = db.update(WordDatabase.WordEntry.TABLE_NAME, values, WordDatabase.WordEntry.COL_WORD + " = " + wordId + (!TextUtils.isEmpty(selection) ? " AND (" + selection + ')' : ""));
        break;
    default:
        throw new IllegalArgumentException("Unknown URI " + uri);
}
if (count > 0) {
    getContext().getContentResolver().notifyChange(uri, null);
    return count;
}
throw new SQLException("Failed to update row " + uri);

```

But in the end, we have a working ContentProvider that supports the same behaviors as the built in User Dictionary (well, except for delete()). We can

now store data in our own database and easily access it off the UI Thread for use in things like ListViews. This is great for if you want to track and store any kind of structured information in your apps.

Chapter 17

Publishing

This short chapter discusses how to publish your Android application, producing a version of the app that can be shared with others. In particular, it explains how to cryptographically sign your app and build it so it can be installed by people who are not using Android Studio.

Before you actually distribute your application, you should make sure it is fully ready to be published. Google provides an excellent list of things to do before releasing your application, as well as a more detailed checklist for releasing an app on the Play Store.

- For example: remove extraneous Logging commands, check for accessibility and localization, etc.

Once you have completed these steps, you are ready to build and sign your app.

17.1 Signing an App

As described in lecture 1, building an Android application involves compiling Java and XML code into DVM bytecode, and then packing this code (along with assets and graphics) into a `.apk` file.

But in order to install this `.apk` file onto a device, it needs to be **cryptographically signed** by including a **public-key certificate**. This certificate acts somewhat like a “password”, in that it corresponds with a *private key* (a secret code) held by you as the developer. Because each public-key cert is associated with a code only you as the developer know (like a password), it is able to act as an identifying *signature* for your app: only you know the secret password, so only you are able to provide this particular certificate. Thus by *signing* the `.apk` with your signature, you are marking the package as being developed by you and not someone else (just like a signature on a check). Android uses these

signatures as a security feature to ensure that any future updates come from the same person (no malicious app updates!), as well as to help verify the source of an installed package.

- The secret *private keys* are stored on your computer in **.keystore** files (think: a database of private keys). You may have multiple different keystores on your machine.

By default, when you build and run an app in Android Studio, the IDE automatically generates a **debug certificate** for you to sign your application with. This certificate is not secure (it's an automatically generated password!) so isn't trustworthy for app stores (like the Play Store)... but it is sufficient for being able to install and run your application through Android Studio.

- By default keys are stored in the `~/.android` folder on Mac and Linux, and the `C:\Users\USER_NAME\.android\` folder on Windows. You can view the debug key (e.g., on Mac) using the command:

```
keytool -list -v -keystore ~/.android/debug.keystore -alias androiddebugkey -storepass android
```

- The `-alias` is a name of the particular certificate, and the `-storepass` and `keypass` arguments are literal passwords associated with the store (database) and certificate (in the database) respectively. The fact that this store is password protected is what makes it accessible only to the developer.
- Scroll down to see the “Certificate fingerprints”; for example, the SHA1 certificate is used when getting a Google Maps API key.
- Importantly, each computer running Android Studio will produce its own *debug certificate*. That means that the “signature” identifying your app will differ for every different computer: even if it has the same package and the same source code, Android will consider it a “different” program because it was built (in debug mode) on a different machine. This is particularly important when things like API keys (e.g., for Google Maps) are linked to a particular digital signature; it means that *each* development machine would need to have its unique signature associated with the API!

In addition to the automatically generated *debug certificates*, you can sign apps with your own generated **release certificate**. This is a certificate not automatically created by Android Studio, but is still associated with a secret “password” that only you know. These certificates are also stored in a **.keystore** file, which is created and password-protected by the developer. Because this keystore is kept secret and locked, only the developer is able to sign the built **.apk** with a verifiable signature, thereby ensuring that any updates to the application must have come from that developer.

I like to think of *debug certificates* as like cheap, easily-reproducible Bic pens, and *release certificates* like fancy golden quills. When multiple developers are working on an app, each will be signing their testing versions with their own cheap Bics, but when it comes to releasing the project, you need to get out the

expensive golden quill to do the signing. In this metaphor, the `.keystore` file is a pen case.

17.1.1 A Release `.apk`

In order to generate a shareable **release `.apk`**, you will need to produce a *release certificate* to sign the app with, then build and sign the `.apk` with that certificate.

Android studio makes it easy to sign a release build (follow the link for more details and examples). In short, select **Build > Generate Signed APK** from the menu, and follow the wizard's instructions!

- You will be prompted for a location for the `.keystore` file to use (e.g., where to store your release pens). I recommend making a file somewhere in your user's home directory (e.g., `~/android-release.jks`). Note that you can use the same private key (found in the keystore) for multiple apps.
- It is also possible to configure Android Studio to automatically sign your application when building for release. Be sure you remove signing information from your build files so your passwords don't get uploaded to GitHub!

The built and signed `.apk` will be created in the destination folder you selected. This file can then be shared: uploaded to the Google Play Store, hosted on a web page, or emailed directly to someone to install.

- Note that installing `.apk` files from outside the Play Store—even when signed—requires the user to opt-in for apps from unknown sources.

Chapter 18

Special Topics: Kotlin

This lecture introduces Kotlin, an open source programming language that runs on the Java Virtual Machine and is fully interoperable with Java Code. It is designed to be a more concise, more flexible, and faster alternative to Java while offering language-level support to features such as `null`-checking and functional programming techniques. As of May 2017, Google offers first-class support for using Kotlin when developing Android applications.

- Kotlin was developed by JetBrains, the creators of the IntelliJ IDE which forms the basis for Android Studio.

This lecture references code found at <https://github.com/info448-s17/lecture16-kotlin>. Kotlin demo code can be found in the `kotlin` folder; build and run this code through gradle with the command `gradle -q`.

- Note that the provided gradle build script includes the Kotlin standard library for Java 8, making (simplified) versions of Java classes available.

18.1 Kotlin Syntax

The Kotlin language draws many syntactical structures from popular modern languages, including JavaScript and Swift (used for iOS development); I find it has a lot in common with TypeScript.

The full documentation for the Kotlin language can be found at <https://kotlinlang.org/docs/reference/>; practice and examples are available in the form of Kotlin Koans. This lecture does not aim to be a complete reference but rather to highlight some of the most noticable or interesting aspects of the language.

18.1.1 Variables

Kotlin variables are *declared* by using the keyword **var** (for mutable variables) or **val** (for read-only variables); this is similar to **let** and **const** in JavaScript ES5. Like Java, Kotlin is a statically-typed language—the variable type is written *after* the variable name, separated by a colon (:). For example:

```
val x:Int = 448 //read-only
var stepCount:Int = 9000 //mutable
stepCount++ //can change the variable
val message:String = "Hello" + " " + "world" //supports normal operators
```

Notice that each of these statements **lacks semicolons**! Similar to many scripting languages, statements can be separated either by a colon or by a newline.

In Kotlin, primitive types (e.g., **int**, **double**, **boolean**) are implemented using classes, allowing for all values to support instance methods and variables (called *properties*). These classes are named after their Java equivalents (though of course start with a capital letter, since they are classes!)

- The compiler optimizes the types to avoid extraneous overhead.

Additionally, variable type can often be **inferred** from the assigned value, so may be omitted:

```
var x = 448 //`Int` type is inferred
x-40 //valid mathematical operation
```

- Note even without the explicit type declaration, the variable *is strongly typed*—it’s just that the variable type is determined by the compiler. I encourage you to include the explicit type declaration, particularly when it helps clarify the semantic meaning of the variable.

One of Kotlin’s major features is null safety, or the ability to catch null-pointer errors *at compile time*. In Kotlin, we need to explicitly declare that a variable can be assigned null as a value. We do this by including a question mark **?** immediately after the type declaration:

```
var message:String = "Hello"
message = null //compilation error!

var possiblyNull:String? = "Hello"
possiblyNull = null //no problems!
```

- Kotlin provides a number of other structures using the **?** to check for and handle null values; see Null Safety for details.

Basic Kotlin types work pretty much the same as basic Java types. A few notable differences and features:

- *Warning:* Because of the classes Kotlin uses for numeric types, it is unable to automatically convert to a “larger” type (e.g., from **Int** to **Double**).

This casting needs to occur explicitly:

```
val integer:Int = 5
var root:Double = Math.sqrt(integer) //compile type error!
                                     //sqrt() takes in a double
root = Math.sqrt(integer.toDouble()) //no problems!
```

- *Fun feature:* in Kotlin, numeric literals can be written with underscores (`_`) as readability separators; the underscores are removed during compile time.

```
val oneMillion:Int = 1_000_000
```

- *Fun feature:* Kotlin also supports string templating, in which variables used within the String are automatically evaluated (avoiding the need for complex String concatenation). Variables to evaluate are prepended with a dollar sign `$`, while more complex expressions can be evaluated from inside `${}`

```
val quantity = 5
val price = 2.95
val cost:String = "$quantity items at $price costs ${quantity*price}"
```

- *Note:* Arrays in Kotlin are represented by the `Array<T>` class. The `Array<T>` class has a private constructor though; in order to create an array, use the `arrayOf()` factory method (to create an array out of the given parameters), or `arrayOfNulls()` to create an array of *n* null elements. Note that arrays still support using *bracket notation* (`[]`) for accessing values.

```
var numbers:Array<Int> = arrayOf(1,2,3,4,5) //create an array
println(numbers.size) //kotlin uses `size` property for array length
println(numbers[3]) //4
numbers[4] = 10 //assign value as normal
```

- Kotlin also provides specialized classes for arrays of basic types, e.g., `IntArray`

18.1.2 Functions

Kotlin functions are in some ways closer to JavaScript functions than to Java methods. For one, Kotlin supports package-level functions that do not exist as members of a particular class, as an alternative to `static` functions in Java. Thus we can talk about Kotlin functions independent of classes (which are discussed below).

Functions in Kotlin are declared with the **fun** keyword (not because they are fun, though they can be). This is followed by the name of the function and the

parameter list (where the parameters are given explicit types). The return type is declared *after* the parameter list, following a colon (:). For example:

```
fun makeFullName(first:String, last:String): String {
    val full = first + " " + last
    reurn full
}

val fullName = makeFullName("Ada", "Jones")
```

Java's `void` return type is in Kotlin represented by the singular value `Unit`. If a function returns `Unit`, it can and should be omitted:

```
fun sayHello() { //returns Unit, but type omitted
    println("Hello world");
}
```

Kotlin functions also support named default arguments: you can provide a default value for an argument in the function declaration. If that (positional) argument is omitted, then the default value is used instead. Additionally, arguments can be specified by name when *calling* the function, allowing you to include them out of order.

```
fun greet(personTo:String = "world", personFrom:String = "Me") {
    println("Hello $personTo, from $personFrom")
}

greet() //use defaults for arguments
greet("y'all") //use default for second argument
greet(personFrom="Myself", personTo="You") //named arguments (out of order)
```

Similar to JavaScript arrow functions, Kotlin functions whose body is just a single expression can leave off the *block* entirely, instead writing the expression to return after an equals sign (=)—as though that expression were assigned to the function:

```
//a function square() that takes in an Int and returns that number squared
fun square(n:Int):Int = n*n
```

- Note that you can omit the return type from single expression functions, as it can be inferred.

This provides a very concise way of writing simple functions!

Similar to JavaScript (and drawing from Java 8), Kotlin supports higher order anonymous functions and lambda functions. These are functions that can be *assigned to variables* (including function parameter), just like any other object! These are highly effective when using function programming paradigms (e.g., `map()` and `reudce()`), or when specifying event callback functions.

Anonymous functions are normal functions (whether with a block body or just a

single expression), but written without a name. These functions can be assigned to variables, or passed directly to functions that take in appropriate callbacks:

```
val square = fun(n:Int):Int {
    return n*n
}

val numbers:IntArray = intArrayOf(1,2,3,4,5)
println(numbers.contentToString()) //1, 2, 3, 4, 5

val squares:List<Int> = numbers.map(square) //transform each element with square()
println(squares.joinToString()) //1, 4, 9, 16, 25
```

- Note that the `square` variable here has an *inferred* type that is a function which takes in an `Int` and returns an `Int`. We can explicitly declare this type using the following syntax:

```
val square:(Int) -> Int
```

The argument types are listed in parentheses, followed by an arrow `->`, followed by the return type.

Anonymous functions that are a single expression can also be written as *lambda* expressions. Lambda expressions are placed inside curly braces `{}`, with the parameter list coming first (not in parentheses). This is followed by an arrow `->`, followed by the expression that should be evaluated.

```
val add = { x:Int, y:Int -> x+y }

//with an explicit typed (so inferred in the expression)
val add:(Int, Int) -> Int
add = { x,y -> x+y }
```

In fact, Kotlin is able to figure out the signature for a lambda function with only a single parameter (e.g., because the lambda is being anonymous passed in as a defined callback function, so must meet the required interface), it will allow us to *omit* the signature entirely. In this case, the single parameter is automatically assigned to the variable **it**:

```
val numbers:IntArray = intArrayOf(3,1,4,2,5)

//filter() takes a callback with a single parameter that returns boolean,
//so the signature can be inferred
val filtered:List<Int> = numbers.filter( {it > 2} )

println(filtered.joinToString()) //3, 4, 5
```

This allows us to write somewhat readable code using functional programming approaches. As an example from the documentation:

```
fruits
    .filter { it.startsWith("a") }
    .sortedBy { it }
    .map { it.toUpperCase() }
    .forEach { println(it) }
```

18.1.3 Classes

Kotlin is an object-oriented language, just like Java. Thus despite being able to support package-level functions, Kotlin is primarily written using **classes** with **attributes** and **methods**.

As in Java, Kotlin classes are declared using the `class` keyword. Additionally, most Kotlin classes have a *primary constructor*, the parameters of which can be included as part of the class declaration.

```
//declares a class `Dog` whose constructor takes two parameters
class Dog(name:String, breed:String) {
    var name = name //assign to properties
    val breed = breed
}
```

- Of course constructor parameters can support default named arguments as well!
- Kotlin **properties** (instance variables) default to being **public**, but can be declared **private** if desired. See Visibility Modifiers.
- Note that **methods** in Kotlin are simply functions (written as above) declared inside the class body.

The primary constructor parameters can directly declare the variables by including either `var` or `val` as appropriate. Thus a shortcut for the above constructor and initialization is:

```
//declares instance variables
class Dog(var name:String, val breed:String) {
}
```

- Additional constructors are specified using the **constructor** keyword as the method name. See the documentation for details.

Objects in Kotlin are instantiated by simply calling the constructor as a normal function, *without* the `new` keyword.

```
val myDog = Dog("Fido","mutt") //no new keyword!
myDog.name  //"Fido"
myDog.breed  //"mutt"
```

As with any other object-oriented language, Kotlin also supports **inheritance**, with all classes existing within an *inheritance hierarchy*. Note that in Kotlin, all classes by default inherit from the class `Any`, rather than from `java.lang.Object`.

We can specify a classes inheritance by putting the parent type after a colon (`:`) in the declaration. If the child class has a *primary constructor*, then we also include the parameters which should be passed to the parent's constructor.

```
class Dog(var name:String, val breed:String) : Animal() {
}
```

- Interfaces are implemented the same way, as part of a comma-separated list of inherited classes. That is, there is no distinction between *extending* a class and *implementing* an interface.

Importantly, Kotlin requires us to explicitly mark classes as “subclassable” (they are otherwise compiled to `final` classes). We do this by using the **open** keyword as an annotation in the class declaration:

```
//declare class as open
open class Animal(var name:String) { }

//constructor parameters can be passed to parent constructor
class Dog(var name:String) : Animal(name) { }
```

The **open** keyword is also needed if we want to allow a *method* to be overridden. Additionally, any methods that override a parent version need to be annotated as such with the **override** keyword.

```
open class Animal() {
    //function can be overridden
    open fun speak() {
        println("The animal speaks")
    }
}

class Dog() : Animal() {
    //overrides parent function
    override fun speak() {
        println("The dog barks")
    }

    //overriding toString() using an expression function
    override fun toString() = "A dog"
}
```

Note that Kotlin does not have **static** class methods; instead, just use package-

level functions!

Kotlin also supports a few other special kinds of classes:

- Data Classes are declared using the **data** keyword as an annotation in the class declaration. These are classes that do nothing but hold data: they have only attributes, no methods (similar to a **struct** in C). The compiler will automatically provide implementations of `toString()` and `equals()` for these classes.

```
data class Ball(var x:Int, var y:Int, val color:String)

val myBall = Ball(30,30,"red")
print(myBall) //Ball(x=30, y=30, color=red)
```

- Nested classes can be made into **inner classes** (e.g., “non-static” classes with access to the containing class’s instance variables) using the **inner** annotation in the class declaration.
- *Anonymous classes* (called Object expressions) can be created with the **object** keyword in place of a **class** and the class name:

```
button.addActionListener(object : ActionListener() {
    //class definition (including methods to override) goes in here!
    override fun actionPerformed(ActionEvent event) {
        //...
    }
});
```

This is pretty similar to Java, but using **object** instead of **new** to instantiate the anonymous class.

18.2 Kotlin for Android

Kotlin is built into Android Studio 3.0 by default, but is also available via a plugin for earlier versions. You can install this plugins through the **Preferences > Plugins** menu: click the **Install JetBrains plugin...** button at the bottom and select **Kotlin**. Note that you will need to *restart* Android Studio.

After you’ve installed the plugin, you can use Android Studio to convert an existing Java file to a Kotlin source code file (**.kt**) by selecting **Code > Convert Java File to Kotlin File** from the menu. Once you start editing the file, you will be prompted to configure the project to use Kotlin. This will modify the Gradle build scripts to include Kotlin support, allowing you to build and run your app as usual.

For example, we can convert the provided `MainActivity`, and consider the changes that have been made:

- The `adapter` instance variable can be null, so its type includes a `?`.
- Notice how Intents are addressed, particularly the `::class.java` syntax.
- For loops use `for ... in` syntax, and Kotlin supports ranges.
- You can fix the syntax error with the adapter by explicitly casting the `ListView` as a `ListView` (this is an example of the converting misunderstanding the code; it happens!)
- Static variables are wrapped in a companion object.

This section of the lecture is incomplete.

18.2.1 The Android Extension

<https://kotlinlang.org/docs/tutorials/android-plugin.html>

To include:

apply plugin: 'kotlin-android-extensions'

To avoid `findViewById()`

```
import kotlinx.android.synthetic.main.<layout>.*
```

18.2.2 Anko

<https://github.com/Kotlin/anko>

```
dependencies {
    compile "org.jetbrains.anko:anko-commons:$anko_version"
}
```

Logging: <https://github.com/Kotlin/anko/wiki/Anko-Commons-%E2%80%93-93-Logging>

- Avoids the explicit call to `Log`, and uses the class name as the TAG. There are other Java libraries that support easier logging as well.

```
info("London is the capital of Great Britain")
debug(5) // .toString() method will be executed
warn(null) // "null" will be printed
```

Intents: <https://github.com/Kotlin/anko/wiki/Anko-Commons-%E2%80%93-93-Intents>

```
startActivity(intentFor<SomeOtherActivity>("id" to 5).singleTop())
//or
startActivity<SomeOtherActivity>("id" to 5)
```

Toast and Alerts: <https://github.com/Kotlin/anko/wiki/Anko-Commons-%E2%80%93-93-Dialogs>

```
//toasts
toast("Hi there!")
longToast("Wow, such a duration")

//alert
alert("Hi, I'm Roy", "Have you tried turning it off and on again?") {
    yesButton { toast("Oh...") }
    noButton {}
}.show()
```

Part II

Additional Topics (Labs)

Chapter 19

Accessibility

This chapter will discuss how to support **Accessibility** when developing Android applications—specifically, supporting users with levels of physical disability. Accessibility is an incredibly important software quality that is often overlooked, but making Android apps accessible requires only a few minor changes to the implementation details discussed in this course.

19.1 Universal Usability

When developing any kind of interactive system, there are different *design principles* (e.g., Shneiderman and Plaisant’s Golden Rules) that can provide guidelines for how to develop effective and usable system.

One of the most important design principles is **Universal Usability** (also known as Universal Design), which is the principle that designed products should be *inherently accessible*. This principle takes as its premise that designing for *accessibility*—to be usable by all people no matter their ability (physical or otherwise)—benefits not just those with some form of limitation or disability, but *everyone*.

The classic example of Universal Design are curb cuts: the “slopes” built into curbs to accommodate people in wheelchairs. However, this design decision end up making curbs more usability for *everyone*: curb cuts help people with rollerbags, strollers, temporary injuries, or who just have problems climbing steps.

- If you design a piece of technology to be used by a person with only one arm, then you support people with a disability. But you **also** support people with a *temporary disability* (e.g., their arm is unusable because it is in a sling or a cast), *and* people who are just currently inconvenienced

(e.g., they are holding a baby in that arm). You make the interaction and life better for everyone.

Universal usability is equally important in the domain of mobile design:

- If you support people with vision impairments (e.g., by providing touch and voice controls), you also support people who just want to use the app while driving or otherwise visually occupied.
- If you support people who cannot afford high-end devices with unlimited 4G connections (e.g., by functioning on older versions of Android, or being frugal when downloading data), you also support people who are currently without data connections (being out in the woods, on an airplane, over their data plan, etc).

People with disabilities cannot ethically be excluded from consideration in app design, and by considering their needs you will also improve the usability of your app for all population—two for the price of one! This guideline is increasingly being acknowledged by companies as key to usability, and thus it is important that you apply it to your own design work.

19.2 Implementing Accessibility

The Android framework provides a number of ways to **make apps more accessible**, including a handy **accessibility developer checklist** that you can follow. Some specific actions are described in more detail below: you should perform the listed tasks to test and improve an app’s accessibility.

These exercises build on the lecture code found at <https://github.com/info448-s17/lecture07-loaders> (use the `completed` branch). You will need to adjust `MainActivity` so that it shows the provided `MovieFragment` by default; you will be testing and improving the accessibility of that `Fragment`.

19.2.1 Supporting Vision Impairment

One of the most important ways to support accessibility is to make sure your app is accessible to users with vision impairments.

As mentioned previously, one way to support users with trouble seeing content on small screens is to always use *scalable pixels* (**sp**) as units on `TextViews`. This allows the size of the content to *scale* with user preferences: so if someone wants everything on the phone to be large, it can be!

However, users who are *blind* require extra support. This support is provided by Accessibility Services, which are “background services” that can respond to specific accessibility events (we will discuss Services more in a future lecture). The most common built-in service is called **TalkBack**, which is the Google-developed screen reader for Android. This service will “speak” the name of UI

elements as the user focuses on them, as well as allow the user to drag a finger around a screen and get verbal feedback of what is there.

- *TalkBack* can be turned enabled by going to **Settings > Accessibility > TalkBack**. This service is available on most consumer devices, but will need to be installed manually on the emulator. You can download the packaged `.apk` from here (version 5.1.0 works fine), and install it on the emulator using `adb` on the Terminal:

```
# replace with the package-name
adb install package-name.apk
```

Turn on TalkBack and use it to explore your phone and the test the Loader Demo app. You should do this **without looking at your phone** (avert your eyes, flip it upside down, etc)—try acting as if you were blind but still need to use the device!

- The TalkBack service will start with a tutorial that you can complete (you can also read the user documentation).

In short: drag your finger to browse the device (letting TalkBack tell you what you are selecting), and then double-tap to “click” on an element.

As you *should* notice in testing your app, many interface designs give usability hints (e.g., what a button does) through visual cues: images, icons, and labels. While this may cause the app to “look” nice, it is not very effective for vision-impaired users—such as how the “icon” buttons are just explored as (e.g.) “Button 59”.

Thus for these purely visual elements (e.g., `ImageButton`, `ImageView`) we need to specify what text should be read by TalkBack. Do this by including an **`android:contentDescription`** attribute on these elements, which are given a value of the text that TalkBack should read. **Do this** for all of the visual elements in the `MovieFragment` layout. (You can also set this description for dynamic elements using the `setContentDescription()` function in Java).

- This is equivalent to adding an `alt` or ARIA attribute in HTML.

Including the `android:contentDescription` attribute is an incredibly easy addition (low-hanging fruit!) that does quite a lot to support accessibility of Android apps.

19.2.2 Supporting Alternative Inputs

A second easy change involves supporting interaction that *doesn't* use the Touch Screen. This could be because of physical limitations: the user may interact with the device through an external device such as a keyboard, trackball, or switch.

The best way to support these alternative inputs is by making sure that each navigational element (things the user may select) are focusable. You can do

this by specifying the `android:focusable` attribute in the XML (or use the `View#setFocusable()` method in Java).

Buttons are already focusable by default. But you can also specify the *order* by which elements get focus (similar to the “tab order” in HTML). This is done using XML attributes `android:nextFocusDown`, `android:nextFocusUp`, `android:nextFocusLeft`, and `android:nextFocusRight`. Each of these takes an `id` reference as a value (e.g., “`@id/nextElement`”), which refers to which View should gain focus *instead of the “natural” order*.

- To practice this, ***modify the focus order*** so that the “search input” has focus first, with the “search button” gaining focus on down from there and the “clear button” gaining focus on up.
- In order to test this, you will need to make sure your device supports a physical keyboard and/or D-Pad, but you can also use the arrow keys for the emulator.

19.2.3 Supporting Internationalization

Finally you can make an application accessible to a wider diversity of users by providing Internationalization and supporting different languages and cultures.

Internationalization (i18n) is primarily done by specifying alternative resource, such as using XML to define user-facing Strings in multiple languages. We did an example of this in lecture 3

However, changes in language may also require adjustments to the layout resources themselves: phrases in some languages are significantly longer or shorter than in English, and so may cause problems with spacing or word wrapping.

- One way to test this is to enable pseudo-localization, a “fake” language that *almost* looks like English, but utilizes special characters and extraneous text to help test what the application may look like with different length content. See the link for details on enabling this.

Another significant change involves support right-to-left (RTL) languages such as Arabic. With these languages the “flow” of text goes in the opposite direction than in English, so many positioning elements in layouts may need to be reversed:

In particular, do the following to best support both LTR and RTL languages:

1. Declare that your app supports RTL in the *Manifest* by including an attribute `android:supportsRtl="true"` in the `<application>` element.
2. With *RelativeLayouts*, use positioning attributes based on *start* and *end* rather than *left* and *right*. For example, `android:layout_toRightOf` should instead be `android:layout_toEndOf`. This will allow the relative positioning to automatically “switch” between LTR and RTL. Note that *LinearLayouts* automatically reverse direction!

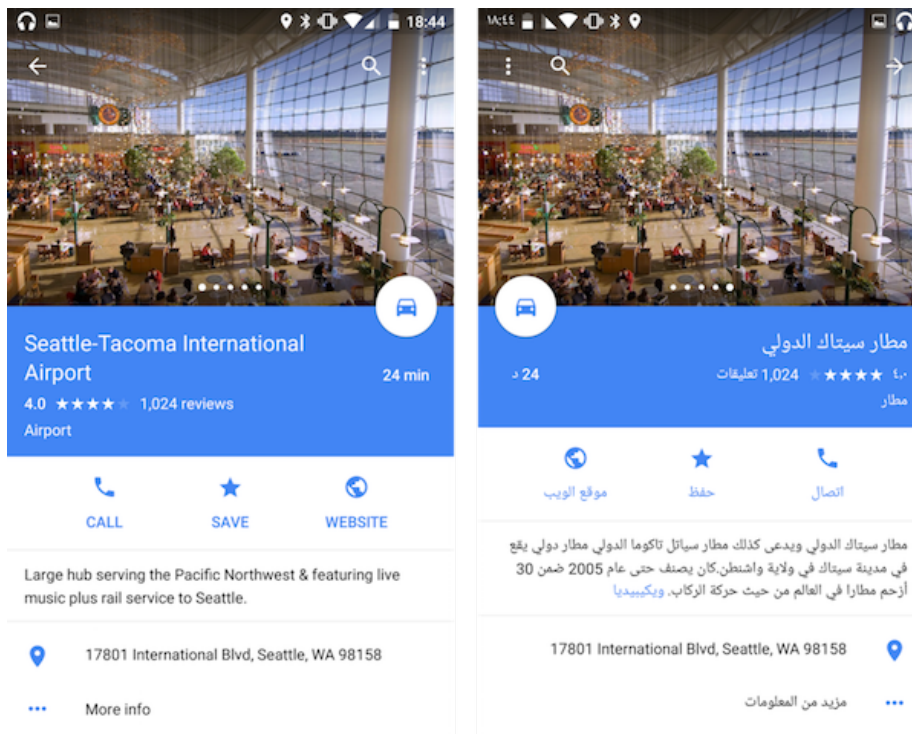


Figure 19.1: English and Arabic layouts. Image by Ryder Ziola.

3. For custom icons and drawables: define separate resources for LTR and RTL (use the `ldrtl` resource qualifier to specify the “layout direction” as right-to-left). This will allow for icons (such as the arrows in the upper start corner of the example) to change direction with the text—you want “back” to actually point “back”!

Make these changes to the `MovieFragment` (there are no custom drawables to adjust). You can test that your changes work by selecting `Settings > Developer options > Force RTL layout direction`.

19.2.4 Further Testing

These are fairly trivial changes you can make to how you define and implement user interfaces, that will go a long way to supporting use by *all* users no matter their level of ability.

The Android Studio IDE will identify and suggest additional changes as “linted” style suggestions—watch out for these warnings and learn to correct them as you develop.

Finally, Google has also developed an Accessibility Scanner app that can be used to check for further accessibility issues (such as contrast levels or touchable areas).

And of course, keep the checklist handy to help you design applications to support universal usability.

Chapter 20

Fragments: ViewPager

In this chapter, you will practice working with Fragments and layouts. Specifically, you will modify the Movie application so that it uses a **ViewPager**, an interactive View offered by the Android Support Library that will allow you to “page” (swipe) through different Fragments. You will modify the application so that the user can swipe through a “search” screen, the list of search results, and the details about a particular movie.

IMPORTANT NOTE: you should **not** modify the `MovieFragment` or the `DetailFragment` (those Fragments are self-contained and so can be used in multiple layouts!). You will need to create one new Fragment though, and make substantial modifications to the `MainActivity`

This chapter will build on the lecture code found at <https://github.com/info448-s17/lecture05-fragments>.

If you haven’t already, you should **Fork and Clone** this repo in order to complete the tutorial. Note that you should complete this tutorial on a separate **viewpager-work** branch. You can create this branch either off of the **completed** branch (containing the completed lecture code), or from the **master** branch of code if you were able to complete the work described in lecture 5:

```
git checkout completed
git checkout -b lab-work
```

20.1 Define a SearchFragment

Your `ViewPager` will need to support three different Fragments. While the `MovieFragment` and `DetailFragment` are defined already, you will need to create a third.

Create a new Fragment called **SearchFragment** (use the `File > New > Fragment > Fragment (Blank)` menu in Android Studio). Your **SearchFragment** will need to include the following components

1. The layout for the Fragment should contain the search `EditText` and `Button` *taken from* the `activity_main` layout. You can add some `layout_gravity` to center the inputs. You can also remove the `onClick` XML attribute, as click handling will be specified in the Java
2. In the **SearchFragment** class, be sure to define a `newInstance()` factory method. The method doesn't need to take any arguments (and thus you don't need to specify an argument bundle).
 - Typing `newInstance` will allow Android Studio to tab-complete the method!
3. The **SearchFragment** will need to communicate with other Fragments, and thus you will need to define an interface (e.g., `OnSearchListener`) that the containing Activity can implement. This interface should support a single public method (e.g., `onSearchSubmitted(String searchTerm)`) which will allow the Fragment to pass the entered search term to the Activity.
 - Remember to check that the containing Activity implements the interface in the Fragment's `onAttach()` callback.
4. Finally, in the `onCreateView()` callback, add a click listener to the button so that when it is clicked, it calls the `onSearchSubmitted()` callback function on the containing Activity (which you've established has that method!)
 - Remember that you can call `findViewById()` on the *root view*.

20.2 Add the ViewPager and Adapter

Your **MainActivity** will need to contain a **ViewPager** View (since all the other Views have been moved to Fragments!).

Add a `android.support.v4.view.ViewPager` element in the `activity_main.xml` layout resource, finding this View in the Activity's `onCreate()` callback.

Just like with a `ListView`, a **ViewPager** requires a (custom) **adapter** in order to map from which “page” is shown to the Fragment that is rendered. Add a new inner class (e.g., `MoviePagerAdapter`) that subclasses `FragmentStatePagerAdapter`.

- As in the documentation example, You will need to provide a constructor that takes in a (Support) `FragmentManager`, and calls the appropriate super constructor.

- The `getItem()` function returns *which* Fragment is shown for a particular page number. You should implement this function so that page 0 shows a `SearchFragment`, page 1 shows a `MoviesFragment`, and page 2 shows a `DetailsFragment`.
 - You can declare each of these three Fragments as **instance variables**, then simply return them from this method.
 - It's okay to “hard-code” this logic for the purposes of this demonstration.
- The `getCount()` function returns how many pages the Pager supports. Note that you will need to include some logic for this: before a search has occurred, there is only one page! After the search, there are two pages (the search and the results), and after a result option is selected there are three pages (the search, the results, and the details).
- Finally, we will be “replacing” Fragments inside the Pager as the user interacts with the app (e.g., changing the `MoviesFragment` to one with different search results)—such as by changing the objects that the instance variables refer to. However, the `ViewPager` “preloads” adjacent Fragment pages as an optimization technique; thus it “caches” the Fragments and won't actually load any updated Views.

As a work-around, override the `getItemPosition()` function (which is called whenever the Pager needs to determine if an item's position has changed):

```
public int getItemPosition(Object object) {  
    return POSITION_NONE;  
}
```

Note that this is a memory-intensive workaround (but works for demonstration purposes); for a cleaner solution, see this discussion.

Once you've defined the your adapter, instantiate it in the Activity's `onCreate()` callback, and use `ViewPager#setAdapter()` to specify the Pager's adapter.

If you also instantiate a `SearchFragment` in the `onCreate()` callback, then you should be able to run the application and see that Fragment appear as a page (though there is nothing else to swipe to yet).

20.3 Add User Interaction

Finally, you will need to adjust the Fragment callback methods inside the Activity (e.g., `onSearchSubmitted()` and `onMovieSelected()`) so that they interact with the `ViewPager`. Note that this will involve removing previous code (the `ViewPager` does not need to utilize `FragmentTransactions`).

When the search term is submitted from the `SearchFragment`, your Activity should instantiate a new (potentially different) `MoviesFragment` result list for that search term. The `PagerAdapter` should return an appropriate page count depending on whether a result list has been instantiated or not.

- However, simply creating a different Fragment will not cause the Adapter to change—you need to let the Adapter know that the *model* it is adapting into a *view* has changed! You can do this by calling the `notifyDataSetChanged()` method on the adapter.

After you’ve modified (and notified!) the Adapter, you can change which page is displayed using the `ViewPager#setCurrentItem()` method. This will let you take the user to the “results” page!

Similarly, modify the movie selection callback so that when a movie is selected from the list, your Activity instantiates a new (potentially different) `DetailFragment`. Remember to notify the adapter that the data set has changed, and to change which page is currently shown.

- This will replace the previous behavior of the callback.

Once you’ve made these changes, you should be able to search for movies, see the results, and view the details for movies. Swipe left and right to navigate between pages!

Chapter 21

Bluetooth

In this chapter you will learn about some of the pieces for creating a connection between two co-located devices using Bluetooth. This will let you gain some familiarity with the Bluetooth API, as well as further practice working with *Intents*.

The code for this tutorial can be found at <https://github.com/info448-s17/lab-bluetooth>.

This tutorial involves filling in the remaining pieces from a Sample Project provided by Google. Google includes lots of samples demonstrating how to use particular pieces of functionality; reading and adapting the provided projects is a great way to learn new skills. There are *a lot* of comments, though that sometimes makes it hard to follow all the pieces. Read carefully!

- Also be sure to open the API documentation for reference!

The emulator doesn't support Bluetooth, so you will need to run this project on a physical device.

Your task is to fill in the missing pieces of code, following the instructions below. I've marked each location with a `TODO` comment, which should show up in blue in Android Studio.

1. Start by reading through The Basics to get a sense for what classes will be used and what their roles are. You only need to focus on the first 4: `BluetoothAdapter`, `BluetoothDevice`, `BluetoothSocket`, and `BluetoothServerSocket` (the rest are for other kinds of Bluetooth connections, like audio transfer and stuff). You don't need to know all the methods or details of these classes, but should be familiar with their general, one-sentence purposes!
2. You'll need to request permission to use Bluetooth. Add the appropriate `<uses-permission>` attributes: one for `BLUETOOTH` (for communication;

included) and one for `BLUETOOTH_ADMIN` (to “discover” devices and make connections).

3. The main UI is defined in the `BluetoothChatFragment` class, which is a `Fragment` that holds the chat system. Start by filling in the `onCreate()` callback by fetching the default Bluetooth adapter and saving it to an instance variable (`mBluetoothAdapter`). If the adapter doesn’t exist (is `null`), you should `Toast` a message that Bluetooth isn’t available (using the `Activity`’s `Application Context` so that the `Toast` lasts), and then call `finish()` on the `Fragment`’s *Activity* (to close the application).
4. You’ll want your app to make sure that the user has Bluetooth turned on. In the `Fragment`’s `onCreate()`, check whether the `BluetoothAdapter` is **enabled**. If **not**, you’ll want to prompt the user to enable it, such as by launching the “Settings” app. Create an **Implicit Intent** for the action `BluetoothAdapter.ACTION_REQUEST_ENABLE`, and send this Intent *for a result* (with the result code of `REQUEST_ENABLE_BT`). Look in the `Fragment`’s `onActivityResult()` method to see what happens when we get a response back!
 - The `BluetoothChatService` (stored in the instance variable `mChatService`) is an object representing a “background service”—think an `AsyncTask` but with a much longer lifespan. This particular service handles sending bytes of data back and forth over Bluetooth. We’ll talk about `Services` more later in the course.
5. In order for a device to connect to yours over Bluetooth, your device will need to be **discoverable**: effectively, it has to respond to public queries about its existence (sort of like having your instant messaging status as “Online/Available”). In the `Fragment`’s `ensureDiscoverable()` helper method, check if the device is currently discoverable by calling `getScanMode()` on the `BluetoothAdapter`; it should return a value of `BluetoothAdapter.SCAN_MODE_CONNECTABLE_DISCOVERABLE`.
 - If this **IS NOT** the case, then you should send another *Implicit Intent* to handle the `BluetoothAdapter.ACTION_REQUEST_DISCOVERABLE` action.

This intent should include (put) an **extra** that has the key `BluetoothAdapter.EXTRA_DISCOVERABLE_DURATION` and a value of `300`, so that we are in “discoverable” mode for 300 seconds.

Note that this intent does **NOT** need to be started for a result!

6. The discovery of devices is controlled by the `DeviceListActivity` `Activity`. This is a separate `Activity` that will actually appear as a popup dialog (though it doesn’t use `DialogFragment`; it just “themes” the `Activity` as a dialog in the `Manifest`). The `Activity`’s `onCreate()` does a lot of UI work (including setting up an `Adapter`!), but it also needs to set up a `BroadcastReceiver` to listen for events like when devices are found. (This is the equivalent of declaring a `<receiver>` and `<intent-filter>`

in the `Manifest`, but we need to do it in Java since the `Receiver` isn't a separate class and since we want to do it dynamically).

- First instantiate a new `IntentFilter` object (giving it the `BluetoothDevice.ACTION_FOUND` action).
 - Then use the `registerReceiver(receiver, intentFilter)` method, passing it the already-existing receiver (`mReceiver`) and the `IntentFilter` you just created!
 - Then repeat the above two steps, but this time for the `Bluetooth.ACTION_DISCOVERY_FINISHED` action. This will register an additional `IntentFilter` on the same receiver.
7. We can actually begin searching for devices by filling in the `Activity`'s `doDiscovery()` helper method (which is called when the Scan button is pressed).
- Add a check to see if the `BluetoothAdapter` currently `isDiscovering()`. If so, then you should tell the adapter to `cancelDiscovery()`.
 - Whether or not the check was `true` (so even if we canceled the discovery), tell the adapter to `startDiscovery()` to begin searching for devices!
8. Once the user has selected a device to connect to, we handle that connection back in the `BluetoothChatFragment`. Fill in that class's `connectDevice()` helper method to connect to the device!
- First you'll want to get the device's "address" (a MAC address that acts as a unique identifier) *from* the `Intent`'s extras: get the `Bundle` of extras from the `Intent`, then get the `String` with the key `DeviceListActivity.EXTRA_DEVICE_ADDRESS`.
 - You can then find the device (a `BluetoothDevice` object) by calling the `.getRemoteDevice()` method on the `BluetoothAdapter` and passing this address.
 - Finally, you can use the `mChatService`'s `.connect()` method to connect to this device (passing down the `secure` option as a second parameter). The `BluetoothChatService#connect()` method creates a new `Thread` to do the communication work, and opens up network sockets so that messages can be passed between the devices. (This is actually part of the hard part of working with Bluetooth; luckily we have a class to abstract that for us!)
9. The last part is to actually send a message! In the `sendMessage()` helper in `BluetoothChatFragment`, fill in the details so that the `String` can be sent to the socket in the chat service.
- First you need to convert the message `String` into a `byte[]` (for communication over the socket). Use the `String`'s `getBytes()` method to convert.

- Then you can tell `mChatService` to `.write()` those bytes!
- We then need to reset the `mOutStringBuffer` instance variable (which keeps track of the message that has been typed so far). Use `.setLength()` to give it a length of `0`, which will effectively make it empty.
- And finally, because we've changed the outgoing message, set the text of the `mOutEditText` `TextView` to be the (now empty) `mOutStringBuffer`.

And that's it! You should now have a working chat system! Search for and connect to someone else's device and try saying "hello"!

Chapter 22

Maps

This chapter will introduce you to the Google Maps Android API which allows you to *very* easily add an interactive map to your application.

22.1 Create a Map Activity

There is no scaffolding code for this tutorial; instead, you should create a new project from scratch. Note that you can test your project either on the emulator or a physical device: just make sure the device has the *Google APIs* included.

Start a new project in Android Studio (“Map Lab” is a fine project name). Target SDK 15 like usual.

But here’s where things get different! Instead of starting with an “Empty Activity”, start with a **Google Maps Activity**. This will create you a new **Activity** whose layout includes an XML-defined **SupportMapFragment**. (This is just another **Fragment** subclass, so you could include it in a layout however you wanted. You can stick with the default layout for now).

22.1.1 Getting an API Key

In order to access and show a Google Map, you need to register and get an API key (this is like a special password that lets your app access Google’s map data). When you create the Maps Activity, Android Studio should open up the `google_maps_api.xml` resource file. This file contains instructions on how to get an API key (i.e., paste the giant pre-generated link into your browser, and then copy the generated key into the XML resource).

(If you already have a Google Maps API Key, you can add this package & device to that key in the Google Developer Console).

```

<resources>
  <!--
  TODO: Before you run your application, you need a Google Maps API key.

  To get one, follow this link, follow the directions and press "Create" at the end:
  https://console.developers.google.com/flows/enableapi?apiid=maps_android_backend&keyType=CLIENT_SIDE_ANDROID
  You can also add your credentials to an existing key, using this line:
  13:76:AF:58:C8:F6:4B:9D:6C:1F:AC:9A:EA:66:FD:81:C2:9E:32:32:edu.uw.maplab
  Alternatively, follow the directions here:
  https://developers.google.com/maps/documentation/android/start#get-key
  Once you have your key (it starts with "AIza"), replace the "google_maps_key"
  string in this file.
  -->
  <string name="google_maps_key" templateMergeStrategy="preserve" translatable="false">YOUR_KEY_HERE</string>
</resources>

```

Figure 22.1: The instructions found in the `google_maps_api.xml` file.

After you’ve entered the key, you should be able to build and run your app, and see a displayed map!

22.1.2 The `SupportMapFragment`

Take a moment to open up the generated `MapsActivity` and its associated layout (by default `layouts/activity_maps.xml`) and **read over the initial code**.

The layout resource contains a single `<fragment>` element (like we’ve defined before), in this case referring to an instance of the `SupportMapFragment` class. This fragment represents the interactive map. It’s just a subclass of `Fragment` (with a few extra methods), so everything we’ve learned about Fragments applies.

- The `Fragment` is defined in the XML, so we don’t need to use a `FragmentManager` to add it in the Java code.

But we do use the `FragmentManager` to get access to that fragment so that we can call a single method on it: `getMapAsync()`. This gets access to a `GoogleMap` object, which does all the work of downloading map tiles, handling pans and zooms, and drawing markers and shapes.

- The `getMapAsync()` method loads this object *asynchronously* (like we’ve with the `GoogleApiClient`), and will notify a listener when the object is available. Because the `MapsActivity` implements the `OnMapReadyCallback` interface, it *is* a listener and so its `onMapReady()` callback will be called and passed the object for us to handle.

Once the the object is available via the callback, we can start calling methods on it: e.g., to show a marker at a particular latitude/longitude (`LatLng`), and to position the map’s “camera” to focus on that spot.

22.2 Specifying the User Interface

The Java code is able to position the map, but if we want to specify a “default” position, you should instead do that work in the Fragment’s definition in the XML resource file.

Check out the list of available XML attributes for defining the user interface of your map. Customize the map so that:

1. It is by default centered on Mary Gates Hall. (You will need to delete the positioning Java code so that doesn’t override your XML).
2. It is zoomed in so that we can see the whole fountain on the map
3. Make the map shows the “zoom control buttons” (so that you can zoom in using the emulator!)
4. Make the map show *both* satellite imagery and roads/buildings.

22.3 Markers and Drawings

Showing a map is great, but what we really want to do is customize what it shows: that is, we want to draw on it! There are a couple of things we can draw, one of the most common of which is Markers that indicate a single location on the map.

You can create a Marker by instantiating a new `MarkerOptions` object and passing it into the `GoogleMap` object’s `addMarker()` method.

- See the documentation for ways to customize these markers. The most common options are setting the `position` (required), the `title` (text that appears when the user clicks the marker), and `snippet` (additional text).

Create a marker centered in the center of the fountain. The marker should be purple or gold in color, and clicking on it should tell the user something about the ducks who dwell there!

- You can show customized information (including pictures, etc) when markers are clicked using Info Windows.

22.3.1 Drawing Shapes

You can also draw free-form shapes on the map, anchored to particular locations. These include lines, circles, and generic polygons.

One of the best options for drawing is the Polyline, which is a series of connected line segments (like a “path” in SVG).

- In order to create a Polyline, you *actually* instantiate a `PolylineOptions` object. You can `add()` points (`LatLng` objects) to this object, extending the line from one point to the next. This `PolylineOptions` object is then passed to the `GoogleMap` object's `addPolyline()` method.
- You can also specify other visual properties such as the `color` and the `width` of the Polyline. Note that the width is measure in *screen pixels*—it will be the same no matter what zoom level you are at! (If you wanted it to change dynamically, you'd need to do that work on your own).

Using a Polyline, draw a giant “W” in either purple or gold centered on the fountain. Bonus if want to make it look like the UW logo!

- Or better yet: can you use a combination of Polylines, Circles, and Polygons to draw an approximation of the iSchool logo?

Chapter 23

Styles & Themes

In this chapter you will learn to use Android **Styles & Themes** to easily modify and *abstract* the appearance of an app’s user interfaces—that is, the XML resource attributes that define what your **Views** look like.

This tutorial will walk you through creating and using styles to modify views, though you should also reference the official documentation for more details and examples.

The code for this tutorial can be found at <https://github.com/info448-s17/lab-styles>.

You will be working almost exclusively with the **XML resources** (e.g., `res/layout/activity_main.xml`) in the provided code, so make sure to look those over before you begin. The main layout describes a very simple screen showing a pile of `TextViews` organized in a `RelativeLayout`.

23.1 Defining Styles

If you look at the `TextViews`, you’ll see that they share a lot of the same attributes: text sizing, width and height, boldness, etc. If you decided that all of the text should be bigger (e.g., for readability), then you’d need to change 6 different attributes—which is a lot of redundant work.

Enter **Styles**. Styles *encapsulate a collection of XML properties*, allowing you to define a set of properties once and then use a single attribute to apply all of those properties to a view. This provides *almost* the same functionality as a CSS rule describing a class declaration, but without the “cascading” part.

Styles are themselves defined as an XML resource—specifically a `<style>` element inside the `res/values/styles.xml` file.

- This XML file was created for us when Android Studio created the project. Open the file, and you can see that it even has some initial content in it!
- Style resource files, like String resource files, use `<resource>` as a top-level element, declaring that this XML file contains (generic-ish) resources to use.

Styles are declared with a `<style>` tag, which represents a **single** style. You can *almost* think of this as a “class” in CSS (though again, without the cascading behavior).

- The `<style>` element is given a `name` attribute, similar to how we’d define a CSS class name. Names are normally written using PascalCase: they need to be legal Java identifiers since they will be compiled into R, and since they are “classes” we capitalize them!
- We’ll discuss the `parent` attribute in the starter code in the next section.

We define `<item>` elements as *nested children* of the `<style>` element. Each `<item>` represents a *single* attribute we want our style to include, similar to a single *property* of a CSS rule.

- `<item>` elements get a `name` attribute which is the the name of the property you want to include. For example: `name="android:layout_width"` to specify that this item refers to the `layout_width` attribute. The *content* of the `<item>` tag is the value we want to assign to that attribute, e.g., `wrap_content` (not in quotes, because the content of an XML tag is already a String!)

Finally, you can specify that you want a particular `View` (e.g., in your `layout`) to have a style by giving that `View` a `style` attribute, with a value that references the style that you’ve defined (using `@style/...`, since this resource has type “style”).

- Note that the `style` attribute does **not** use the `android` namespace!

Practice: Define a new style (e.g., `TextStyle`) that specifies the attributes *shared* by the 6 `TextView`s: the text size, the with, and the height. Additionally, have the style define the text color as UW purple. Then, refactor these `TextView`s so that they use the style you just defined *instead of* duplicating attributes. See how much code you’ve saved?

- After you’ve done that, go ahead and change the size of *all* the `TextView`s to be 22sp. You should be able to make this change in exactly one place!

23.1.1 Style Inheritance

This is a good start, but we still have some duplicated attributes—in particular, the “labels” share a couple of attributes (e.g., they are all bold). Since each `View` can only have a single style and there is no cascading, if we wanted to create a separate `LabelStyle` style, it would end up duplicating some attributes of the

`TextStyle` (size and color). Ideally we would like to not have to redefine a style if it only changes a little bit.

Luckily, while styles don't cascade, they can **inherit** items from one another (a la Java inheritance, e.g., `extends`). We can establish this inheritance relationship by specifying the `parent` attribute for the `<style>`, and having it reference (with `@`) the “parent” style:

```
<style name="ChildStyle" parent="@style/ParentStyle"> ... </style>
```

This will cause the `ChildStyle` to include all of the `<item>` elements defined in the `parent` style.

- We can then “override” the inherited properties by redefining the `<item>` you want to change, just like when inheriting and overriding Java methods.

When inheriting from our own *custom styles* (e.g., ones that we've defined within the same package), it's also possible to use **Dot Notation** *instead of* the `parent` attribute. For example, naming a style `ParentStyle.ChildStyle` will define a style (`ChildStyle`) that inherits from `ParentStyle`. This would be referenced in the layout as `@style/ParentStyle.ChildStyle`. The dot notation is used to “namespace” the inherited class as if it were a “nested” class we wanted to reference.

- We can chain these together as much as we want: `MyStyle.Red.Big` is a style that inherits from `Red` and `MyStyle`. However, this style cannot also be referenced as `MyStyle.Big.Red` style—it's not using a CSS class selector, but Java class inheritance!
- Note that often name style classes based on this namespaced inheritance, so the “child class” is named after an adjective (e.g., `Big`) that is used to describe the appearance change of the parent element. `Text.Big` would be an appropriate style naming convention.

Practice: Define another style (e.g., `Label`) that **inherits** from your first style to encapsulate attributes shared by the labels (e.g., boldness). Refactor your layout so that the labels use this new style.

Define *another* style (e.g., `Gold`) that **inherits** from your `Label`'s style and has a background color that is UW Gold and a text color of black. Apply this style to *one* of your labels.

It is best to utilize styles for elements that share **semantic meaning**, not just specific attributes! For example, buttons and labels that will be duplicated, headers shared across screens, etc. This will help you avoid needing to frequently change or overwrite styles in the future just because you want to make one button look different; changes to the style should reflect changes to the appearance of semantic elements. This is the same guideline that is used for determining whether you should define a CSS class or not! This blog post has a good summary.

23.1.2 Built-in Styles

Android also includes a large number of built-in platform styles that we can apply and/or inherit from. These **must** be inherited via the **parent** attribute (you can't use dot notation for them). They are referenced with the format:

```
<style name="MyStyle" parent="@android:style/StyleName">...</style>
```

There are a bunch of these, all of which are defined in the `R.style`. This makes discoverability difficult, as not all of the styles are documented. To understand exactly what style effects you're inheriting, Android recommends you browse the source code and seeing how they are defined.

- Yes, this is like trying to learn Bootstrap by reading the CSS file.
- Author's opinion: most of the styles are not very effective bases for inheritance; you're often better using your own.

Practice: *Define a new style* for the `Button` at the bottom of the screen that inherits from the built-in `MediaButton` style (but give it a text size of `22sp`). What does the inheritance do to the appearance?

23.2 Themes

Unlike CSS, Android styling is *NOT* inherited by child elements: that is, if you apply a style to a `ViewGroup` (a layout), that style will not be applied to all the child components of that `ViewGroup`. Thus you can't "style" a layout and have the styling rule apply throughout the layout.

The option that is available is to apply a that style as a **Theme**. Themes are styles that are applied to *every* `View` in a `Context` (an *Activity* or the whole *Application*). You can't get any finer granularity of style sharing (without moving to per-View *Styles*). Theme styles will apply to *every* `View` in the context, though we can overwrite the styling for a particular `View` as normal.

Themes *are* styles, and so are defined the exact same way (as `<style>` elements inside a resource XML file). You can define them in either `styles.xml`, `theme.xml`, or any other `values` file—resource filenames are arbitrary, and their content will still be compiled into `R` no matter which file the elements are defined in.

Themes are applied to an `Activity` or `Application` by specifying an `android:theme` attribute in the `Manifest` (where the `Activity`/`Application` is defined). If you look at the starter project's `Manifest` created by Android Studio, you'll see that it already has a theme (`AppTheme`). In fact, this is the `<style>` that was provided inside `styles.xml`!

Practice: *Experiment with removing the theme attribute from the application.* How does your app's appearance change? *NOTE:* you will need

to change `MainActivity` to subclass `Activity`, not `AppCompatActivity`, in order to fully adjust the theme.

- You might also try commenting out the stylings you applied to the individual `TextViews` to *really* see what happens.

23.2.1 Material Themes

Along with built-in styles, Android provides a number of platform-specific themes. And again, the somewhat unhelpful recommendation is to understand these by browsing the source code, or the list in `R.style` (scroll down to constants that start with `Theme`).

One of the most useful set of Android-provided themes are the **Material Themes**. These are themes that support Google’s Material Design, a visual design language Google uses (or aims to use) across its products, including Android. Material themes were introduced in Lollipop (API 21) and so are only available on devices running API 21+ (though there are compatibility options).

There are two main Material themes:

- `@android:style/Theme.Material`: a Dark version of the theme
- `@android:style/Theme.Material.Light`: a Light version of the theme

And many variants:

- `@android:style/Theme.Material.Light.DarkActionBar`: a Light version with a Dark action bar (Dark background, Light contents)
- `@android:style/Theme.Material.Light.LightStatusBar`: a Light version with a Light action bar (Light background, Dark contents)
- `@android:style/Theme.Material.Light.NoActionBar`: a Light version with no action bar.
- ... etc. See `R.style` for more options (do a ctrl-f “find” for `Material`)

Practice: Experiment with applying different material themes to your application How does your app’s appearance change? Give your application a Dark Material theme!

23.2.2 Theme Attributes

One of the big advantages of Themes is that they can be used to define **theme attributes** that can be referenced from inside individual, per-View Styles. This allows the Theme to effectively “skin” the View. For example, a Theme could define a “color scheme” as a set of attributes; these attributes can then be referenced by the Style as e.g., “the primary color of the current theme”.

Theme-level attributes are referenced in the XML using the `?` symbol (in place of the `@` symbol). For example: `?android:textColorPrimary` will refer to the value of the `<item name="textColorPrimary">` element inside the Theme.

Indeed, one of the advantages of the Material Themes is that they are implemented to utilize a small set of color theme attributes, making it incredibly easy to specify a color scheme for your app. See *Customize the Color Palette* for a diagram of what theme attributes color what parts of the screen.

- Note it is possible to apply a Theme to an individual `View` or `ViewGroup`, causing the theme attributes (and *ONLY* the theme attributes!) to be “inherited” by any child elements. This allows you to specify color palettes for specific parts of your layout.

Practice: Redefine the colors in your custom Styles (from the first practice steps) so that they reference the theme attribute colors instead of purple and gold. What happens now when you change the application’s Material Theme between light and dark?

- Can you have the logo image reference those color theme attributes as well? Hint: use the `tint` attribute.

Practice: Modify the provided AppTheme style (in `styles.xml`) with the following changes:

- Have it **inherit** from a Material Theme (your choice of which)
- Have it define theme attribute colors using the UW colors (purple and gold). Use these theme attribute colors to “Huskify” your app (including the colors in your custom Styles)

Finally, set the theme of your app back to `AppTheme`—and you should now have a UW flavored app!

Chapter 24

Multi-Touch

In this short chapter, you will practice working with touch interaction by implementing support for **multi-touch gestures**, or the ability to detect two or more different “contacts” (fingers) independently. Multi-touch is actually a pretty awesome interaction mode; it’s very “sci-fi”.

Specifically, you will be adding support to the drawn animation demo so that the drawn graphics tracks the location of all 5 of your fingers. This chapter will thus build on the lecture code found at <https://github.com/info448-s17/lecture15-animation>.

If you haven’t already, you should **Fork and Clone** this repo in order to complete the tutorial. Note that you should complete this tutorial on a separate **multitouch** branch. You can create this branch either off of the **completed** branch (containing the completed lecture code), or from the **master** branch of code if you were able to complete the work described in lecture 15:

```
git checkout completed
git checkout -b multitouch-work
```

The emulator doesn’t support multi-touch, so you will need to run this project on a physical device.

24.1 Identifying Fingers

Android lets you react to multiple touches by responding to `ACTION_POINTER_DOWN` events, which occur when a second “pointer” (finger) joins the gesture (*after* `ACTION_DOWN`).

- The first finger starts the gesture with an `ACTION_DOWN` event. then subsequent fingers produce `ACTION_POINTER_DOWN` events.

- Similarly, there are `ACTION_POINTER_UP` events for removing fingers, until the last finger which causes the `ACTION_UP` event.

Practice: add further cases to the `onTouchEvent()` callback and log out when subsequent fingers are placed and lifted.

Here the tricky part: each finger that is currently “down” can cause events *independently*. That is, if we move a finger, then an `ACTION_MOVE` event will occur. Similarly, if we remove a finger, then an `ACTION_POINTER_UP` event will occur. So the question is, how do we know which finger caused the event?

Underneath the hood, pointers are stored in a *list* (think: an `ArrayList`), so each has a **pointer index** (a number representing their index in that list). But these indices can change as you interact with the device. For example, lifting up a finger will could cause that pointer to be removed from the list, thus moving all of the other pointers up an index. IN fact, the index is allowed to change *between each event*—while they often stay in order, there is no assurance that they will. The exact behavior of these indices is not specified or enforced by the framework, so we need to treat those values as unstable and cannot use them to “track” particular fingers.

However, each pointer that comes down *is* assigned a consistent **pointer id** number that we can refer to it by. This id will be associated with that finger for the length of time that contact is being made. In general the first finger down will be id 0, and no matter what happens to the list order that pointer’s id will stay the same.

Practice: track pointer ids using the following procedure:

1. When a Touch event occurs, determine the **pointer index** which caused the event. Do this by calling the `MotionEventCompat.getActionIndex(event)` method. Note that this only actually applies to `POINTER_DOWN` or `POINTER_UP` events, otherwise it will just return 0 (for the “main finger” of the event).
2. Get the unique **pointer id** for whatever finger caused the event. Do this by calling the `MotionEventCompat.getPointerId(event, pointerIndex)` method. This will give you the unique id associated with the event’s finger.

The `MotionEventCompat` class is just a wrapper around `MotionEvent` methods, so that the correct version of `MotionEvent` is used. We could alternatively just call `event.getActionIndex()`.

24.2 Drawing Touches

Once you know *which* pointer has gone up and down, you can respond to it by modifying the drawing displayed by the App. Add the falling func-

tionality to the custom drawing View. Modify either the `DrawingView` or `DrawingSurfaceView` (your choice of which to use):

- Add an instance variable `touches` that is a `HashMap` mapping *pointer ids* (`Integers`) to `Ball` objects. This will track a single “ball” for each touch.
- Add a method `addTouch()` that takes in a *pointer id* as well as the `x,y` coordinates of the touch point. This method should add a new `Ball` (at the given coordinates) to the `touches` map (with the given *pointer id*).
 - Because this method will need to work across threads in the `DrawingSurfaceView`, you should make sure the method is synchronized (specifying that keyword in the method signature).
 - *Call this method on the drawing View from MainActivity when a new finger is put down—including the first finger!* This may be from two different types of events.
 - * Pass the **pointer index** as a parameter to the `getX()` and `getY()` methods to determine the coordinates of that particular pointer!
- Add a method `removeTouch()` that takes in a *pointer id*, and removes the `Ball` that corresponds to that touch.
 - This method should also be synchronized.
 - *Call this method on the drawing View from MainActivity when a finger is lifted—including the last finger!*
- Modify the `render()` method (or the `onDraw()` method) so that the View draws *each* of the `Ball` objects in the `HashMap` at their stored location. You can use gold paint for this. Recall that you can get an iterable sequence of the values for a `HashMap` using the `.values()` method.

This should cause your app to show a small ball underneath each finger that goes down, with the balls disappearing when a finger is lifted. *Make sure each ball is big enough to see!*

24.3 Moving Fingers

Now we just need to handle finger movements. With a `MOVE` action, the event doesn’t track *which* finger has moved—instead, the **pointer index** of that action is always going to be `0` (the main pointer), even if a different finger moved!

However, the event does include information about *how many* pointers are involved in it (that is: how many pointers are currently down): we can get that number with the `MotionEvent.getPointerCount()` method (or an equivalent `MotionEventCompat` method). We don’t know which *pointer index* each finger has, but we do know that they will be **consecutive** indices (because they are stored in a list). Moreover, as above *each* pointer will have its own `x` and `y`

coordinates, representing the current position of that pointer—this may or may not have “moved” from the previous event.

Thus we can just **loop** through all of the *pointer indices* and get the **pointer id** for each one. We can then specify that we want the *corresponding Ball* to update its position to match the “current” pointer position. Again, most of the Balls will not have moved, but we know at least one of them did and so we will just update everything to make sure it works!

- Add a method `moveTouch()` to the drawing View that takes in a *pointer id* (e.g., Ball id), and the “latest” *x,y* coordinates for that Ball. Update the appropriate Ball’s position to reflect these latest coordinates (use `.get()` to access a `HashMap` value by its key).
 - This method should again be **synchronized**.
- In `MainActivity`, when a `MOVE` event occurs, loop through all of the *pointer indices* in the event. Get the *pointer id* and *x,y* coordinates of each, and use those to call the `moveTouch()` method on the drawing View. You will be “moving” all of the balls, even if most are just moving to the same place they were.

And with that, you should have multi-touch tracking! Try adding and removing fingers in unique orders, moving them around, and make sure that the Balls follow the contacts.

- Note that tracking individual ids in this way is more commonly used to make sure you’re *ignoring* extra multiple touches. See the docs or this developer blog post for details.

24.4 Other Multi-Touch Gestures

We can respond to common multi-touch gestures (like “pinch to scale”) by using *another* kind of `GestureDetector` called a `ScaleGestureDetector`. As before, we subclass the simple version (`ScaleGestureDetector.SimpleOnScaleGestureListener`), and fill in the `onScale()` method. You can get the “scale factor” from the gesture with the `.getScaleFactor()` method. As a further bonus exercise, you might try to use the gesture to scale the size of a single ball.

Chapter 25

Memory Management

Android is designed to run on *resource constrained* devices, and one of the most constrained resources is the device's **memory**. Because of this, a large part of the Android framework and how we interact with application components deals with how the system manages memory, making sure sufficient memory is available for whatever the user wants to do.

In this short tutorial, you will explore how the Android operating system handles memory, and learn how to use the Android Monitor's Memory Monitor to view your application's memory usage and identify potential memory leaks.

The code for this tutorial can be found at <https://github.com/info448-s17/lab-memory>. Note that you will not be required to write much code for this lab; it is more about using the tools and inspecting the logged output to get a sense for how memory is handled in Android. You should be able to complete this tutorial on *either* the emulator or a physical device.

25.1 Memory Allocation

First, a short introduction to how memory is handled by a computer (including mobile computers):

The basic idea is that your computer has some amount of storage space (in RAM) dedicating to remembering all of the variables and objects that you create in your program. If you declare a new variable

```
int number = 448;
```

that value (448) is “written down” in memory so it can be used later. For example, this `int` takes up 32 bits, or 4 bytes, of memory. Every single variable you create takes up some amount of memory (see e.g., [here](#)).

This data is stored in a section of memory called the “**heap**”, which is the part of memory dedicated to *dynamic* memory (e.g., values that may only need to be remembered for a short time). You can think of the heap as a something like a giant *array* or *list* of bytes, a certain number of which are **allocated** (given) to each new value that needs to be stored. Thus if spots 0 through 100 in the heap are allocated, declaring a new variable may be allocated (placed) at spot 101.

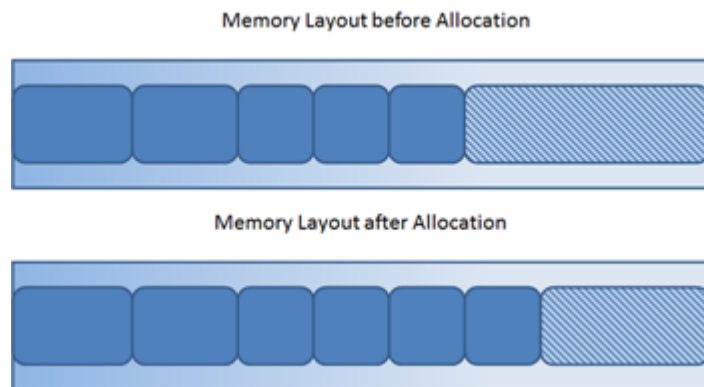


Figure 25.1: Example of memory allocation, from dynatrace.com.

Memory management thus involves answering two questions:

1. Where do we put new values that we need to allocate memory for?
2. What do we do with variables that we no longer need to remember?

Java (and by extension, Android) answers the second question in part by using what is called the **garbage collector**. This is a system process that periodically “sweeps” (searches) for any values that are no longer being used—that is, the variables are out of scope or otherwise cannot be referenced. These values are then “garbage collected”: the space is *deallocated* so that future values can be placed there instead.

- Garbage collection is a bit like going through an apartment and marking rooms as “vacant” if no one lives there anymore.
- Java’s garbage collection means we don’t need to handle deallocating memory ourselves—unlike in languages such as **C** where you need to manually manage your own memory!

The Android framework is structured so that when memory gets low, the system will destroy any *stopped* Activities, thereby allowing them to be garbage collected (and freeing up the memory to be used by a different application). You’ll be able to see this process in action in the next section.

25.2 The Memory Monitor

Since we're interested in the memory used by the application, you should enable and view the Memory Monitor provided by Android Studio. If you look at the bottom panel (the **Android Monitor** panel) where you normally see the **Logcat** results, you should see a tab called **Monitors**. Click on this to view the memory usage over time (you can ignore the other monitors for now).

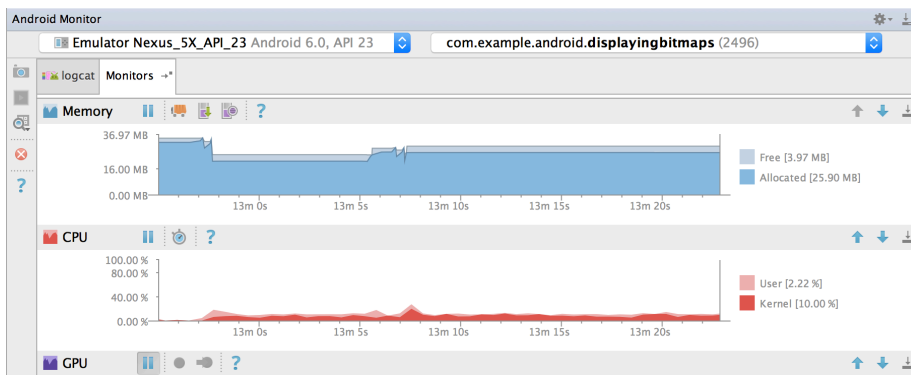


Figure 25.2: Android Memory Monitor (Google)

The dark-blue section represents **allocated** memory (i.e., the amount of memory being used to store variables), while the light-blue section represents **free** memory (in this case, the amount of memory that the *application* is budgeted by the operating system). Each section also has a size in megabytes listed on the right. We're primarily interested in the dark-blue **allocated** memory, but check in with the instructor if you have questions about the free memory.

When you first start up the app, you should see that some memory has been allocated, but it shouldn't be changing at all (since the `MainActivity` doesn't create any new variables after it is created). But let's change that!

While watching the monitor, click on the **"BLANK ACTIVITY"** button to be taken to a new (blank) Activity. *Did you see the bar go up?!* This is because opening a new Activity required allocating additional memory for that Activity (particularly its Views, since it doesn't do much else).

- Of course, the bar didn't go up by much; that's because this simple Activity doesn't require a lot of memory. In practice, even a lot of **Buttons** and **TextViews** don't require large amounts of memory.

Navigate back to the `MainActivity`. You might see the memory allocation increase a little more, as restarting the Activity can cause the Views to need to be recreated.

25.2.1 Garbage Collection


Let's see how the Java (technically, Dalvik) virtual machine handles memory. From the `MainActivity`, click on the button to go to the `ProgressActivity`. This Activity will show the progress towards completing a number of undefined tasks (it's just showing a bunch of `ProgressBar` Views, which use a bit more memory than standard buttons).

- When you visited this Activity, you should have seen the memory allocation jump up!

Now try navigating back and forth between the `MainActivity` and the `ProgressActivity`. You should see the allocated memory continue to increase (since we need to keep recreating those spinners), getting closer and closer to the amount of “free” memory. Eventually, Android will decide that it's out of memory, and will initiate **garbage collection**, deallocating the memory that has previously been used to create the old spinners which are no longer needed (because that *instance* of the Activity is gone).

- Android will sometimes increase the amount of free memory available as the app asks for more. This is normal.
- When the garbage collection occurs, you should see the amount of allocated memory suddenly drop. Those “cliffs” are the garbage collector running.

There are actually different forms of garbage collection (which make different decisions about which values are “old enough” to be deallocated), and the one that you just triggered may not have collected everything. You can also use the memory monitor to **manually** initiate garbage collection—this is useful for checking if memory is *actually* being used, or just hasn't been cleaned up yet.

- Manually initiate the garbage collection by clicking the “**Initiate GC**” button () at the top of the memory monitor panel. *What happens? Were there other values that could be cleaned up?*
- Note that in practice, you should **not** try to perform garbage collection on your own—let the system do its own work (it is optimized to make sure that the computer doesn't slow down too much when trying to do cleanup, which requires additional processing). This button is purely for testing and inspection.

25.3 Memory Leaks

Android's garbage collection does a fine job of cleaning up memory... assuming that it can correctly identify the values that aren't being used. This can sometimes be tricky: Java decides that a value is eligible for garbage collection whenever there are no longer any *references* to that value (e.g., no variables

are in scope). However, if you're not careful it's often easy to leave an extra reference floating around that you didn't intend, thereby keeping the memory from being deallocated. This is referred to as a **memory leak** (because the amount of available space is "leaking" away).

For example, consider the `BirdActivity` class, that you can view by clicking on the **"BIRD ACTIVITY"** button. This activity shows a relatively high-resolution image of a bird—when you open the Activity, you should see the amount of allocated memory jump up dramatically since we need to load that `Drawable` into memory.

If you click on the `BirdActivity`'s button, you'll be taken to (another) blank Activity. Since the bird image is no longer being shown, it should no longer be used and thus should be eligible for garbage collection. Hit the "Initiate GC" button again to request that Android sweep up and reclaim that memory.

What happens?

You'll notice that the large amount of memory allocated to the image doesn't go away... it looks like the bird isn't being garbage collected!

- Why not? Recall that when we start new Activities, old Activities are put on a back stack, allowing us to be able to hit the "back" button and return to the previous Activity. This means that each Activity in the stack contains a reference to the previous ones... including the resources that they have loaded into memory! So there is in fact a reference to that image—it's in the object that is stored on the backstack!
- This can be a problem. It means that because we have that history, the amount of memory available to our application is smaller even though we're not actually looking at the pretty bird right now.

We can fix this by utilizing the Activity lifecycle callbacks. Specifically, you can remove the reference to the image when the the Activity **stops**, and then reload the image when the Activity **starts** again.

- ***For practice***, in the `BirdActivity`, override the `onStop()` method. Inside this method, set the `ImageView`'s drawable to be `null`.
- Similarly, override the `onStart()` method so it loads and displays the image when the Activity is (re)started. You can just move the relevant code from `onCreate()`.

Once you've done this, try navigating to the `BirdActivity` and clicking the button to go to the `BlankBirdActivity`. Use the "Initiate GC" button to force a garbage collection sweep—***does the image's memory get cleaned up now?***

- While this does mean that we're not using as much memory when the Activity isn't shown, it does mean that returning to the Activity is *slightly* slower (since we need to reload the image). This is the fundamental trade-off in all of programming optimization: *use of space vs. use of time*.

Now you should have a sense for how values in Android can influence memory usage. The main take-away is that you want to be careful to de-reference any object that take significant memory (like images or other media; this is why we released the `MediaPlayer` when discussing Services).

- Additionally: note that `static` variables are *never* de-referenced and so are *never* garbage-collected. Thus you want to avoid `static` variables for anything more complex than a `String` to avoid more memory leaks!

Finally, if you use the memory monitor and see memory usage stacking up, that is not necessarily a memory leak or other problem: it could just be that the system hasn't run garbage collection yet! A memory leak is when resources that *should* be able to be reclaimed cannot be—but as long as you keep variables local and de-reference large objects, you'll be fine!

Android Studio includes numerous other monitors for profiling the performance of your application. See Android Monitor and Performance and Power for more details.

Avoid pre-mature optimization! Make sure that you can get your app *working* first, and then utilize these tools to solve specific problems, such as slow performance.

Appendix A

Java Review

Android applications are written primarily in the Java Language. This appendix contains a review of some Java fundamentals needed when developing for Android, presented as a set of practice exercises.

The code for these exercises can be found at <https://github.com/info448-s17/lab-java-review>.

A.1 Building Apps with Gradle

Consider the included `Dog` class found in the `src/main/java/edu/info448/review/` folder. This is a very basic class representing a Dog. You can instantiate and call methods on this class by building and running the `Tester` class found in the same folder. - You can just use any text editor, like *VS Code*, *Atom*, or *Sublime Text* to view and edit these files.

You’ve probably run Java programs using an IDE, but let’s consider what is involved in building this app “by hand”, or just using the JDK tools. There are two main steps to running a Java program:

1. **Compiling** This converts the Java source code (in `.java` files) into JVM bytecode that can be understood by the virtual machine (in `.class` files).
2. **Running** This actually loads the bytecode into the virtual machine and executes the `main()` method.

Compiling is done with the `javac` (“java compile”) command. For example, from inside the code repo’s directory, you can compile both the `.java` files with:

```
# Compile all .java files
javac src/main/java/edu/info448/review/*.java
```

Running is then done with the `java` command: you specify the full package name of the class you wish to run, as well as the classpath so that Java knows where to go find classes it depends on:

```
# Runs the Tester#main() method with the `src/main/java` folder as the classpath
java -classpath ./src/main/java edu.info448.review.Tester
```

Practice: Compile and run this application now.

Practice: Modify the `Dog` class so that its `.bark()` method barks twice ("Bark Bark!"). What do you have to do to test that your change worked?

You may notice that this development cycle can get pretty tedious: there are two commands we need to execute to run our code, and both are complex enough that they are a pain to retype.

Enter **Gradle**. Gradle is a build automation system: a “script” that you can run that will automatically perform the multiple steps required to build and run an application. This script is defined by the `build.gradle` configuration file. *Practice: open that file and look through its contents.* The task `run()` is where the “run” task is defined: do you see how it defines the same arguments we otherwise passed to the `java` command?

You can run the version of Gradle included in the repo with the `gradlew <task>` command, specifying what task you want the build system to perform. For example:

```
# on Mac/Linux
./gradlew tasks

# on Windows
gradlew tasks
```

Will give you a list of available tasks. Use `gradlew classes` to compile the code, and `gradlew run` to compile *and* run the code.

- **Helpful hint:** you can specify the “quite” flag with `gradlew -q <task>` to not have Gradle output its build status (handy for the run task)

Practice: Use gradle to build and run your Dog program. See how much easier that is?

We will be using Gradle to build our Android applications (which are much more complex than this simple Java demo)!

A.2 Class Basics

Now consider the `Dog` class in more detail. Like all classes, it has two parts:

1. **Attributes** (a.k.a., instance variables, fields, or member variables). For example, `String name`.
 - Notice that all of these attributes are **private**, meaning they are not accessible to members of another class! This is important for **encapsulation**: it means we can change how the `Dog` class is implemented without changing any other class that depends on it (for example, if we want to store `breed` as a number instead of a `String`).
2. **Methods** (a.k.a., functions). For example `bark()`
 - Note the *method declaration* `public void wagTail(int)`. This combination of access modifier (`public`), return type (`void`), method name (`wagTail`) and parameters (`int`) is called the **method signature**: it is the “autograph” of that particular method. When we call a method (e.g., `myDog.wagTail(3)`), Java will look for a method definition that *matches* that signature.
 - Method signatures are very important! They tell us what the inputs and outputs of a method will be. We should be able to understand how the method works *just* from its signature.

Notice that one of the methods, `.createPuppies()` is a **static** method. This means that the method belongs to the **class**, not to individual object instances of the class! **Practice: try running the following code (by placing it in the `main()` method of the `Tester` class):**

```
Dog[] pups = Dog.createPuppies(3);
System.out.println(Arrays.toString(pups));
```

Notice that to call the `createPuppies()` method you didn’t need to have a `Dog` object (you didn’t need to use the `new` keyword): instead you went to the “template” for a `Dog` and told that template to do some work. *Non-static* methods (ones without the `static` keyword, also called “instance methods”) need to be called on an object.

Practice: Try to run the code `Dog.bark()`. What happens? This is because you can’t tell the “template” for a `Dog` to bark, only an actual `Dog` object!

In general, in 98% of cases, your methods should **not** be **static**, because you want to call them on a specific object rather than on a general “template” for objects. Variables should **never** be static, unless they are **also** **final** constants (like the `BEST_BREED` variable).

- In Android, **static** variables cause significant memory leaks, as well as just being generally poor design.

A.3 Inheritance

*Practice: Create a new file **Husky.java** that declares a new **Husky** class:*

```
package edu.info448.review; //package declaration (needed)

public class Husky extends Dog {
    /* class body goes here */
}
```

The `extends` keyword means that `Husky` is a **subclass** of `Dog`, inheriting all of its methods and attributes. It also means that that a `Husky` instance **is a** `Dog` instance.

*Practice: In the Tester, instantiate a new **Husky** and call `bark()` on it. What happens?*

- Because we've inherited from `Dog`, the `Husky` class gets all of the methods defined in `Dog` for free!
- Try adding a constructor that takes in a single parameter (name) and calls the appropriate `super()` constructor so that the breed is "Husky", which makes this a little more sensible.

We can also add more methods to the **subclass** that the **parent class** doesn't have. *Practice: add a method called `.pullSled()` to the **Husky** class.*

- Try calling `.pullSled()` on your `Husky` *object*. What happens? Then try calling `.pullSled()` on a `Dog` *object*. What happens?

Finally, we can **override** methods from the parent class. *Practice: add a `bark()` method to **Husky** (with the same signature), but that has the **Husky** "woof" instead of "bark".* Test out your code by calling the method in the Tester.

A.4 Interfaces

*Practice: Create a new file **Huggable.java** with the following code:*

```
package edu.info448.review;

public interface Huggable {
    public void hug();
}
```

This is an example of an **interface**. An **interface** is a list of methods that a class *promises* to provide. By *implementing* the interface (with the `interface` keyword in the class declaration), the class promises to include any methods listed in the interface.

- This is a lot like hanging a sign outside your business that says “*Accepts Visa*”. It means that if someone comes to you and tries to pay with a Visa card, you’ll be able to do that!
- Implementing an interface makes no promise about *what* those methods do, just that the class will include methods with those signatures. ***Practice: change the Husky class declaration:***

```
java public class Husky extends Dog implements Huggable {...}
```

Now the the `Husky` class needs to have a `public void hug()` method, but what that method *does* is up to you!

- A class can still have a `.hug()` method even without implementing the `Huggable` interface (see `TeddyBear`), but we gain more benefits by announcing that we support that method.
 - Just like how hanging an “Accepts Visa” sign will bring in more people who would be willing to pay with a credit card, rather than just having that option available if someone asks about it.

Why not just make `Huggable` a superclass, and have the `Husky` extend that?

- Because `Husky` extends `Dog`, and you can only have one parent in Java!
- And because not all dogs are `Huggable`, and not all `Huggable` things are `Dogs`, there isn’t a clear hierarchy for where to include the interface.
- In addition, we can implement multiple interfaces (`Husky` implements `Huggable`, `Petttable`), but we can’t inherit from multiple classes
 - This is great for when we have other classes of different types but similar behavior: e.g., a `TeddyBear` can be `Huggable` but can’t `bark()` like a `Dog`!
 - ***Practice: Make the class `TeddyBear` implement `Huggable`. Do you need to add any new methods?***

What’s the difference between inheritance and interfaces? The main rule of thumb: use *inheritance* (`extends`) when you want classes to share **code** (implementation). Use *interfaces* (`implements`) when you want classes to share **behaviors** (method signatures). In the end, *interfaces* are more important for doing good Object-Oriented design. Favor interfaces over inheritance!

A.5 Polymorphism

Implementing an interface also establishes an **is a** relationship: so a `Husky` object **is a** `Huggable` object. This allows the greatest benefit of interfaces and inheritance: **polymorphism**, or the ability to treat one object as the type of another!

Consider the standard variable declaration:

```
Dog myDog; //= new Dog();
```

The variable type of `myDog` is `Dog`, which means that variable can refer to any value (object) that **is a Dog**.

Practice: Try the following declarations (note that some will not compile!)

```
Dog v1 = new Husky();
Husky v2 = new Dog();
Huggable v2 = new Husky();
Huggable v3 = new TeddyBear();
Husky v4 = new TeddyBear();
```

If the **value** (the thing on the right side) *is an* instance of the **variable type** (the type on the left side), then you have a valid declaration.

Even if you declare a variable `Dog v1 = new Husky()`, the **value** in that object *is* a `Husky`. If you call `.bark()` on it, you'll get the `Husky` version of the method (*Practice: try overriding the method to print out "barks like a Husky" to see*).

You can **cast** between types if you need to convert from one to another. As long as the **value** *is a* instance of the type you're casting to, the operation will work fine.

```
Dog v1 = new Husky();
Husky v2 = (Husky)v1; //legal casting
```

The biggest benefit from polymorphism is abstraction. Consider:

```
ArrayList<Huggable> hugList = new ArrayList<Huggable>(); //a list of huggable things
hugList.add(new Husky()); //a Husky is Huggable
hugList.add(new TeddyBear()); //so are Teddybears!

//enhanced for loop ("foreach" loop)
//read: "for each Huggable in the hugList"
for(Huggable thing : hugList) {
    thing.hug();
}
```

Practice: What happens if you run the above code? Because Huskies and Teddy Bears share the same behavior (interface), we can treat them as a single “type”, and so put them both in a list. And because everything in the list supports the `Huggable` interface, we can call `.hug()` on each item in the list and we know they'll have that method—they promised by implementing the interface after all!

A.6 Abstract Methods and Classes

Take another look at the `Huggable` interface you created. It contains a single method declaration... followed by a semicolon instead of a method body. This is an **abstract method**: in fact, you can add the `abstract` keyword to this method declaration without changing anything (all methods are interfaces are implicitly `abstract`, so it isn't required):

```
public abstract void hug();
```

An **abstract method** is one that does not (yet) have a method body: it's just the signature, but no actual implementation. It is "unfinished." In order to instantiate a class (using the `new` keyword), that class needs to be "finished" and provide implementations for *all* abstract methods—e.g., all the ones you've inherited from an interface. This is exactly how you've used `interfaces` so far: it's just another way of thinking about why you need to provide those methods.

If the `abstract` keyword is implied for interfaces, what's the point? Consider the `Animal` class (which is a parent class for `Dog`). The `.speak()` method is "empty"; in order for it to do anything, the subclass needs to override it. And currently there is nothing to stop someone who is subclassing `Animal` from forgetting to implement that method!

We can *force* the subclass to override this method by making the method `abstract`: effectively, leaving it unfinished so that if the subclass (e.g., `Dog`) wants to do anything, it must finish up the method. ***Practice: Make the `Animal#speak()` method abstract. What happens when you try and build the code?***

If the `Animal` class contains an unfinished (`abstract`) method... then that class itself is unfinished, and Java requires us to mark it as such. We do this by declaring the *class* as `abstract` in the class declaration :

```
public abstract class MyAbstractClass {...}
```

Practice: Make the `Animal` class abstract. You will need to provide an implementation of the `.speak()` method in the `Dog` class: try just having it call the `.bark()` method (method composition for-the-win!).

Only abstract classes and `interfaces` can contain `abstract` methods. In addition, an `abstract` class is unfinished, meaning it can't be instantiated. ***Practice: Try to instantiate a new `Animal()`. What happens?*** Abstract classes are great for containing "most" of a class, but making sure that it isn't used without all the details provided. And if you think about it, we'd never want to ever instantiate a generic `Animal` anyway—we'd instead make a `Dog` or a `Cat` or a `Turtle` or something. All that the `Animal` class is doing is acting as an **abstraction** for these other classes to allow them to share implementations (e.g., of a `walk()` method).

- Abstract classes are a bit like “templates” for classes... which are themselves “templates” for objects.

A.7 Generics

Speaking of templates: think back to the `ArrayList` class you’ve used in the past, and how you specified the “type” inside that List by using angle brackets (e.g., `ArrayList<Dog>`). Those angle brackets indicate that `ArrayList` is a generic class: a template for a class where a *data type* for that class is itself a variable.

Consider the `GiftBox` class, representing a box containing a `TeddyBear`. ***What changes would you need to make to this class so that it contains a Husky instead of a TeddyBear? What about if it contained a String instead?***

You should notice that the only difference between `TeddyGiftBox` and `HuskyGiftBox` and `StringGiftBox` would be the **variable type** of the contents. So rather than needing to duplicate work and write the same code for every different type of gift we might want to give... we can use **generics**.

Generics let us specify a data type (e.g., what is currently `TeddyBear` or `String`) as a *variable*, which is set when we instantiate the class using the angle brackets (e.g., `new GiftBox<TeddyBear>()` would create an object of the class with that type variable set to be `TeddyBear`).

We specify generics by declaring the data type variable in the class declaration:

```
public class GiftBox<T> {...}
```

(`T` is a common variable name, short for “Type”. Other options include `E` for Elements in lists, `K` for Keys and `V` for Values in maps).

And then everywhere you would have put a datatype (e.g., `TeddyBear`), you can just put the `T` variable instead. This will be replaced by an *actual* type **at compile time**.

- Warning: *always* use single-letter variable names for generic types! If you try to name it something like `String` (e.g., `public class GiftBox<String>`), then Java will interpret the word `String` to be that variable type, rather than referring to the `java.lang.String` class. This is a lot like declaring a variable `int Dog = 448`, and then calling `Dog.createPuppies()`.

Practice: Try to make the `GiftBox` class generic and instantiate a new `GiftBox<Husky>`

A.8 Nested Classes

One last piece: we’ve been putting *attributes* and *methods* into classes... but we can also define additional *classes* inside a class! These are called **nested** or **inner classes**.

We’ll often nest “helper classes” inside a bigger class: for example, you may have put a `Node` class inside a `LinkedList` class:

```
public class LinkedList {  
    //nested class  
    public class Node {  
        private int data;  
  
        public Node(int data) {  
            this.data = data;  
        }  
    }  
  
    private Node start;  
  
    public LinkedList() {  
        this.start = new Node(448);  
    }  
}
```

Or maybe we want to define a `Smell` class inside the `Dog` class to represent different smells, allowing us to talk about different `Dog.Smell` objects. (And of course, the `Dog.Smell` class would implement the `Sniffable` interface...)

Nested classes we define are usually **static**: meaning they belong to the *class* not to object instances of that class. This means that there is only one copy of that nested blueprint class in memory; it’s the equivalent to putting the class in a separate file, but nesting lets us keep them in the same place and provides a “namespacing” function (e.g., `Dog.Smell` rather than just `Smell`).

Non-static nested classes (or **inner classes**) on the other hand are defined for each object. This is important only if the behavior of that class is going to depend on the object in which it lives. This is a subtle point that we’ll see as we provide inner classes required by the Android framework.

Appendix B

Swing Framework

Android applications are user-driven graphical applications. In order to become familiar with some of the *coding patterns* involved in this kind of software (without the overhead of the Android framework), let's consider how to build simple graphical applications in Java using the Swing library

This appendix references code found at <https://github.com/info448-s17/lecture02-activities>, in the `java/` folder. Note that this tutorial involves Java Programming; while it is possible to do this in Android Studio, it's often easier to just utilize a light-weight text editor such as Visual Studio Code or Sublime Text.

The **Swing** library is a set of Java classes used to specify graphical user interfaces (GUIs). These classes can be found in the `javax.swing` package. They also rely on the `java.awt` package (the “Advanced Windowing Toolkit”), which is an older GUI library that Swing builds on top of.

- Fun fact: Swing library is named after the dance style: the developers wanted to name it after something hip and cool and popular. In the mid-90s.

Let's look at an incredibly basic GUI class: `MyGUI` found in the `src/main/java/` folder. The class *subclasses* (extends) `JFrame`. `JFrame` represents a “window” in your operating system, and does all the work of making that window show up and interact with the operating system in a normal way. By subclassing `JFrame`, we get that functionality for free! This is how we build all GUI applications using this framework.

Most of the work defining a Swing GUI happens in the `JFrame` constructor (called when the GUI is “created”).

1. We first call the parent constructor (passing in the title for the window), and then call a method to specify what happens when we hit the “close” button.

2. We then instantiate a `JButton`, which is a class representing a Java Button. Note that `JButton` is the Swing version of a button, building off of the older `java.awt.Button` class.
3. We then `.add()` this button to the `JFrame`. This puts the button inside the window. This process is similar to using jQuery to add an HTML element to web page.
4. Finally, we call `.pack()` to tell the Frame to resize itself to fit the contents, and then `.setVisible()` to make it actually appear.
5. We run this program from `main` by just instantiating our specialized `JFrame`, which will contain the button.

You can compile and run this program with `./gradlew -q run`. And voila, we have a basic button app!

B.1 Events

If we click the button... nothing happens. Let's make it print out a message when clicked. We can do this through **event-based programming** (if you remember handling `click` events from JavaScript, this is the same idea).

Most computer systems see interactions with its GUI as a series of **events**: the *event* of clicking a button, the *event* of moving the mouse, the *event* of closing a window, etc. Each thing you interact with *generates* and *emits* these events. So when you click on a button, it creates and emits an "I was clicked!" event. (You can think of this like the button shouting "Hey hey! I was pressed!") We can write code to respond to this shouting to have our application do something when the button is clicked.

Events, like everything else in Java, are Objects (of the `EventObject` type) that are created by the emitter. A `JButton` in particular emits `ActionEvents` when pressed (the "action" being that it was pressed). In other words, when buttons are pressed, they shout out `ActionEvents`.

In order to respond to this shouting, we need to "listen" for these events. Then whenever we hear that there is an event happening, we can react to it. This is like a person manning a submarine radar, or hooking up a baby monitor, or following someone on Twitter.

But this is Java, and everything in Java is based on Objects, we need an object to listen for these events: a "listener" if you will. Luckily, Java provides a type that can listen for `ActionEvents`: `ActionListener`. This type has an `actionPerformed()` method that can be called in response to an event.

We use the Observer Pattern to connect this listener object to the button (`button.addActionListener(listener)`). This *registers* the listener, so that

the Button knows who to shout at when something happens. (Again, like following someone on Twitter). When the button is pressed, it will go to any listeners registered with it and call their `actionPerformed()` methods, passing in the `ActionEvent` it generated.

But look carefully: `ActionListener` is not a concrete class, but an abstract **interface**. This means if we want to make an `ActionListener` object, we need to create a class that **implements** this interface (and provides the `actionPerformed()` method that can be called when the event occurs). There are a few ways we can do this:

1. We already have a class we're developing: `MyGUI`! So we can just make *that* class **implement** `ActionListener`. We'll fill in the provided method, and then specify that `this` object is the listener, and voila.
 - This is my favorite way to create listeners in Java (since it keeps everything self-contained: the `JFrame` handles the events its buttons produce).
 - We'll utilize a variant of this pattern in Android: we'll make classes implement listeners, and then "register" that listener somewhere else in the code (often in a nested class).
2. But what if we want to *reuse* our listener across different classes, but don't want to have to create a new `MyGUI` object to listen for a button to be clicked? We can instead use an **inner** or **nested** class. For example, create a nested class `MyActionListener` that implements the interface, and then just instantiate one of those to register with the button.
 - This could be a **static** nested class, but then it wouldn't be able to access instance variables (because it belongs to the *class*, not the *object*). So you might want to make it an inner class instead. Of course then you can't re-use it elsewhere without making the `MyGUI` (whose instance variables it references anyway)... but at least we've organized the functionality.
3. It seems sort of silly to create a whole new `MyActionListener` class that has one method and is just going to be instantiated once. So what if instead of giving it a name, we just made it an **anonymous class**? This is similar to how you've made *anonymous variables* by instantiating objects without assigning them to named variables, you're just doing the same thing with a class that just implements an interface. The syntax looks like:

```
button.addActionListener(new ActionListener() {  
    //class definition (including methods to override) goes in here!  
    public void actionPerformed(ActionEvent event) {  
        //...  
    }  
});
```

This is how buttons are often used in Android: we'll create an anonymous listener object to respond to the event that occurs when they are pressed.

B.2 Layouts and Composites

What if we want to add a second button? If we try to just `.add()` another button... it replaces the one we previously had! This is because Java doesn't know *where* to put the second button. Below? Above? Left? Right?

In order to have the `JFrame` contain multiple components, we need to specify a **layout**, which knows how to organize items that are added to the Frame. We do this with the `.setLayout()` method. For example, we can give the frame a `BoxLayout()` with a `PAGE_AXIS` orientation to have it lay out the buttons in a vertical row.

```
container.setLayout(new BoxLayout(container, BoxLayout.PAGE_AXIS));
container.add(theButton);
container.add(otherButton);
```

- Java has different `LayoutManagers` that each have their own way of organizing components. We'll see this same idea in Android.

What if we want to do more complex layouts? We could look for a more complex `LayoutManager`, but we can actually achieve a lot of flexibility simply by using *multiple containers*.

For example, we can make a `JPanel` object, which is basically an “empty” component. We can then add multiple buttons to this this panel, and add *that panel* to the `JFrame`. Because `JPanel` is a `Component` (just like `JButton` is), we can use the `JPanel` exactly as we used the `JButton`—this panel just happens to have multiple buttons.

And since we can put any `Component` in a `JPanel`, and `JPanel` is itself a `Component`... we can create nest these components together into a tree in an example of the Composite Pattern. This allows us to create very complex user interfaces with just a simple `BoxLayout`!

- This is similar to how we can create complex web layouts just by nesting lots of `<div>` elements.

Appendix C

Threads and HTTP Requests

This appendix introduces concepts in **concurrency and threading**, which are used extensively by Android through a framework-specific classes and options. For clarity, these concepts are introduced through a set of practice exercises in straight Java (though similar code can be utilized in Android).

The code for these exercises can be found at <https://github.com/info448-s17/lab-threads-http>.

Additionally, this appendix introduces the Java code used to send **network requests**. Android will use *exactly* this code, but in order to experiment with it separate from the Android framework you'll be making network connections directly from Java.

C.1 Concurrency

Concurrency the process by which we have multiple *processes* (think: methods) running at the same time. This can be contrasted with processes that run **serially**, or one after another.

C.1.1 An Example: Algorithm Races!

As an example, note that one of the main concerns of computer science and software in general is speed: how fast will a particular program or algorithm run? For example, give two of the many sorting algorithms that have been invented, which one can sort a list of numbers more quickly?

- Sorting algorithms are usually covered in UW’s *CSE 373* course, but don’t worry if you haven’t taken that course yet! All you need to know is that there are different techniques for sorting numbers, these techniques are given funny names, and one technique may be faster than another

Consider the provided `SortRacer.java` class (found in the `src/main/java` folder). The `main` method for this program runs two different sorting algorithms (currently Merge Sort and Quicksort), reporting when each one is finished.

Practice: *Run this program using gradle:* `./gradlew -q runSorts`. Note that it may take a few seconds for it to build and begin running, and the sorting itself may take a few seconds!

Of course, it’s not really a “race” at the moment: rather, each sorting algorithm is run **serially** (that is, one after another). If we really wanted them to race, we’d like the algorithms to run **concurrently** (at the same time).

Computers as a general rule do exactly one thing a time: your central processing unit (CPU) just adds two number together over and over again, billions of times a second

- The standard measure for *rate* (how many times per second) is the **hertz** (Hz). So a 2 gigahertz (GHz) processor can do 2 billion operations per second.

However, we don’t realize that computers do only one thing at a time! This is because computers are really good at *multitasking*: they will do a tiny bit of one task, and then jump over to another task and do a little of that, and then jump over to another task and do a little of that, and then back to the first task, and so on.

These “tasks” are divided up into two types: **processes** and **threads**. *Read this brief summary of the difference between them.*

So by breaking up a program into threads (which are “interwoven”), we can in effect cause the computer to do two tasks at once. This is *especially* useful if one of the “tasks” might take a really long time—rather than **blocking** the application, we can let other tasks also make some progress while we’re waiting for the long task to finish.

C.1.2 Threading the Race

Currently the two sorting algorithms run in the same thread, one after another. You should break them into two *different* threads that can run **concurrently**, letting them actually be able to race!

In Java, we create a Thread by creating a class that implements the **Runnable** interface. This represents a class that can be “run” in a separate thread! The `run()` method required by the interface acts a bit like the “main” method for

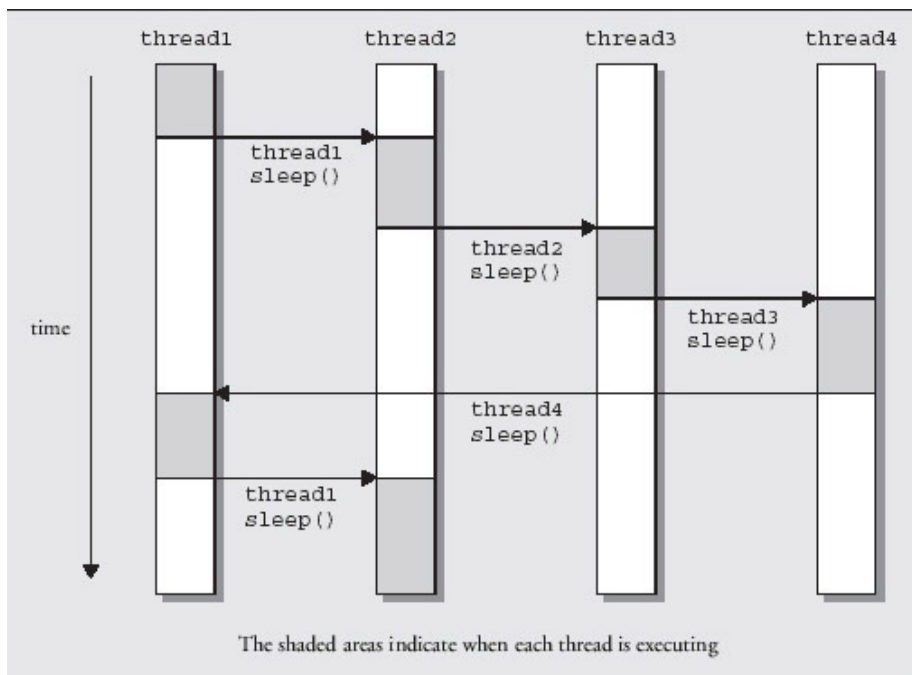


Figure C.1: Diagram of thread switching (source unknown)

that Thread: when we start the Thread running, that is the method that will get called.

Practice: *Create two new Runnable classes, one for each Sorting method.*

- These should be nested classes (think: should they be `static`?).
- When each Runnable is run, you should create a new *shuffled* array of numbers and then call the appropriate sorting method on that list. Remember to print out when you start and finish sorting (just like is currently done in the `main()` method).

If we just instantiate the Runnable() and call its `run()` method, that won't actually execute the method on a different thread (remember: an interface is just a "sign"; we could have called the interface and method whatever we wanted and it would still compile). Instead, we execute code on a separate thread by using an instance of the **Thread** class. This class actually does the work of running code on a separate thread.

Thread has a constructor that takes in a Runnable instance as a parameter—you pass an object representing the "code to run" to the Thread object (this is an example of the *Strategy Pattern*). You then can actually **start** the Thread by calling its `.start()` method (*not* the `run` method!).

Practice: *Modify the main() method so you create new Threads to execute each Runnable* Make sure you actually `start()` the threads!

- Anonymous variables will be useful here; you don't need to assign a variable name to the Runnable objects or even the Thread objects if you just use them directly.

Now run your program! Do you see the Threads running at the same time? Try running the program multiple times and see what kind of differences you get.

- There are some print statements you can uncomment in the **Sorting** class if you want to see more concrete evidence of the Threads running concurrently.
- You are also welcome to try racing different sorting algorithms (you'll want to use a smaller list of numbers, particularly for the painfully slow BubbleSort). You can even race more than two algorithms—just create additional Threads!

And that's the basics of creating Threads in Java!

C.2 HTTP Requests

Consider the provided `MovieDownloader.java` class (found in the `src/main/java/` folder). This Java code (which is *directly* portable to

Android) accesses the database at `omdbapi.com`, a wrapper around the IMDB API calls for getting information about movies.

You can run this program with the `./gradlew -q runMovies` task. It will prompt you for a movies to search for, and then print out the results (in JSON format).

Practice: *add descriptive comments to the `downloadMovieData()` method*, explaining what the code does and how it works. The goal is to understand the classes and methods are that are being used here (particularly the use of `URLConnection`, `InputStream`, and `BufferedReader`), and demonstrate that understanding through explanatory comments. You should also pay particular attention to the use of `try/catch` blocks (see here for one explanation).

Note that we'll utilize this exact code in Android, so you should be familiar with what it is doing!