

Android Studio Bumble Bee Essentials

Kotlin Edition

Android Studio Bumble Bee Essentials – Kotlin Edition

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Table of Contents

1. Introduction	1
1.1 Downloading the Code Samples	1
1.2 Feedback	2
1.3 Errata	2
2. Setting up an Android Studio Development Environment	3
2.1 System Requirements	3
2.2 Downloading the Android Studio Package	3
2.3 Installing Android Studio	4
2.3.1 Installation on Windows	4
2.3.2 Installation on macOS	4
2.3.3 Installation on Linux	5
2.4 The Android Studio Setup Wizard	5
2.5 Installing Additional Android SDK Packages	6
2.6 Making the Android SDK Tools Command-line Accessible	9
2.6.1 Windows 8.1	9
2.6.2 Windows 10	10
2.6.3 Windows 11	10
2.6.4 Linux	10
2.6.5 macOS	10
2.7 Android Studio Memory Management	11
2.8 Updating Android Studio and the SDK	12
2.9 Summary	12
3. Creating an Example Android App in Android Studio	13
3.1 About the Project	13
3.2 Creating a New Android Project	13
3.3 Creating an Activity	14
3.4 Defining the Project and SDK Settings	14
3.5 Modifying the Example Application	15
3.6 Modifying the User Interface	16
3.7 Reviewing the Layout and Resource Files	21
3.8 Adding the Kotlin Extensions Plugin	24
3.9 Adding Interaction	25
3.10 Summary	26
4. Creating an Android Virtual Device (AVD) in Android Studio	27
4.1 About Android Virtual Devices	27
4.2 Starting the Emulator	28
4.3 Running the Application in the AVD	29
4.4 Running on Multiple Devices	31
4.5 Stopping a Running Application	31
4.6 Supporting Dark Theme	32
4.7 Running the Emulator in a Separate Window	33

Table of Contents

4.8 Enabling the Device Frame.....	34
4.9 AVD Command-line Creation	35
4.10 Android Virtual Device Configuration Files.....	37
4.11 Moving and Renaming an Android Virtual Device	37
4.12 Summary	37
5. Using and Configuring the Android Studio AVD Emulator	39
5.1 The Emulator Environment	39
5.2 Emulator Toolbar Options	39
5.3 Working in Zoom Mode	41
5.4 Resizing the Emulator Window.....	41
5.5 Extended Control Options.....	41
5.5.1 Location	42
5.5.2 Displays.....	42
5.5.3 Cellular	42
5.5.4 Battery.....	42
5.5.5 Camera.....	42
5.5.6 Phone	42
5.5.7 Directional Pad.....	42
5.5.8 Microphone.....	42
5.5.9 Fingerprint	42
5.5.10 Virtual Sensors	43
5.5.11 Snapshots.....	43
5.5.12 Record and Playback	43
5.5.13 Google Play	43
5.5.14 Settings	43
5.5.15 Help.....	43
5.6 Working with Snapshots.....	43
5.7 Configuring Fingerprint Emulation	44
5.8 The Emulator in Tool Window Mode.....	45
5.9 Summary	46
6. A Tour of the Android Studio User Interface	47
6.1 The Welcome Screen	47
6.2 The Main Window	48
6.3 The Tool Windows	49
6.4 Android Studio Keyboard Shortcuts	52
6.5 Switcher and Recent Files Navigation	53
6.6 Changing the Android Studio Theme	53
6.7 Summary	54
7. Testing Android Studio Apps on a Physical Android Device.....	55
7.1 An Overview of the Android Debug Bridge (ADB)	55
7.2 Enabling USB Debugging ADB on Android Devices.....	55
7.2.1 macOS ADB Configuration	56
7.2.2 Windows ADB Configuration	57
7.2.3 Linux adb Configuration.....	58
7.3 Resolving USB Connection Issues	58
7.4 Enabling Wireless Debugging on Android Devices	59
7.5 Testing the adb Connection	61
7.6 Summary	61

8. The Basics of the Android Studio Code Editor.....	63
8.1 The Android Studio Editor.....	63
8.2 Splitting the Editor Window.....	65
8.3 Code Completion.....	66
8.4 Statement Completion.....	67
8.5 Parameter Information.....	68
8.6 Parameter Name Hints.....	68
8.7 Code Generation.....	68
8.8 Code Folding.....	69
8.9 Quick Documentation Lookup.....	70
8.10 Code Reformatting.....	71
8.11 Finding Sample Code.....	71
8.12 Live Templates.....	72
8.13 Summary.....	72
9. An Overview of the Android Architecture	73
9.1 The Android Software Stack.....	73
9.2 The Linux Kernel.....	74
9.3 Android Runtime – ART.....	74
9.4 Android Libraries.....	74
9.4.1 C/C++ Libraries.....	75
9.5 Application Framework.....	75
9.6 Applications.....	76
9.7 Summary.....	76
10. The Anatomy of an Android Application	77
10.1 Android Activities.....	77
10.2 Android Fragments.....	77
10.3 Android Intents.....	78
10.4 Broadcast Intents.....	78
10.5 Broadcast Receivers.....	78
10.6 Android Services.....	78
10.7 Content Providers.....	79
10.8 The Application Manifest.....	79
10.9 Application Resources.....	79
10.10 Application Context.....	79
10.11 Summary.....	79
11. An Introduction to Kotlin.....	81
11.1 What is Kotlin?.....	81
11.2 Kotlin and Java.....	81
11.3 Converting from Java to Kotlin.....	81
11.4 Kotlin and Android Studio.....	82
11.5 Experimenting with Kotlin.....	82
11.6 Semi-colons in Kotlin.....	83
11.7 Summary.....	83
12. Kotlin Data Types, Variables, and Nullability	85
12.1 Kotlin Data Types.....	85
12.1.1 Integer Data Types.....	86
12.1.2 Floating-Point Data Types.....	86

Table of Contents

12.1.3 Boolean Data Type.....	86
12.1.4 Character Data Type.....	86
12.1.5 String Data Type.....	86
12.1.6 Escape Sequences	87
12.2 Mutable Variables.....	88
12.3 Immutable Variables	88
12.4 Declaring Mutable and Immutable Variables.....	88
12.5 Data Types are Objects	88
12.6 Type Annotations and Type Inference	89
12.7 Nullable Type.....	90
12.8 The Safe Call Operator	90
12.9 Not-Null Assertion.....	91
12.10 Nullable Types and the let Function.....	91
12.11 Late Initialization (lateinit)	92
12.12 The Elvis Operator	93
12.13 Type Casting and Type Checking	93
12.14 Summary.....	94
13. Kotlin Operators and Expressions	95
13.1 Expression Syntax in Kotlin.....	95
13.2 The Basic Assignment Operator.....	95
13.3 Kotlin Arithmetic Operators	95
13.4 Augmented Assignment Operators	96
13.5 Increment and Decrement Operators	96
13.6 Equality Operators	97
13.7 Boolean Logical Operators	97
13.8 Range Operator	98
13.9 Bitwise Operators.....	98
13.9.1 Bitwise Inversion	98
13.9.2 Bitwise AND	99
13.9.3 Bitwise OR.....	99
13.9.4 Bitwise XOR.....	99
13.9.5 Bitwise Left Shift.....	100
13.9.6 Bitwise Right Shift.....	100
13.10 Summary.....	101
14. Kotlin Control Flow	103
14.1 Looping Control flow	103
14.1.1 The Kotlin <i>for-in</i> Statement.....	103
14.1.2 The <i>while</i> Loop	104
14.1.3 The <i>do ... while</i> loop	105
14.1.4 Breaking from Loops	105
14.1.5 The <i>continue</i> Statement	106
14.1.6 Break and Continue Labels.....	106
14.2 Conditional Control Flow.....	107
14.2.1 Using the <i>if</i> Expressions	107
14.2.2 Using <i>if ... else ...</i> Expressions	108
14.2.3 Using <i>if ... else if ...</i> Expressions	108
14.2.4 Using the <i>when</i> Statement	108
14.3 Summary	109

15. An Overview of Kotlin Functions and Lambdas	111
15.1 What is a Function?	111
15.2 How to Declare a Kotlin Function	111
15.3 Calling a Kotlin Function.....	112
15.4 Single Expression Functions.....	112
15.5 Local Functions	112
15.6 Handling Return Values	113
15.7 Declaring Default Function Parameters.....	113
15.8 Variable Number of Function Parameters	113
15.9 Lambda Expressions	114
15.10 Higher-order Functions	115
15.11 Summary	116
16. The Basics of Object Oriented Programming in Kotlin	117
16.1 What is an Object?	117
16.2 What is a Class?	117
16.3 Declaring a Kotlin Class	117
16.4 Adding Properties to a Class.....	118
16.5 Defining Methods	118
16.6 Declaring and Initializing a Class Instance.....	118
16.7 Primary and Secondary Constructors.....	118
16.8_INITIALIZER Blocks.....	121
16.9 Calling Methods and Accessing Properties	121
16.10 Custom Accessors	121
16.11 Nested and Inner Classes	122
16.12 Companion Objects.....	123
16.13 Summary	125
17. An Introduction to Kotlin Inheritance and Subclassing.....	127
17.1 Inheritance, Classes and Subclasses.....	127
17.2 Subclassing Syntax	127
17.3 A Kotlin Inheritance Example.....	128
17.4 Extending the Functionality of a Subclass	129
17.5 Overriding Inherited Methods.....	130
17.6 Adding a Custom Secondary Constructor.....	131
17.7 Using the SavingsAccount Class	131
17.8 Summary	131
18. An Overview of Android View Binding.....	133
18.1 Find View by Id and Synthetic Properties	133
18.2 View Binding	134
18.3 Converting the AndroidSample project.....	134
18.4 Enabling View Binding.....	134
18.5 Using View Binding	135
18.6 Choosing an Option	136
18.7 View Binding in the Book Examples	136
18.8 Migrating a Project to View Binding.....	136
18.9 Summary	137
19. Understanding Android Application and Activity Lifecycles	139
19.1 Android Applications and Resource Management.....	139

Table of Contents

19.2 Android Process States	139
19.2.1 Foreground Process	140
19.2.2 Visible Process	140
19.2.3 Service Process	140
19.2.4 Background Process.....	140
19.2.5 Empty Process	141
19.3 Inter-Process Dependencies	141
19.4 The Activity Lifecycle.....	141
19.5 The Activity Stack.....	141
19.6 Activity States	142
19.7 Configuration Changes	142
19.8 Handling State Change.....	143
19.9 Summary	143
20. Handling Android Activity State Changes.....	145
20.1 New vs. Old Lifecycle Techniques.....	145
20.2 The Activity and Fragment Classes.....	145
20.3 Dynamic State vs. Persistent State.....	147
20.4 The Android Lifecycle Methods	147
20.5 Lifetimes	149
20.6 Foldable Devices and Multi-Resume	150
20.7 Disabling Configuration Change Restarts	150
20.8 Lifecycle Method Limitations.....	150
20.9 Summary	151
21. Android Activity State Changes by Example	153
21.1 Creating the State Change Example Project	153
21.2 Designing the User Interface	154
21.3 Overriding the Activity Lifecycle Methods	154
21.4 Filtering the Logcat Panel.....	156
21.5 Running the Application.....	157
21.6 Experimenting with the Activity.....	157
21.7 Summary	159
22. Saving and Restoring the State of an Android Activity	161
22.1 Saving Dynamic State	161
22.2 Default Saving of User Interface State	161
22.3 The Bundle Class	162
22.4 Saving the State.....	163
22.5 Restoring the State	164
22.6 Testing the Application.....	164
22.7 Summary	164
23. Understanding Android Views, View Groups and Layouts	165
23.1 Designing for Different Android Devices	165
23.2 Views and View Groups	165
23.3 Android Layout Managers	165
23.4 The View Hierarchy	167
23.5 Creating User Interfaces	168
23.6 Summary	168
24. A Guide to the Android Studio Layout Editor Tool	169

24.1 Basic vs. Empty Activity Templates	169
24.2 The Android Studio Layout Editor	173
24.3 Design Mode.....	173
24.4 The Palette	174
24.5 Design Mode and Layout Views.....	175
24.6 Night Mode	176
24.7 Code Mode.....	176
24.8 Split Mode	176
24.9 Setting Attributes.....	177
24.10 Transforms	178
24.11 Tools Visibility Toggles.....	179
24.12 Converting Views.....	181
24.13 Displaying Sample Data	182
24.14 Creating a Custom Device Definition	182
24.15 Changing the Current Device.....	183
24.16 Layout Validation (Multi Preview)	184
24.17 Summary	184
25. A Guide to the Android ConstraintLayout.....	187
25.1 How ConstraintLayout Works.....	187
25.1.1 Constraints.....	187
25.1.2 Margins.....	188
25.1.3 Opposing Constraints.....	188
25.1.4 Constraint Bias	189
25.1.5 Chains.....	190
25.1.6 Chain Styles.....	190
25.2 Baseline Alignment.....	191
25.3 Configuring Widget Dimensions.....	191
25.4 Guideline Helper	192
25.5 Group Helper	192
25.6 Barrier Helper	192
25.7 Flow Helper	194
25.8 Ratios	195
25.9 ConstraintLayout Advantages	195
25.10 ConstraintLayout Availability.....	196
25.11 Summary	196
26. A Guide to Using ConstraintLayout in Android Studio	197
26.1 Design and Layout Views.....	197
26.2 Autoconnect Mode	198
26.3 Inference Mode.....	199
26.4 Manipulating Constraints Manually.....	199
26.5 Adding Constraints in the Inspector	200
26.6 Viewing Constraints in the Attributes Window.....	201
26.7 Deleting Constraints.....	202
26.8 Adjusting Constraint Bias	202
26.9 Understanding ConstraintLayout Margins.....	203
26.10 The Importance of Opposing Constraints and Bias	204
26.11 Configuring Widget Dimensions.....	206
26.12 Design Time Tools Positioning	207

Table of Contents

26.13 Adding Guidelines	208
26.14 Adding Barriers	210
26.15 Adding a Group	211
26.16 Working with the Flow Helper	212
26.17 Widget Group Alignment and Distribution	213
26.18 Converting other Layouts to ConstraintLayout	214
26.19 Summary	214
27. Working with ConstraintLayout Chains and Ratios in Android Studio	215
27.1 Creating a Chain	215
27.2 Changing the Chain Style	217
27.3 Spread Inside Chain Style	217
27.4 Packed Chain Style	218
27.5 Packed Chain Style with Bias	218
27.6 Weighted Chain	218
27.7 Working with Ratios	219
27.8 Summary	221
28. An Android Studio Layout Editor ConstraintLayout Tutorial	223
28.1 An Android Studio Layout Editor Tool Example	223
28.2 Creating a New Activity	223
28.3 Preparing the Layout Editor Environment	225
28.4 Adding the Widgets to the User Interface	226
28.5 Adding the Constraints	229
28.6 Testing the Layout	230
28.7 Using the Layout Inspector	231
28.8 Summary	232
29. Manual XML Layout Design in Android Studio	233
29.1 Manually Creating an XML Layout	233
29.2 Manual XML vs. Visual Layout Design	236
29.3 Summary	236
30. Managing Constraints using Constraint Sets	237
30.1 Kotlin Code vs. XML Layout Files	237
30.2 Creating Views	237
30.3 View Attributes	238
30.4 Constraint Sets	238
30.4.1 Establishing Connections	238
30.4.2 Applying Constraints to a Layout	238
30.4.3 Parent Constraint Connections	238
30.4.4 Sizing Constraints	239
30.4.5 Constraint Bias	239
30.4.6 Alignment Constraints	239
30.4.7 Copying and Applying Constraint Sets	239
30.4.8 ConstraintLayout Chains	239
30.4.9 Guidelines	240
30.4.10 Removing Constraints	240
30.4.11 Scaling	240
30.4.12 Rotation	241
30.5 Summary	241

31. An Android ConstraintSet Tutorial.....	243
31.1 Creating the Example Project in Android Studio	243
31.2 Adding Views to an Activity.....	243
31.3 Setting View Attributes.....	244
31.4 Creating View IDs.....	245
31.5 Configuring the Constraint Set	246
31.6 Adding the EditText View	247
31.7 Converting Density Independent Pixels (dp) to Pixels (px).....	248
31.8 Summary	249
32. A Guide to using Apply Changes in Android Studio.....	251
32.1 Introducing Apply Changes.....	251
32.2 Understanding Apply Changes Options	251
32.3 Using Apply Changes.....	252
32.4 Configuring Apply Changes Fallback Settings	253
32.5 An Apply Changes Tutorial.....	253
32.6 Using Apply Code Changes	253
32.7 Using Apply Changes and Restart Activity.....	254
32.8 Using Run App	254
32.9 Summary	254
33. An Overview and Example of Android Event Handling	255
33.1 Understanding Android Events.....	255
33.2 Using the android:onClick Resource.....	255
33.3 Event Listeners and Callback Methods	256
33.4 An Event Handling Example	256
33.5 Designing the User Interface	257
33.6 The Event Listener and Callback Method.....	258
33.7 Consuming Events	259
33.8 Summary	260
34. Android Touch and Multi-touch Event Handling	261
34.1 Intercepting Touch Events	261
34.2 The MotionEvent Object	262
34.3 Understanding Touch Actions.....	262
34.4 Handling Multiple Touches	262
34.5 An Example Multi-Touch Application	263
34.6 Designing the Activity User Interface	263
34.7 Implementing the Touch Event Listener.....	263
34.8 Running the Example Application.....	266
34.9 Summary	266
35. Detecting Common Gestures Using the Android Gesture Detector Class	267
35.1 Implementing Common Gesture Detection.....	267
35.2 Creating an Example Gesture Detection Project	268
35.3 Implementing the Listener Class.....	268
35.4 Creating the GestureDetectorCompat Instance.....	270
35.5 Implementing the onTouchEvent() Method.....	270
35.6 Testing the Application.....	271
35.7 Summary	271

36. Implementing Custom Gesture and Pinch Recognition on Android	273
36.1 The Android Gesture Builder Application.....	273
36.2 The GestureOverlayView Class	273
36.3 Detecting Gestures.....	273
36.4 Identifying Specific Gestures	273
36.5 Installing and Running the Gesture Builder Application	274
36.6 Creating a Gestures File	274
36.7 Creating the Example Project.....	274
36.8 Extracting the Gestures File from the SD Card	275
36.9 Adding the Gestures File to the Project	275
36.10 Designing the User Interface	275
36.11 Loading the Gestures File	276
36.12 Registering the Event Listener.....	277
36.13 Implementing the onGesturePerformed Method.....	277
36.14 Testing the Application.....	278
36.15 Configuring the GestureOverlayView.....	278
36.16 Intercepting Gestures.....	279
36.17 Detecting Pinch Gestures.....	279
36.18 A Pinch Gesture Example Project.....	279
36.19 Summary.....	281
37. An Introduction to Android Fragments.....	283
37.1 What is a Fragment?	283
37.2 Creating a Fragment	283
37.3 Adding a Fragment to an Activity using the Layout XML File.....	284
37.4 Adding and Managing Fragments in Code	286
37.5 Handling Fragment Events	287
37.6 Implementing Fragment Communication.....	287
37.7 Summary	289
38. Using Fragments in Android Studio - An Example.....	291
38.1 About the Example Fragment Application	291
38.2 Creating the Example Project.....	291
38.3 Migrating a Fragment to View Binding	293
38.4 Adding the Second Fragment.....	294
38.5 Adding the Fragments to the Activity	295
38.6 Making the Toolbar Fragment Talk to the Activity	296
38.7 Making the Activity Talk to the Text Fragment	299
38.8 Testing the Application.....	300
38.9 Summary	300
39. Modern Android App Architecture with Jetpack.....	301
39.1 What is Android Jetpack?	301
39.2 The “Old” Architecture.....	301
39.3 Modern Android Architecture.....	301
39.4 The ViewModel Component	302
39.5 The LiveData Component.....	302
39.6 ViewModel Saved State.....	303
39.7 LiveData and Data Binding.....	304
39.8 Android Lifecycles	304

39.9 Repository Modules	304
39.10 Summary	305
40. An Android Jetpack ViewModel Tutorial	307
40.1 About the Project	307
40.2 Creating the ViewModel Example Project	307
40.3 Reviewing the Project	308
40.3.1 The Main Activity	308
40.3.2 The Content Fragment	308
40.3.3 The ViewModel	309
40.4 Designing the Fragment Layout	310
40.5 Implementing the View Model	310
40.6 Associating the Fragment with the View Model	311
40.7 Modifying the Fragment	311
40.8 Accessing the ViewModel Data	312
40.9 Testing the Project	313
40.10 Summary	313
41. An Android Jetpack LiveData Tutorial	315
41.1 LiveData - A Recap	315
41.2 Adding LiveData to the ViewModel	315
41.3 Implementing the Observer	317
41.4 Summary	318
42. An Overview of Android Jetpack Data Binding	319
42.1 An Overview of Data Binding	319
42.2 The Key Components of Data Binding	319
42.2.1 The Project Build Configuration	319
42.2.2 The Data Binding Layout File	320
42.2.3 The Layout File Data Element	321
42.2.4 The Binding Classes	322
42.2.5 Data Binding Variable Configuration	322
42.2.6 Binding Expressions (One-Way)	323
42.2.7 Binding Expressions (Two-Way)	324
42.2.8 Event and Listener Bindings	324
42.3 Summary	325
43. An Android Jetpack Data Binding Tutorial	327
43.1 Removing the Redundant Code	327
43.2 Enabling Data Binding	328
43.3 Adding the Layout Element	329
43.4 Adding the Data Element to Layout File	330
43.5 Working with the Binding Class	330
43.6 Assigning the ViewModel Instance to the Data Binding Variable	331
43.7 Adding Binding Expressions	332
43.8 Adding the Conversion Method	333
43.9 Adding a Listener Binding	333
43.10 Testing the App	334
43.11 Summary	334
44. An Android ViewModel Saved State Tutorial	335

Table of Contents

44.1 Understanding ViewModel State Saving.....	335
44.2 Implementing ViewModel State Saving	336
44.3 Saving and Restoring State.....	337
44.4 Adding Saved State Support to the ViewModelDemo Project.....	337
44.5 Summary	339
45. Working with Android Lifecycle-Aware Components	341
45.1 Lifecycle Awareness	341
45.2 Lifecycle Owners	341
45.3 Lifecycle Observers	342
45.4 Lifecycle States and Events.....	342
45.5 Summary	343
46. An Android Jetpack Lifecycle Awareness Tutorial	345
46.1 Creating the Example Lifecycle Project.....	345
46.2 Creating a Lifecycle Observer.....	345
46.3 Adding the Observer	346
46.4 Testing the Observer.....	347
46.5 Creating a Lifecycle Owner.....	347
46.6 Testing the Custom Lifecycle Owner.....	349
46.7 Summary	349
47. An Overview of the Navigation Architecture Component.....	351
47.1 Understanding Navigation	351
47.2 Declaring a Navigation Host.....	352
47.3 The Navigation Graph	354
47.4 Accessing the Navigation Controller	355
47.5 Triggering a Navigation Action	355
47.6 Passing Arguments.....	356
47.7 Summary	356
48. An Android Jetpack Navigation Component Tutorial	357
48.1 Creating the NavigationDemo Project.....	357
48.2 Adding Navigation to the Build Configuration.....	357
48.3 Creating the Navigation Graph Resource File.....	358
48.4 Declaring a Navigation Host.....	359
48.5 Adding Navigation Destinations.....	361
48.6 Designing the Destination Fragment Layouts.....	362
48.7 Adding an Action to the Navigation Graph.....	363
48.8 Implement the OnFragmentInteractionListener	365
48.9 Adding View Binding Support to the Destination Fragments	366
48.10 Triggering the Action	366
48.11 Passing Data Using Safeargs	367
48.12 Summary	370
49. An Introduction to MotionLayout.....	371
49.1 An Overview of MotionLayout	371
49.2 MotionLayout	371
49.3 MotionScene	371
49.4 Configuring ConstraintSets.....	372
49.5 Custom Attributes.....	373

49.6 Triggering an Animation.....	374
49.7 Arc Motion.....	376
49.8 Keyframes.....	376
49.8.1 Attribute Keyframes.....	376
49.8.2 Position Keyframes	377
49.9 Time Linearity	380
49.10 KeyTrigger.....	380
49.11 Cycle and Time Cycle Keyframes	381
49.12 Starting an Animation from Code.....	381
49.13 Summary	382
50. An Android MotionLayout Editor.....	383
50.1 Creating the MotionLayoutDemo Project	383
50.2 ConstraintLayout to MotionLayout Conversion	383
50.3 Configuring Start and End Constraints	385
50.4 Previewing the MotionLayout Animation.....	387
50.5 Adding an OnClick Gesture	388
50.6 Adding an Attribute Keyframe to the Transition.....	389
50.7 Adding a CustomAttribute to a Transition.....	392
50.8 Adding Position Keyframes	393
50.9 Summary	396
51. A MotionLayout KeyCycle Tutorial	397
51.1 An Overview of Cycle Keyframes	397
51.2 Using the Cycle Editor.....	401
51.3 Creating the KeyCycleDemo Project.....	402
51.4 Configuring the Start and End Constraints.....	402
51.5 Creating the Cycles	404
51.6 Previewing the Animation	406
51.7 Adding the KeyFrameSet to the MotionScene	406
51.8 Summary	408
52. Working with the Floating Action Button and Snackbar	409
52.1 The Material Design.....	409
52.2 The Design Library	409
52.3 The Floating Action Button (FAB)	409
52.4 The Snackbar.....	410
52.5 Creating the Example Project.....	411
52.6 Reviewing the Project.....	411
52.7 Removing Navigation Features.....	412
52.8 Changing the Floating Action Button	413
52.9 Adding an Action to the Snackbar.....	414
52.10 Summary	414
53. Creating a Tabbed Interface using the TabLayout Component	415
53.1 An Introduction to the ViewPager2	415
53.2 An Overview of the TabLayout Component	415
53.3 Creating the TabLayoutDemo Project.....	416
53.4 Creating the First Fragment.....	416
53.5 Duplicating the Fragments.....	418
53.6 Adding the TabLayout and ViewPager2.....	419

Table of Contents

53.7 Creating the Pager Adapter.....	420
53.8 Performing the Initialization Tasks.....	421
53.9 Testing the Application.....	423
53.10 Customizing the TabLayout.....	423
53.11 Summary.....	424
54. Working with the RecyclerView and CardView Widgets.....	425
54.1 An Overview of the RecyclerView.....	425
54.2 An Overview of the CardView.....	427
54.3 Summary.....	428
55. An Android RecyclerView and CardView Tutorial.....	429
55.1 Creating the CardDemo Project.....	429
55.2 Modifying the Basic Activity Project.....	429
55.3 Designing the CardView Layout.....	430
55.4 Adding the RecyclerView.....	431
55.5 Adding the Image Files.....	431
55.6 Creating the RecyclerView Adapter.....	431
55.7 Initializing the RecyclerView Component.....	433
55.8 Testing the Application.....	434
55.9 Responding to Card Selections.....	435
55.10 Summary.....	436
56. A Layout Editor Sample Data Tutorial.....	437
56.1 Adding Sample Data to a Project.....	437
56.2 Using Custom Sample Data.....	441
56.3 Summary.....	444
57. Working with the AppBar and Collapsing Toolbar Layouts.....	445
57.1 The Anatomy of an AppBar.....	445
57.2 The Example Project.....	446
57.3 Coordinating the RecyclerView and Toolbar.....	446
57.4 Introducing the Collapsing Toolbar Layout.....	448
57.5 Changing the Title and Scrim Color.....	451
57.6 Summary.....	452
58. An Android Studio Primary/Detail Flow Tutorial.....	453
58.1 The Primary/Detail Flow.....	453
58.2 Creating a Primary/Detail Flow Activity.....	454
58.3 Modifying the Primary/Detail Flow Template.....	455
58.4 Changing the Content Model.....	455
58.5 Changing the Detail Pane.....	457
58.6 Modifying the WebsiteDetailFragment Class.....	458
58.7 Modifying the WebsiteListFragment Class.....	459
58.8 Adding Manifest Permissions.....	459
58.9 Running the Application.....	460
58.10 Summary.....	460
59. An Overview of Android Intents.....	461
59.1 An Overview of Intents.....	461
59.2 Explicit Intents.....	461
59.3 Returning Data from an Activity.....	462

59.4 Implicit Intents	463
59.5 Using Intent Filters.....	464
59.6 Automatic Link Verification	464
59.7 Manually Enabling Links	467
59.8 Checking Intent Availability	468
59.9 Summary	469
60. Android Explicit Intents – A Worked Example	471
60.1 Creating the Explicit Intent Example Application.....	471
60.2 Designing the User Interface Layout for MainActivity.....	471
60.3 Creating the Second Activity Class.....	472
60.4 Designing the User Interface Layout for SecondActivity	473
60.5 Reviewing the Application Manifest File	473
60.6 Creating the Intent.....	474
60.7 Extracting Intent Data	475
60.8 Launching SecondActivity as a Sub-Activity.....	476
60.9 Returning Data from a Sub-Activity.....	476
60.10 Testing the Application.....	477
60.11 Summary	477
61. Android Implicit Intents – A Worked Example	479
61.1 Creating the Android Studio Implicit Intent Example Project	479
61.2 Designing the User Interface	479
61.3 Creating the Implicit Intent	480
61.4 Adding a Second Matching Activity.....	481
61.5 Adding the Web View to the UI.....	481
61.6 Obtaining the Intent URL	482
61.7 Modifying the MyWebView Project Manifest File	483
61.8 Installing the MyWebView Package on a Device.....	484
61.9 Testing the Application.....	485
61.10 Manually Enabling the Link	485
61.11 Automatic Link Verification	487
61.12 Summary	489
62. Android Broadcast Intents and Broadcast Receivers	491
62.1 An Overview of Broadcast Intents.....	491
62.2 An Overview of Broadcast Receivers	492
62.3 Obtaining Results from a Broadcast.....	493
62.4 Sticky Broadcast Intents	493
62.5 The Broadcast Intent Example.....	494
62.6 Creating the Example Application.....	494
62.7 Creating and Sending the Broadcast Intent.....	494
62.8 Creating the Broadcast Receiver	495
62.9 Registering the Broadcast Receiver.....	496
62.10 Testing the Broadcast Example	497
62.11 Listening for System Broadcasts.....	497
62.12 Summary	497
63. An Introduction to Kotlin Coroutines.....	499
63.1 What are Coroutines?	499
63.2 Threads vs Coroutines	499

Table of Contents

63.3 Coroutine Scope	500
63.4 Suspend Functions	500
63.5 Coroutine Dispatchers	500
63.6 Coroutine Builders	501
63.7 Jobs	501
63.8 Coroutines – Suspending and Resuming	502
63.9 Returning Results from a Coroutine	503
63.10 Using withContext	503
63.11 Coroutine Channel Communication	505
63.12 Summary	506
64. An Android Kotlin Coroutines Tutorial	507
64.1 Creating the Coroutine Example Application	507
64.2 Adding Coroutine Support to the Project	507
64.3 Designing the User Interface	507
64.4 Implementing the SeekBar	509
64.5 Adding the Suspend Function	509
64.6 Implementing the launchCoroutines Method	510
64.7 Testing the App	511
64.8 Summary	511
65. An Overview of Android Services	513
65.1 Started Services	513
65.2 Intent Service	513
65.3 Bound Service	514
65.4 The Anatomy of a Service	514
65.5 Controlling Destroyed Service Restart Options	515
65.6 Declaring a Service in the Manifest File	515
65.7 Starting a Service Running on System Startup	516
65.8 Summary	516
66. Implementing an Android Started Service – A Worked Example	517
66.1 Creating the Example Project	517
66.2 Designing the User Interface	517
66.3 Creating the Service Class	517
66.4 Adding the Service to the Manifest File	519
66.5 Starting the Service	519
66.6 Testing the IntentService Example	520
66.7 Using the Service Class	520
66.8 Creating the New Service	521
66.9 Launching the Service	522
66.10 Running the Application	522
66.11 Using a Coroutine for the Service Task	523
66.12 Summary	524
67. Android Local Bound Services – A Worked Example	525
67.1 Understanding Bound Services	525
67.2 Bound Service Interaction Options	525
67.3 A Local Bound Service Example	525
67.4 Adding a Bound Service to the Project	526
67.5 Implementing the Binder	526

67.6 Binding the Client to the Service	528
67.7 Completing the Example.....	529
67.8 Testing the Application.....	531
67.9 Summary	531
68. Android Remote Bound Services – A Worked Example	533
68.1 Client to Remote Service Communication.....	533
68.2 Creating the Example Application.....	533
68.3 Designing the User Interface	533
68.4 Implementing the Remote Bound Service.....	534
68.5 Configuring a Remote Service in the Manifest File.....	535
68.6 Launching and Binding to the Remote Service.....	535
68.7 Sending a Message to the Remote Service	537
68.8 Summary	537
69. An Android Notifications Tutorial	539
69.1 An Overview of Notifications.....	539
69.2 Creating the NotifyDemo Project.....	541
69.3 Designing the User Interface	541
69.4 Creating the Second Activity	541
69.5 Creating a Notification Channel	542
69.6 Creating and Issuing a Notification	544
69.7 Launching an Activity from a Notification.....	546
69.8 Adding Actions to a Notification	548
69.9 Bundled Notifications.....	548
69.10 Summary	550
70. An Android Direct Reply Notification Tutorial	551
70.1 Creating the DirectReply Project.....	551
70.2 Designing the User Interface	551
70.3 Creating the Notification Channel.....	552
70.4 Building the RemoteInput Object.....	553
70.5 Creating the PendingIntent.....	554
70.6 Creating the Reply Action.....	554
70.7 Receiving Direct Reply Input.....	556
70.8 Updating the Notification	556
70.9 Summary	558
71. Foldable Devices and Multi-Window Support	559
71.1 Foldables and Multi-Window Support.....	559
71.2 Using a Foldable Emulator	560
71.3 Entering Multi-Window Mode	561
71.4 Enabling and using Freeform Support	562
71.5 Checking for Freeform Support	562
71.6 Enabling Multi-Window Support in an App.....	562
71.7 Specifying Multi-Window Attributes	563
71.8 Detecting Multi-Window Mode in an Activity.....	564
71.9 Receiving Multi-Window Notifications	564
71.10 Launching an Activity in Multi-Window Mode	565
71.11 Configuring Freeform Activity Size and Position.....	565
71.12 Summary	566

72. An Overview of Android SQLite Databases	567
72.1 Understanding Database Tables	567
72.2 Introducing Database Schema	567
72.3 Columns and Data Types	567
72.4 Database Rows	568
72.5 Introducing Primary Keys	568
72.6 What is SQLite?	568
72.7 Structured Query Language (SQL)	568
72.8 Trying SQLite on an Android Virtual Device (AVD)	569
72.9 The Android Room Persistence Library.....	571
72.10 Summary	571
73. The Android Room Persistence Library	573
73.1 Revisiting Modern App Architecture	573
73.2 Key Elements of Room Database Persistence.....	573
73.2.1 Repository	574
73.2.2 Room Database	574
73.2.3 Data Access Object (DAO)	574
73.2.4 Entities	574
73.2.5 SQLite Database	574
73.3 Understanding Entities.....	575
73.4 Data Access Objects.....	577
73.5 The Room Database.....	578
73.6 The Repository.....	579
73.7 In-Memory Databases	580
73.8 Database Inspector.....	580
73.9 Summary	581
74. An Android TableLayout and TableRow Tutorial	583
74.1 The TableLayout and TableRow Layout Views	583
74.2 Creating the Room Database Project	584
74.3 Converting to a LinearLayout.....	584
74.4 Adding the TableLayout to the User Interface.....	585
74.5 Configuring the TableRows	586
74.6 Adding the Button Bar to the Layout	587
74.7 Adding the RecyclerView.....	588
74.8 Adjusting the Layout Margins	589
74.9 Summary	589
75. An Android Room Database and Repository Tutorial.....	591
75.1 About the RoomDemo Project.....	591
75.2 Modifying the Build Configuration.....	591
75.3 Building the Entity	592
75.4 Creating the Data Access Object.....	593
75.5 Adding the Room Database.....	594
75.6 Adding the Repository	595
75.7 Modifying the ViewModel	598
75.8 Creating the Product Item Layout	599
75.9 Adding the RecyclerView Adapter.....	600
75.10 Preparing the Main Fragment	601

75.11 Adding the Button Listeners.....	602
75.12 Adding LiveData Observers	603
75.13 Initializing the RecyclerView.....	604
75.14 Testing the RoomDemo App.....	604
75.15 Using the Database Inspector.....	604
75.16 Summary	605
76. Accessing Cloud Storage using the Android Storage Access Framework.....	607
76.1 The Storage Access Framework.....	607
76.2 Working with the Storage Access Framework.....	608
76.3 Filtering Picker File Listings.....	608
76.4 Handling Intent Results.....	609
76.5 Reading the Content of a File	609
76.6 Writing Content to a File	610
76.7 Deleting a File.....	611
76.8 Gaining Persistent Access to a File.....	611
76.9 Summary	611
77. An Android Storage Access Framework Example.....	613
77.1 About the Storage Access Framework Example.....	613
77.2 Creating the Storage Access Framework Example.....	613
77.3 Designing the User Interface	613
77.4 Adding the Activity Launchers.....	614
77.5 Creating a New Storage File.....	615
77.6 Saving to a Storage File.....	617
77.7 Opening and Reading a Storage File	619
77.8 Testing the Storage Access Application	620
77.9 Summary	620
78. Video Playback on Android using the VideoView and MediaController Classes.....	621
78.1 Introducing the Android VideoView Class	621
78.2 Introducing the Android MediaController Class	622
78.3 Creating the Video Playback Example	622
78.4 Designing the VideoPlayer Layout	622
78.5 Downloading the Video File.....	623
78.6 Configuring the VideoView.....	623
78.7 Adding the MediaController to the Video View.....	625
78.8 Setting up the onPreparedListener	625
78.9 Summary	626
79. Android Picture-in-Picture Mode.....	627
79.1 Picture-in-Picture Features.....	627
79.2 Enabling Picture-in-Picture Mode.....	628
79.3 Configuring Picture-in-Picture Parameters	628
79.4 Entering Picture-in-Picture Mode	629
79.5 Detecting Picture-in-Picture Mode Changes	629
79.6 Adding Picture-in-Picture Actions.....	629
79.7 Summary	630
80. An Android Picture-in-Picture Tutorial.....	631
80.1 Adding Picture-in-Picture Support to the Manifest.....	631

80.2 Adding a Picture-in-Picture Button	631
80.3 Entering Picture-in-Picture Mode	631
80.4 Detecting Picture-in-Picture Mode Changes	633
80.5 Adding a Broadcast Receiver	634
80.6 Adding the PiP Action.....	635
80.7 Testing the Picture-in-Picture Action	637
80.8 Summary	638
81. Making Runtime Permission Requests in Android	639
81.1 Understanding Normal and Dangerous Permissions.....	639
81.2 Creating the Permissions Example Project.....	641
81.3 Checking for a Permission	641
81.4 Requesting Permission at Runtime.....	642
81.5 Providing a Rationale for the Permission Request	644
81.6 Testing the Permissions App.....	645
81.7 Summary	646
82. Android Audio Recording and Playback using MediaPlayer and MediaRecorder	647
82.1 Playing Audio	647
82.2 Recording Audio and Video using the MediaRecorder Class	648
82.3 About the Example Project	649
82.4 Creating the AudioApp Project.....	649
82.5 Designing the User Interface	649
82.6 Checking for Microphone Availability	650
82.7 Initializing the Activity.....	650
82.8 Implementing the recordAudio() Method.....	652
82.9 Implementing the stopAudio() Method.....	652
82.10 Implementing the playAudio() method	653
82.11 Configuring and Requesting Permissions	653
82.12 Testing the Application.....	656
82.13 Summary	656
83. Printing with the Android Printing Framework	657
83.1 The Android Printing Architecture	657
83.2 The Print Service Plugins	657
83.3 Google Cloud Print.....	658
83.4 Printing to Google Drive.....	658
83.5 Save as PDF	659
83.6 Printing from Android Devices	659
83.7 Options for Building Print Support into Android Apps.....	660
83.7.1 Image Printing.....	660
83.7.2 Creating and Printing HTML Content	661
83.7.3 Printing a Web Page.....	662
83.7.4 Printing a Custom Document	663
83.8 Summary	663
84. An Android HTML and Web Content Printing Example	665
84.1 Creating the HTML Printing Example Application	665
84.2 Printing Dynamic HTML Content	665
84.3 Creating the Web Page Printing Example.....	668
84.4 Removing the Floating Action Button	668

84.5 Removing Navigation Features.....	668
84.6 Designing the User Interface Layout	669
84.7 Accessing the WebView from the Main Activity	670
84.8 Loading the Web Page into the WebView	670
84.9 Adding the Print Menu Option.....	671
84.10 Summary	673
85. A Guide to Android Custom Document Printing.....	675
85.1 An Overview of Android Custom Document Printing	675
85.1.1 Custom Print Adapters.....	675
85.2 Preparing the Custom Document Printing Project.....	676
85.3 Creating the Custom Print Adapter.....	677
85.4 Implementing the onLayout() Callback Method	678
85.5 Implementing the onWrite() Callback Method	681
85.6 Checking a Page is in Range	683
85.7 Drawing the Content on the Page Canvas	684
85.8 Starting the Print Job	686
85.9 Testing the Application.....	687
85.10 Summary	687
86. An Introduction to Android App Links.....	689
86.1 An Overview of Android App Links	689
86.2 App Link Intent Filters	689
86.3 Handling App Link Intents	690
86.4 Associating the App with a Website.....	690
86.5 Summary	691
87. An Android Studio App Links Tutorial	693
87.1 About the Example App	693
87.2 The Database Schema	693
87.3 Loading and Running the Project.....	694
87.4 Adding the URL Mapping.....	695
87.5 Adding the Intent Filter.....	698
87.6 Adding Intent Handling Code.....	698
87.7 Testing the App.....	701
87.8 Creating the Digital Asset Links File	701
87.9 Testing the App Link.....	702
87.10 Summary	702
88. An Android Biometric Authentication Tutorial.....	703
88.1 An Overview of Biometric Authentication.....	703
88.2 Creating the Biometric Authentication Project	703
88.3 Configuring Device Fingerprint Authentication	704
88.4 Adding the Biometric Permission to the Manifest File.....	704
88.5 Designing the User Interface	705
88.6 Adding a Toast Convenience Method	705
88.7 Checking the Security Settings.....	706
88.8 Configuring the Authentication Callbacks.....	707
88.9 Adding the CancellationSignal.....	708
88.10 Starting the Biometric Prompt	708
88.11 Testing the Project.....	709

88.12 Summary	710
89. Creating, Testing and Uploading an Android App Bundle.....	711
89.1 The Release Preparation Process.....	711
89.2 Android App Bundles.....	711
89.3 Register for a Google Play Developer Console Account.....	712
89.4 Configuring the App in the Console	713
89.5 Enabling Google Play App Signing.....	714
89.6 Creating a Keystore File	714
89.7 Creating the Android App Bundle.....	716
89.8 Generating Test APK Files	717
89.9 Uploading the App Bundle to the Google Play Developer Console.....	718
89.10 Exploring the App Bundle	719
89.11 Managing Testers	720
89.12 Rolling the App Out for Testing.....	720
89.13 Uploading New App Bundle Revisions.....	721
89.14 Analyzing the App Bundle File	722
89.15 Summary.....	722
90. An Overview of Android Dynamic Feature Modules.....	725
90.1 An Overview of Dynamic Feature Modules.....	725
90.2 Dynamic Feature Module Architecture	725
90.3 Creating a Dynamic Feature Module	726
90.4 Converting an Existing Module for Dynamic Delivery.....	728
90.5 Working with Dynamic Feature Modules.....	731
90.6 Handling Large Dynamic Feature Modules	732
90.7 Summary	733
91. An Android Studio Dynamic Feature Tutorial.....	735
91.1 Creating the DynamicFeature Project.....	735
91.2 Adding Dynamic Feature Support to the Project	735
91.3 Designing the Base Activity User Interface	736
91.4 Adding the Dynamic Feature Module.....	737
91.5 Reviewing the Dynamic Feature Module.....	738
91.6 Adding the Dynamic Feature Activity.....	739
91.7 Implementing the launchIntent() Method.....	742
91.8 Uploading the App Bundle for Testing.....	743
91.9 Implementing the installFeature() Method	744
91.10 Adding the Update Listener.....	745
91.11 Using Deferred Installation	748
91.12 Removing a Dynamic Module	748
91.13 Summary.....	748
92. Working with Material Design 3 Theming	749
92.1 Material Design 2 vs Material Design 3	749
92.2 Understanding Material Design Theming	749
92.3 Material Design 2 Theming	749
92.4 Material Design 3 Theming	751
92.5 Building a Custom Theme.....	752
92.6 Summary	753
93. A Material Design 3 Theming and Dynamic Color Tutorial.....	755

93.1 Creating the ThemeDemo Project	755
93.2 Designing the User Interface	755
93.3 Migrating to Material Design 3	757
93.4 Building a New Theme	758
93.5 Adding the Theme to the Project	759
93.6 Enabling Dynamic Color Support	760
93.7 Summary	761
94. An Overview of Gradle in Android Studio	763
94.1 An Overview of Gradle	763
94.2 Gradle and Android Studio	763
94.2.1 Sensible Defaults	763
94.2.2 Dependencies.....	763
94.2.3 Build Variants	764
94.2.4 Manifest Entries	764
94.2.5 APK Signing.....	764
94.2.6 ProGuard Support.....	764
94.3 The Property and Settings Gradle Build File	764
94.4 The Top-level Gradle Build File.....	765
94.5 Module Level Gradle Build Files.....	766
94.6 Configuring Signing Settings in the Build File.....	768
94.7 Running Gradle Tasks from the Command-line	769
94.8 Summary	770
Index	771

1. Introduction

Fully updated for Android Studio Bumble Bee, the goal of this book is to teach the skills necessary to develop Android-based applications using the Kotlin programming language.

Beginning with the basics, this book provides an outline of the steps necessary to set up an Android development and testing environment followed by an introduction to programming in Kotlin including data types, control flow, functions, lambdas and object-oriented programming.

An overview of Android Studio is included covering areas such as tool windows, the code editor and the Layout Editor tool. An introduction to the architecture of Android is followed by an in-depth look at the design of Android applications and user interfaces using the Android Studio environment.

Chapters are also included covering the Android Architecture Components including view models, lifecycle management, Room database access, the Database Inspector, app navigation, live data, and data binding.

More advanced topics such as intents are also covered, as are touch screen handling, gesture recognition, and the recording and playback of audio. This edition of the book also covers printing, transitions, cloud-based file storage, and foldable device support.

The concepts of material design are also covered in detail, including the use of floating action buttons, Snackbars, tabbed interfaces, card views, navigation drawers, and collapsing toolbars.

Other key features of Android Studio Bumble Bee and Android are also covered in detail including the Layout Editor, the ConstraintLayout and ConstraintSet classes, MotionLayout Editor, view binding, constraint chains, barriers, and direct reply notifications.

Chapters also cover advanced features of Android Studio such as App Links, Dynamic Delivery, Gradle build configuration, and submitting apps to the Google Play Developer Console.

Assuming you already have some programming experience, are ready to download Android Studio and the Android SDK, have access to a Windows, Mac, or Linux system, and have ideas for some apps to develop, you are ready to get started.

1.1 Downloading the Code Samples

The source code and Android Studio project files for the examples contained in this book are available for download at:

<https://www.ebookfrenzy.com/retail/bumblebeekotlin/index.php>

The steps to load a project from the code samples into Android Studio are as follows:

1. From the Welcome to Android Studio dialog, click on the Open button option.
2. In the project selection dialog, navigate to and select the folder containing the project to be imported and click on OK.

1.2 Feedback

We want you to be satisfied with your purchase of this book. If you find any errors in the book, or have any comments, questions or concerns please contact us at feedback@ebookfrenzy.com.

1.3 Errata

While we make every effort to ensure the accuracy of the content of this book, it is inevitable that a book covering a subject area of this size and complexity may include some errors and oversights. Any known issues with the book will be outlined, together with solutions, at the following URL:

<https://www.ebookfrenzy.com/errata/bumblebeekotlin.html>

If you find an error not listed in the errata, please let us know by emailing our technical support team at feedback@ebookfrenzy.com. They are there to help you and will work to resolve any problems you may encounter.

2. Setting up an Android Studio Development Environment

Before any work can begin on the development of an Android application, the first step is to configure a computer system to act as the development platform. This involves several steps consisting of installing the Android Studio Integrated Development Environment (IDE) which also includes the Android Software Development Kit (SDK), the Kotlin plug-in and OpenJDK Java development environment.

This chapter will cover the steps necessary to install the requisite components for Android application development on Windows, macOS, and Linux-based systems.

2.1 System Requirements

Android application development may be performed on any of the following system types:

- Windows 8/10/11 64-bit
- macOS 10.14 or later running on Intel or Apple silicon
- Chrome OS device with Intel i5 or higher
- Linux systems with version 2.31 or later of the GNU C Library (glibc)
- Minimum of 8GB of RAM (see below)
- Approximately 8GB of available disk space
- 1280 x 800 minimum screen resolution

Although Android Studio will run on computers with 8GB of RAM, performance will be greatly improved on systems containing more memory. This is particularly an issue if you plan to test your apps using the Android Virtual Device emulator (AVD).

2.2 Downloading the Android Studio Package

Most of the work involved in developing applications for Android will be performed using the Android Studio environment. The content and examples in this book were created based on Android Studio Bumble Bee 2021.1.1 using the Android API 32 SDK which, at the time of writing, are the current versions.

Android Studio is, however, subject to frequent updates so a newer version may have been released since this book was published.

The latest release of Android Studio may be downloaded from the primary download page which can be found at the following URL:

<https://developer.android.com/studio/index.html>

If this page provides instructions for downloading a newer version of Android Studio it is important to note that there may be some minor differences between this book and the software. A web search for “Android Studio Bumble Bee” should provide the option to download the older version if these differences become a problem.

Setting up an Android Studio Development Environment

Alternatively, visit the following web page to find Android Studio Bumble Bee 2021.1.1 in the archives:

<https://developer.android.com/studio/archive>

2.3 Installing Android Studio

Once downloaded, the exact steps to install Android Studio differ depending on the operating system on which the installation is being performed.

2.3.1 Installation on Windows

Locate the downloaded Android Studio installation executable file (named *android-studio-<version>-windows.exe*) in a Windows Explorer window and double-click on it to start the installation process, clicking the *Yes* button in the User Account Control dialog if it appears.

Once the Android Studio setup wizard appears, work through the various screens to configure the installation to meet your requirements in terms of the file system location into which Android Studio should be installed and whether or not it should be made available to other users of the system. When prompted to select the components to install, make sure that the *Android Studio* and *Android Virtual Device* options are all selected.

Although there are no strict rules on where Android Studio should be installed on the system, the remainder of this book will assume that the installation was performed into *C:\Program Files\Android\Android Studio* and that the Android SDK packages have been installed into the user's *AppData\Local\Android\sdk* sub-folder. Once the options have been configured, click on the *Install* button to begin the installation process.

On versions of Windows with a Start menu, the newly installed Android Studio can be launched from the entry added to that menu during the installation. The executable may be pinned to the taskbar for easy access by navigating to the *Android Studio\bin* directory, right-clicking on the *studio64* executable, and selecting the *Pin to Taskbar* menu option (on Windows 11 this option can be found by selecting *Show more options* from the menu).

2.3.2 Installation on macOS

Android Studio for macOS is downloaded in the form of a disk image (.dmg) file. Once the *android-studio-<version>-mac.dmg* file has been downloaded, locate it in a Finder window and double-click on it to open it as shown in Figure 2-1:

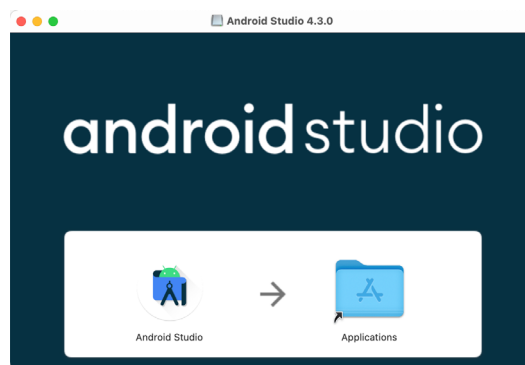


Figure 2-1

To install the package, simply drag the Android Studio icon and drop it onto the Applications folder. The Android Studio package will then be installed into the Applications folder of the system, a process that will typically take a few seconds to complete.

To launch Android Studio, locate the executable in the Applications folder using a Finder window and double-click on it.

For future, easier access to the tool, drag the Android Studio icon from the Finder window and drop it onto the dock.

2.3.3 Installation on Linux

Having downloaded the Linux Android Studio package, open a terminal window, change directory to the location where Android Studio is to be installed and execute the following command:

```
unzip /<path to package>/android-studio-ide-<version>-linux.zip
```

Note that the Android Studio bundle will be installed into a subdirectory named *android-studio*. Assuming, therefore, that the above command was executed in */home/demo*, the software packages will be unpacked into */home/demo/android-studio*.

To launch Android Studio, open a terminal window, change directory to the *android-studio/bin* sub-directory and execute the following command:

```
./studio.sh
```

When running on a 64-bit Linux system, it may be necessary to install some 32-bit support libraries before Android Studio will run. On Ubuntu these libraries can be installed using the following command:

```
sudo apt-get install libc6:i386 libncurses5:i386 libstdc++6:i386 lib32z1 libbz2-1.0:i386
```

On Red Hat and Fedora-based 64-bit systems, use the following command:

```
sudo yum install zlib.i686 ncurses-libs.i686 bzip2-libs.i686
```

2.4 The Android Studio Setup Wizard

If you are installing Android Studio for the first time the initial dialog that appears once the setup process starts may resemble that shown in Figure 2-2 below:

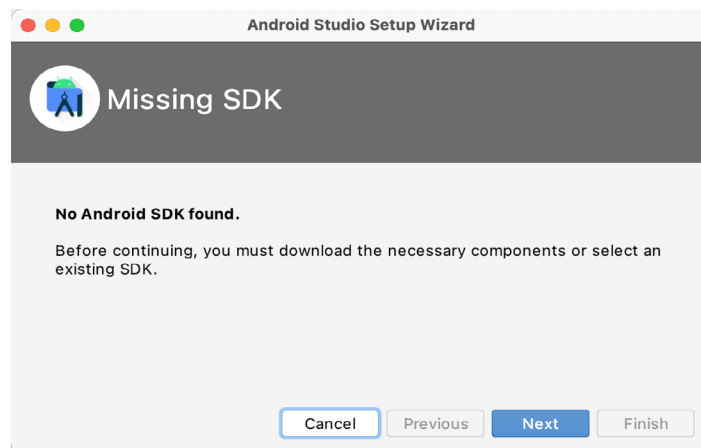


Figure 2-2

If this dialog appears, click the Next button to display the SDK Components Setup dialog (Figure 2-3). Within this dialog, make sure that the Android SDK option is selected along with the latest API package before clicking on the Next button:

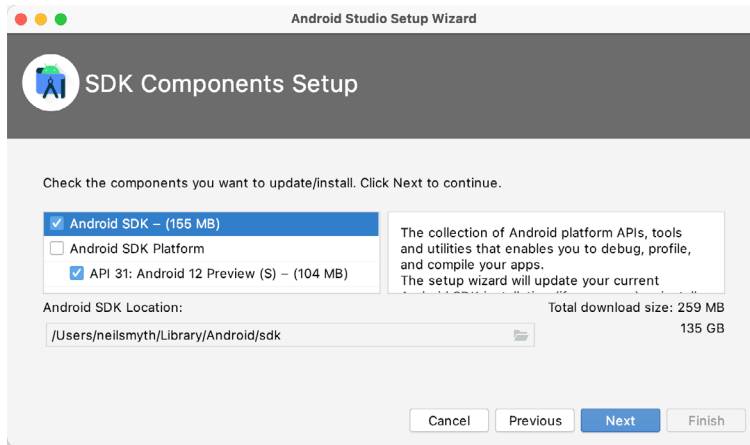


Figure 2-3

After clicking Next, Android Studio will download and install the Android SDK and tools.

If you have previously installed an earlier version of Android Studio, the first time that this new version is launched, a dialog may appear providing the option to import settings from a previous Android Studio version. If you have settings from a previous version and would like to import them into the latest installation, select the appropriate option and location. Alternatively, indicate that you do not need to import any previous settings and click on the OK button to proceed.

After these initial setup steps have been taken, click the Finish button to display the Welcome to Android Studio screen:

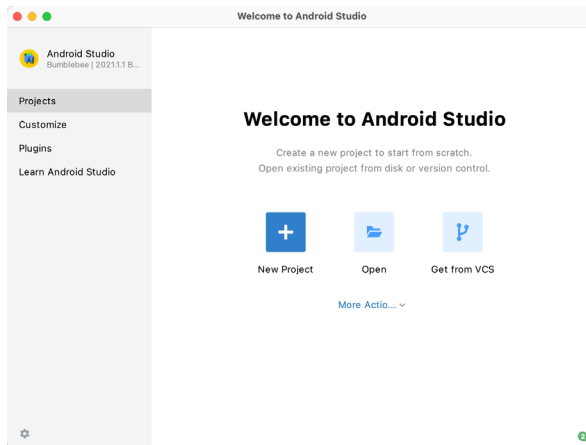


Figure 2-4

2.5 Installing Additional Android SDK Packages

The steps performed so far have installed the Android Studio IDE and the current set of default Android SDK packages. Before proceeding, it is worth taking some time to verify which packages are installed and to install any missing or updated packages.

This task can be performed by clicking on the *More Actions* link within the welcome dialog and selecting the *SDK Manager* option from the drop-down menu. Once invoked, the *Android SDK* screen of the Preferences dialog will appear as shown in Figure 2-5:

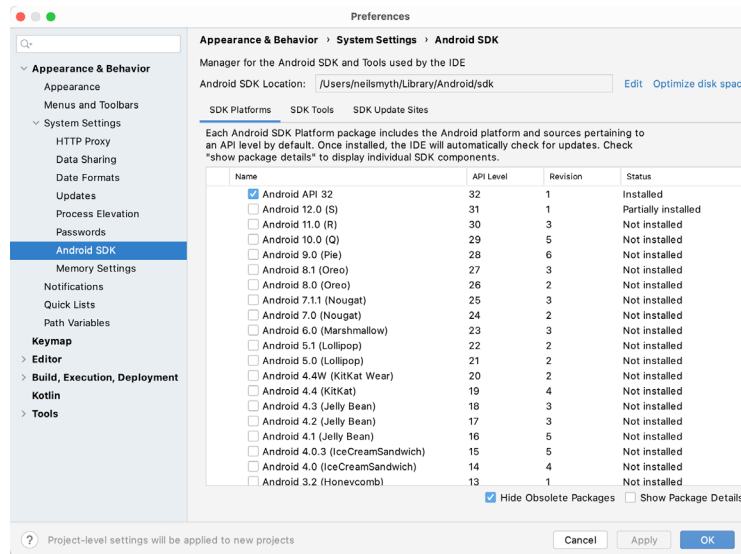


Figure 2-5

Immediately after installing Android Studio for the first, time it is likely that only the latest released version of the Android SDK has been installed. To install older versions of the Android SDK simply select the checkboxes corresponding to the versions and click on the *Apply* button.

Most of the examples in this book will support older versions of Android as far back as Android 8.0 (Oreo). This is to ensure that the apps run on a wide range of Android devices. Within the list of SDK versions, enable the checkbox next to Android 8.0 (Oreo) and click on the *Apply* button. In the resulting confirmation dialog click on the *OK* button to install the SDK. Subsequent dialogs will seek the acceptance of licenses and terms before performing the installation. Click *Finish* once the installation is complete.

It is also possible that updates will be listed as being available for the latest SDK. To access detailed information about the packages that are ready to be updated, enable the *Show Package Details* option located in the lower right-hand corner of the screen. This will display information similar to that shown in Figure 2-6:

	Name	API Level	Revision	Status
<input type="checkbox"/>	Android TV Intel x86 Atom System Image	25	6	Not installed
<input type="checkbox"/>	Android Wear for China ARM EABI v7a System Image	25	3	Not installed
<input type="checkbox"/>	Android Wear for China Intel x86 Atom System Image	25	3	Not installed
<input type="checkbox"/>	Android Wear ARM EABI v7a System Image	25	3	Not installed
<input type="checkbox"/>	Android Wear Intel x86 Atom System Image	25	3	Not installed
<input type="checkbox"/>	Google APIs ARM 64 v8a System Image	25	8	Not installed
<input type="checkbox"/>	Google APIs ARM EABI v7a System Image	25	8	Not installed
<input type="checkbox"/>	Google APIs Intel x86 Atom System Image	25	8	Not installed
<input checked="" type="checkbox"/>	Google APIs Intel x86 Atom_64 System Image	25	6	Update Available: 8
▼ <input type="checkbox"/>	Android 7.0 (Nougat)			
<input type="checkbox"/>	Google APIs	24	1	Not installed

Figure 2-6

The above figure highlights the availability of an update. To install the updates, enable the checkbox to the left of the item name and click on the *Apply* button.

In addition to the Android SDK packages, several tools are also installed for building Android applications. To view the currently installed packages and check for updates, remain within the SDK settings screen and select the *SDK Tools* tab as shown in Figure 2-7:

Setting up an Android Studio Development Environment

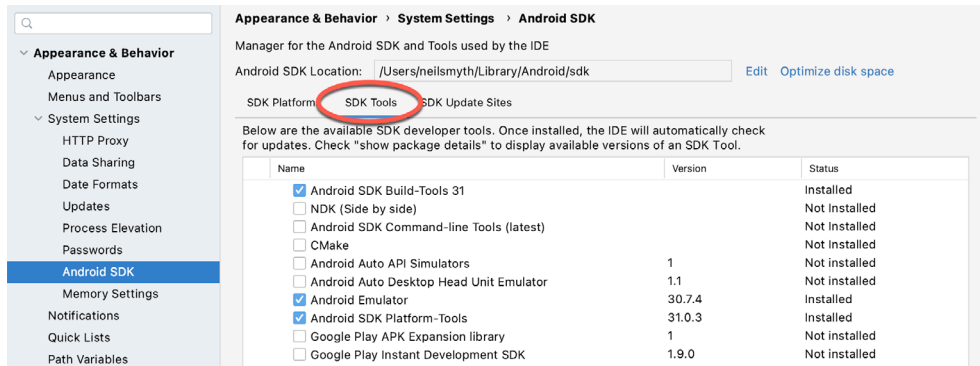


Figure 2-7

Within the Android SDK Tools screen, make sure that the following packages are listed as *Installed* in the Status column:

- Android SDK Build-tools
- Android Emulator
- Android SDK Platform-tools
- Google Play Services
- Intel x86 Emulator Accelerator (HAXM installer)
- Google USB Driver (Windows only)
- Layout Inspector image server for API S

Note the Intel x86 Emulator Accelerator (HAXM installer) cannot be installed on Apple silicon-based Macs.

If any of the above packages are listed as *Not Installed* or requiring an update, simply select the checkboxes next to those packages and click on the *Apply* button to initiate the installation process. If the HAXM emulator settings dialog appears, select the recommended memory allocation:

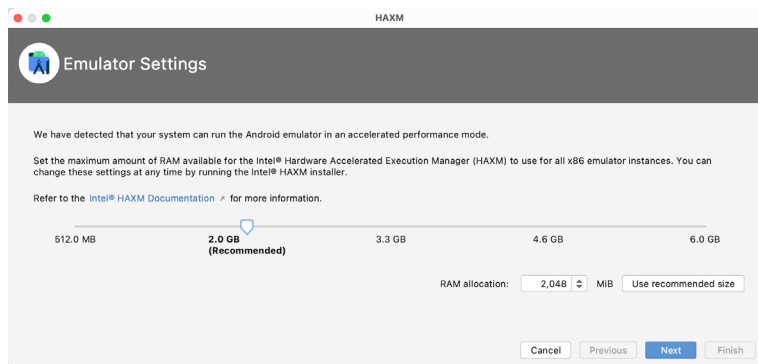


Figure 2-8

Once the installation is complete, review the package list and make sure that the selected packages are now listed as *Installed* in the *Status* column. If any are listed as *Not installed*, make sure they are selected and click on the *Apply* button again.

2.6 Making the Android SDK Tools Command-line Accessible

Most of the time, the underlying tools of the Android SDK will be accessed from within the Android Studio environment. That being said, however, there will also be instances where it will be useful to be able to invoke those tools from a command prompt or terminal window. For the operating system on which you are developing to be able to find these tools, it will be necessary to add them to the system's *PATH* environment variable.

Regardless of operating system, the *PATH* variable needs to be configured to include the following paths (where *<path_to_android_sdk_installation>* represents the file system location into which the Android SDK was installed):

```
<path_to_android_sdk_installation>/sdk/tools
<path_to_android_sdk_installation>/sdk/tools/bin
<path_to_android_sdk_installation>/sdk/platform-tools
```

The location of the SDK on your system can be identified by launching the SDK Manager and referring to the *Android SDK Location*: field located at the top of the settings panel as highlighted in Figure 2-9:

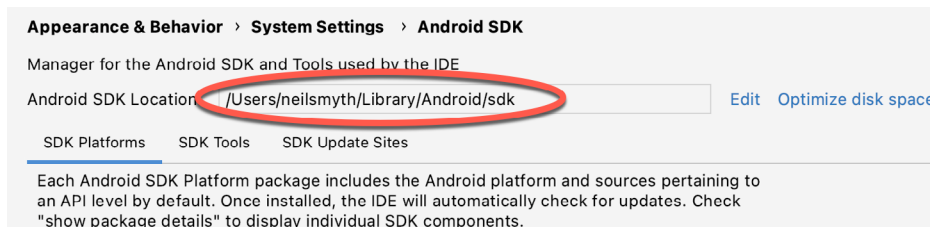


Figure 2-9

Once the location of the SDK has been identified, the steps to add this to the *PATH* variable are operating system dependent:

2.6.1 Windows 8.1

1. On the start screen, move the mouse to the bottom right-hand corner of the screen and select Search from the resulting menu. In the search box, enter Control Panel. When the Control Panel icon appears in the results area, click on it to launch the tool on the desktop.
2. Within the Control Panel, use the Category menu to change the display to Large Icons. From the list of icons select the one labeled System.
3. In the Environment Variables dialog, locate the Path variable in the System variables list, select it and click on the *Edit...* button. Using the *New* button in the edit dialog, add three new entries to the path. For example, assuming the Android SDK was installed into C:\Users\demo\AppData\Local\Android\Sdk, the following entries would need to be added:

```
C:\Users\demo\AppData\Local\Android\Sdk\platform-tools
C:\Users\demo\AppData\Local\Android\Sdk\tools
C:\Users\demo\AppData\Local\Android\Sdk\tools\bin
```

4. Click on OK in each dialog box and close the system properties control panel.

Open a command prompt window by pressing Windows + R on the keyboard and entering *cmd* into the Run dialog. Within the Command Prompt window, enter:

```
echo %Path%
```

The returned path variable value should include the paths to the Android SDK platform tools folders. Verify that

Setting up an Android Studio Development Environment

the *platform-tools* value is correct by attempting to run the *adb* tool as follows:

```
adb
```

The tool should output a list of command-line options when executed.

Similarly, check the *tools* path setting by attempting to run the AVD Manager command-line tool (don't worry if the *avdmanager* tool reports a problem with Java - this will be addressed later):

```
avdmanager
```

If a message similar to the following message appears for one or both of the commands, it is most likely that an incorrect path was appended to the Path environment variable:

```
'adb' is not recognized as an internal or external command,  
operable program or batch file.
```

2.6.2 Windows 10

Right-click on the Start menu, select Settings from the resulting menu and enter “Edit the system environment variables” into the *Find a setting* text field. In the System Properties dialog, click the *Environment Variables...* button. Follow the steps outlined for Windows 8.1 starting from step 3.

2.6.3 Windows 11

Right-click on the Start icon located in the taskbar and select Settings from the resulting menu. When the Settings dialog appears, scroll down the list of categories and select the “About” option. In the About screen, select *Advanced system settings* from the Related links section. When the System Properties window appears, click on the *Environment Variables...* button. Follow the steps outlined for Windows 8.1 starting from step 3.

2.6.4 Linux

On Linux, this configuration can typically be achieved by adding a command to the *.bashrc* file in your home directory (specifics may differ depending on the particular Linux distribution in use). Assuming that the Android SDK bundle package was installed into */home/demo/Android/sdk*, the export line in the *.bashrc* file would read as follows:

```
export PATH=/home/demo/Android/sdk/platform-tools:/home/demo/Android/sdk/tools:/  
home/demo/Android/sdk/tools/bin:/home/demo/android-studio/bin:$PATH
```

Note also that the above command adds the *android-studio/bin* directory to the PATH variable. This will enable the *studio.sh* script to be executed regardless of the current directory within a terminal window.

2.6.5 macOS

Several techniques may be employed to modify the \$PATH environment variable on macOS. Arguably the cleanest method is to add a new file in the */etc/paths.d* directory containing the paths to be added to \$PATH. Assuming an Android SDK installation location of */Users/demo/Library/Android/sdk*, the path may be configured by creating a new file named *android-sdk* in the */etc/paths.d* directory containing the following lines:

```
/Users/demo/Library/Android/sdk/tools  
/Users/demo/Library/Android/sdk/tools/bin  
/Users/demo/Library/Android/sdk/platform-tools
```

Note that since this is a system directory it will be necessary to use the *sudo* command when creating the file. For example:

```
sudo vi /etc/paths.d/android-sdk
```


2.7 Android Studio Memory Management

Android Studio is a large and complex software application that consists of many background processes. Although Android Studio has been criticized in the past for providing less than optimal performance, Google has made significant performance improvements in recent releases and continues to do so with each new version. These improvements include allowing the user to configure the amount of memory used by both the Android Studio IDE and the background processes used to build and run apps. This allows the software to take advantage of systems with larger amounts of RAM.

If you are running Android Studio on a system with sufficient unused RAM to increase these values (this feature is only available on 64-bit systems with 5GB or more of RAM) and find that Android Studio performance appears to be degraded it may be worth experimenting with these memory settings. Android Studio may also notify you that performance can be increased via a dialog similar to the one shown below:

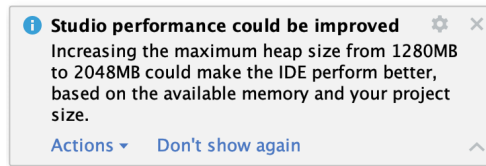


Figure 2-10

To view and modify the current memory configuration, select the *File -> Settings...* (*Android Studio -> Preferences...* on macOS) menu option and, in the resulting dialog, select the *Memory Settings* option listed under *System Settings* in the left-hand navigation panel as illustrated in Figure 2-11 below.

When changing the memory allocation, be sure not to allocate more memory than necessary or than your system can spare without slowing down other processes.

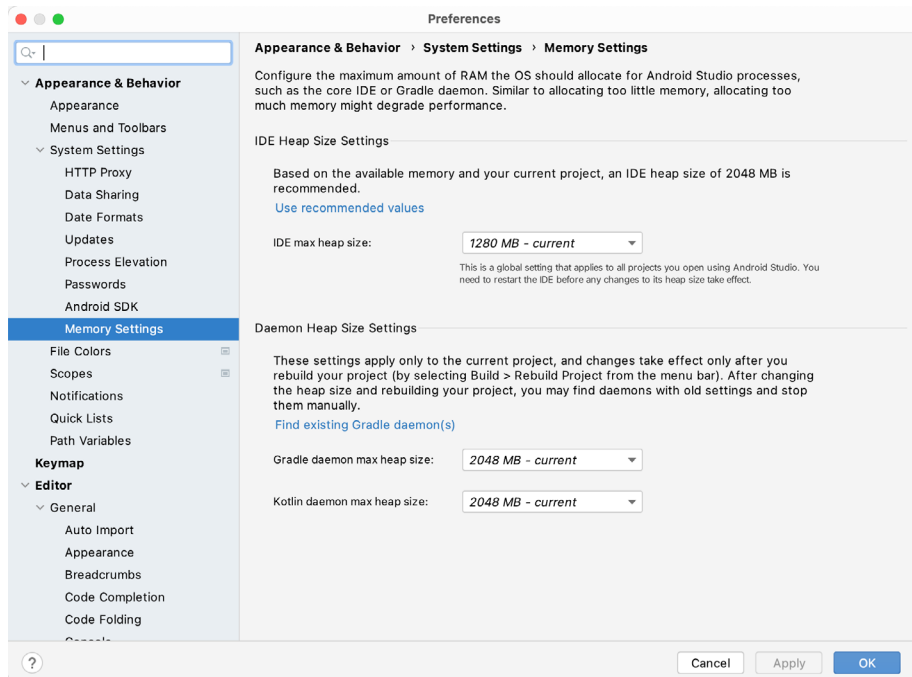


Figure 2-11

Setting up an Android Studio Development Environment

The IDE memory setting adjusts the memory allocated to Android Studio and applies regardless of the currently loaded project. When a project is built and run from within Android Studio, on the other hand, a number of background processes (referred to as daemons) perform the task of compiling and running the app. When compiling and running large and complex projects, build time may potentially be improved by adjusting the daemon heap settings. Unlike the IDE heap settings, these settings apply only to the current project and can only be accessed when a project is open in Android Studio.

2.8 Updating Android Studio and the SDK

From time to time new versions of Android Studio and the Android SDK are released. New versions of the SDK are installed using the Android SDK Manager. Android Studio will typically notify you when an update is ready to be installed.

To manually check for Android Studio updates, use the *Help -> Check for Updates...* menu option from the Android Studio main window (*Android Studio -> Check for Updates...* on macOS).

2.9 Summary

Before beginning the development of Android-based applications, the first step is to set up a suitable development environment. This consists of the Android SDKs and Android Studio IDE (which also includes the OpenJDK development environment). In this chapter, we have covered the steps necessary to install these packages on Windows, macOS, and Linux.

3. Creating an Example Android App in Android Studio

The preceding chapters of this book have covered the steps necessary to configure an environment suitable for the development of Android applications using the Android Studio IDE. Before moving on to slightly more advanced topics, now is a good time to validate that all of the required development packages are installed and functioning correctly. The best way to achieve this goal is to create an Android application and compile and run it. This chapter will cover the creation of an Android application project using Android Studio. Once the project has been created, a later chapter will explore the use of the Android emulator environment to perform a test run of the application.

3.1 About the Project

The project created in this chapter takes the form of a rudimentary currency conversion calculator (so simple, in fact, that it only converts from dollars to euros and does so using an estimated conversion rate). The project will also make use of one of the most basic of Android Studio project templates. This simplicity allows us to introduce some of the key aspects of Android app development without overwhelming the beginner by trying to introduce too many concepts, such as the recommended app architecture and Android architecture components, at once. When following the tutorial in this chapter, rest assured that all of the techniques and code used in this initial example project will be covered in much greater detail in later chapters.

3.2 Creating a New Android Project

The first step in the application development process is to create a new project within the Android Studio environment. Begin, therefore, by launching Android Studio so that the “Welcome to Android Studio” screen appears as illustrated in Figure 3-1:

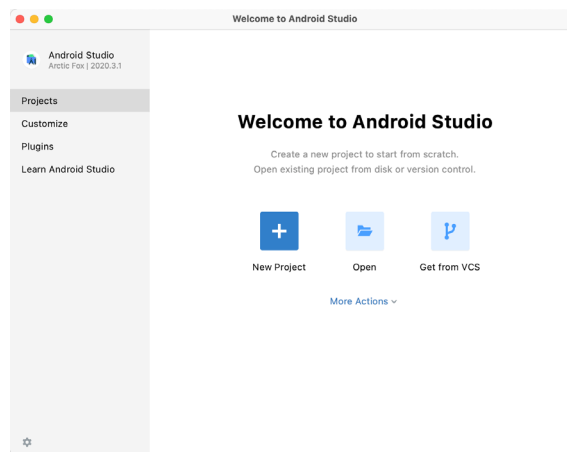


Figure 3-1

Once this window appears, Android Studio is ready for a new project to be created. To create the new project, simply click on the *New Project* option to display the first screen of the *New Project* wizard.

3.3 Creating an Activity

The first step is to define the type of initial activity that is to be created for the application. Options are available to create projects for Phone and Tablet, Wear OS, TV, Android Audio or Android Things. A range of different activity types is available when developing Android applications, many of which will be covered extensively in later chapters. For the purposes of this example, however, simply select the *Phone and Tablet* option from the Templates panel followed by the option to create an *Empty Activity*. The Empty Activity option creates a template user interface consisting of a single TextView object.

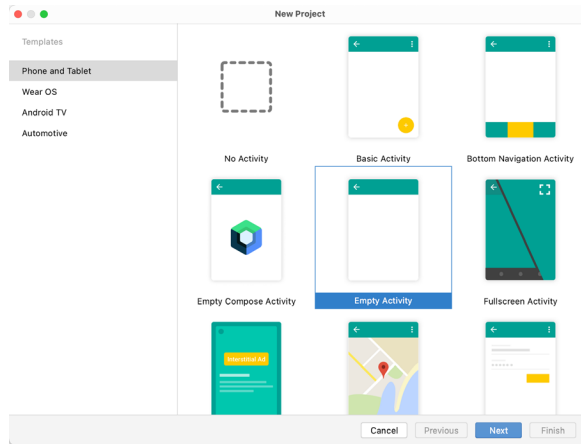


Figure 3-2

With the Empty Activity option selected, click *Next* to continue with the project configuration.

3.4 Defining the Project and SDK Settings

In the project configuration window (Figure 3-3), set the *Name* field to *AndroidSample*. The application name is the name by which the application will be referenced and identified within Android Studio and is also the name that would be used if the completed application were to go on sale in the Google Play store.

The *Package name* is used to uniquely identify the application within the Android application ecosystem. Although this can be set to any string that uniquely identifies your app, it is traditionally based on the reversed URL of your domain name followed by the name of the application. For example, if your domain is *www.mycompany.com*, and the application has been named *AndroidSample*, then the package name might be specified as follows:

```
com.mycompany.androidsample
```

If you do not have a domain name you can enter any other string into the Company Domain field, or you may use *example.com* for the purposes of testing, though this will need to be changed before an application can be published:

```
com.example.androidsample
```

The *Save location* setting will default to a location in the folder named *AndroidStudioProjects* located in your home directory and may be changed by clicking on the folder icon to the right of the text field containing the current path setting.

Set the minimum SDK setting to API 26: Android 8.0 (Oreo). This is the minimum SDK that will be used in most of the projects created in this book unless a necessary feature is only available in a more recent version. The objective here is to build an app using the latest Android SDK, while also retaining compatibility with devices running older versions of Android (in this case as far back as Android 8.0). The text beneath the Minimum SDK

setting will outline the percentage of Android devices currently in use on which the app will run. Click on the *Help me choose* button (highlighted in Figure 3-3) to see a full breakdown of the various Android versions still in use:

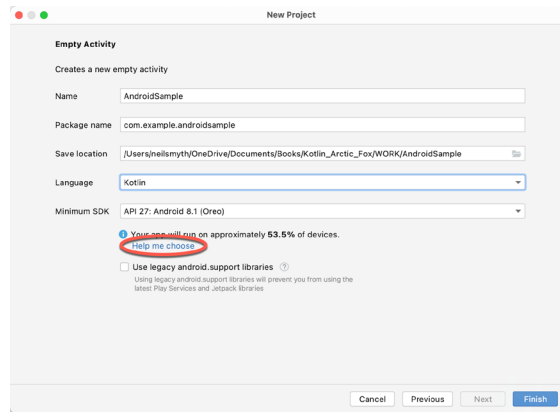


Figure 3-3

Finally, change the *Language* menu to *Kotlin* and click on *Finish* to initiate the project creation process.

3.5 Modifying the Example Application

At this point, Android Studio has created a minimal example application project and opened the main window.

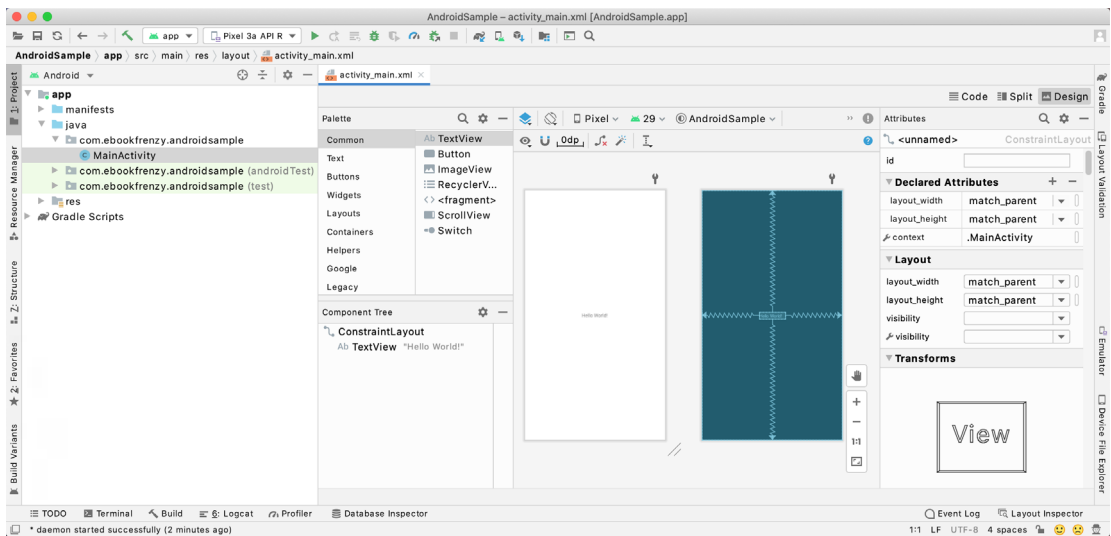


Figure 3-4

The newly created project and references to associated files are listed in the *Project* tool window located on the left-hand side of the main project window. The Project tool window has a number of modes in which information can be displayed. By default, this panel should be in *Android* mode. This setting is controlled by the menu at the top of the panel as highlighted in Figure 3-5. If the panel is not currently in Android mode, use the menu to switch mode:

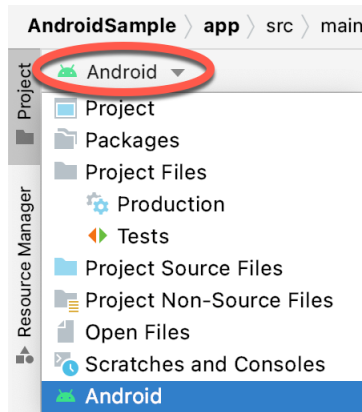


Figure 3-5

3.6 Modifying the User Interface

The user interface design for our activity is stored in a file named *activity_main.xml* which, in turn, is located under *app -> res -> layout* in the project file hierarchy. Once located in the Project tool window, double-click on the file to load it into the user interface Layout Editor tool which will appear in the center panel of the Android Studio main window:

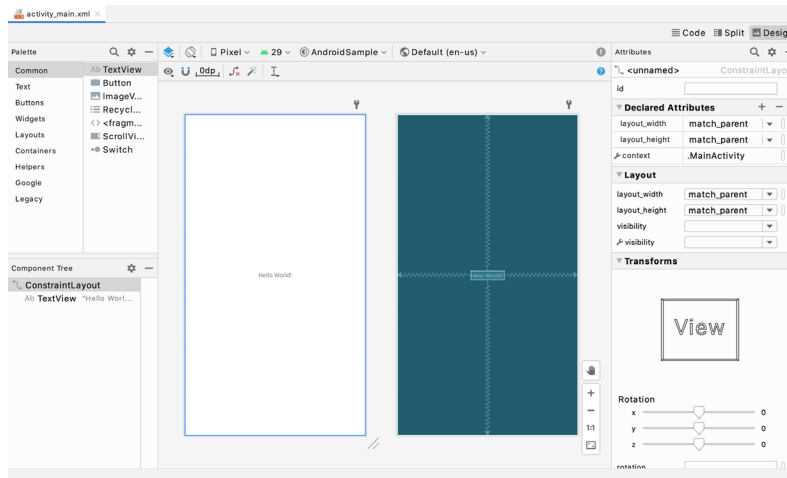



Figure 3-6

In the toolbar across the top of the Layout Editor window is a menu (currently set to *Pixel* in the above figure) which is reflected in the visual representation of the device within the Layout Editor panel. A wide range of other device options are available for selection by clicking on this menu.

To change the orientation of the device representation between landscape and portrait simply use the drop down menu immediately to the left of the device selection menu showing the  icon.

As can be seen in the device screen, the content layout already includes a label that displays a “Hello World!” message. Running down the left-hand side of the panel is a palette containing different categories of user interface components that may be used to construct a user interface, such as buttons, labels and text fields. It should be noted, however, that not all user interface components are obviously visible to the user. One such category consists of *layouts*. Android supports a variety of layouts that provide different levels of control over how visual

user interface components are positioned and managed on the screen. Though it is difficult to tell from looking at the visual representation of the user interface, the current design has been created using a *ConstraintLayout*. This can be confirmed by reviewing the information in the *Component Tree* panel which, by default, is located in the lower left-hand corner of the Layout Editor panel and is shown in Figure 3-7:

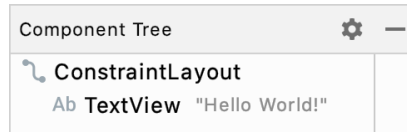


Figure 3-7

As we can see from the component tree hierarchy, the user interface layout consists of a *ConstraintLayout* parent and a *TextView* child object.

Before proceeding, also check that the Layout Editor's Autoconnect mode is enabled. This means that as components are added to the layout, the Layout Editor will automatically add constraints to make sure the components are correctly positioned for different screen sizes and device orientations (a topic that will be covered in much greater detail in future chapters). The Autoconnect button appears in the Layout Editor toolbar and is represented by a magnet icon. When disabled the magnet appears with a diagonal line through it (Figure 3-8). If necessary, re-enable Autoconnect mode by clicking on this button.

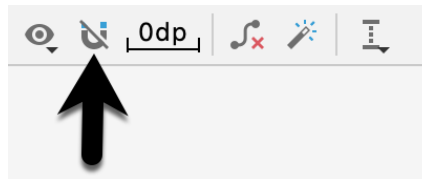


Figure 3-8

The next step in modifying the application is to add some additional components to the layout, the first of which will be a *Button* for the user to press to initiate the currency conversion.

The *Palette* panel consists of two columns with the left-hand column containing a list of view component categories. The right-hand column lists the components contained within the currently selected category. In Figure 3-9, for example, the *Button* view is currently selected within the *Buttons* category:

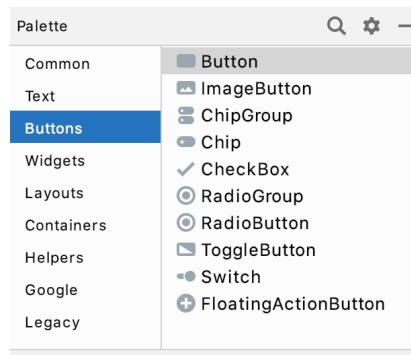


Figure 3-9

Click and drag the *Button* object from the Buttons list and drop it in the horizontal center of the user interface design so that it is positioned beneath the existing *TextView* widget:

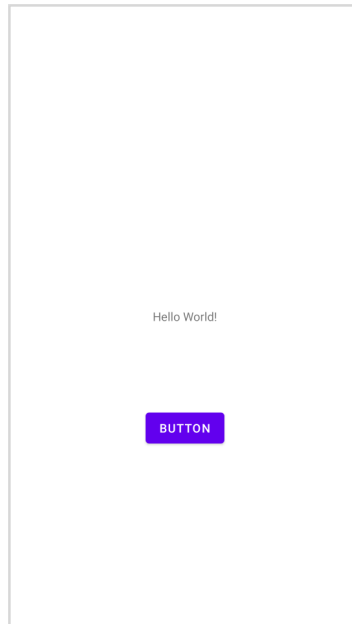


Figure 3-10

The next step is to change the text that is currently displayed by the Button component. The panel located to the right of the design area is the Attributes panel. This panel displays the attributes assigned to the currently selected component in the layout. Within this panel, locate the *text* property in the Common Attributes section and change the current value from “Button” to “Convert” as shown in Figure 3-11:

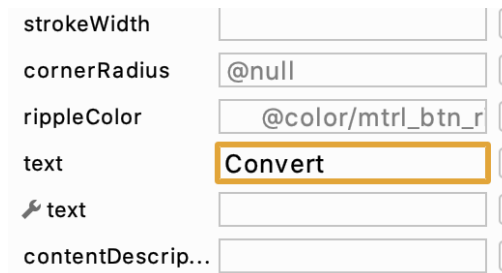


Figure 3-11

The second text property with a wrench next to it allows a text property to be set which only appears within the Layout Editor tool but is not shown at runtime. This is useful for testing the way in which a visual component and the layout will behave with different settings without having to run the app repeatedly.

Just in case the Autoconnect system failed to set all of the layout connections, click on the Infer constraints button (Figure 3-12) to add any missing constraints to the layout:

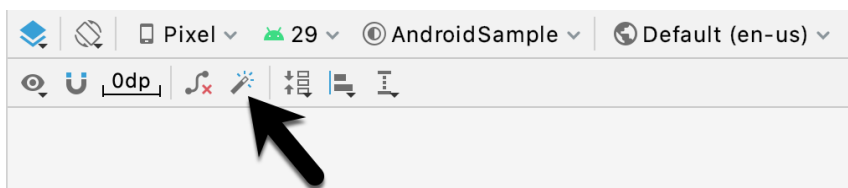


Figure 3-12

At this point it is important to explain the warning button located in the top right-hand corner of the Layout Editor tool as indicated in Figure 3-13. Obviously, this is indicating potential problems with the layout. For details on any problems, click on the button:

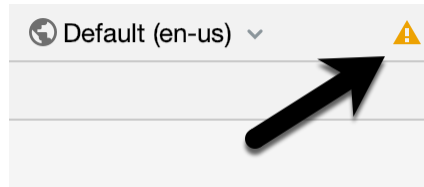


Figure 3-13

When clicked, a panel (Figure 3-14) will appear describing the nature of the problems and offering some possible corrective measures:

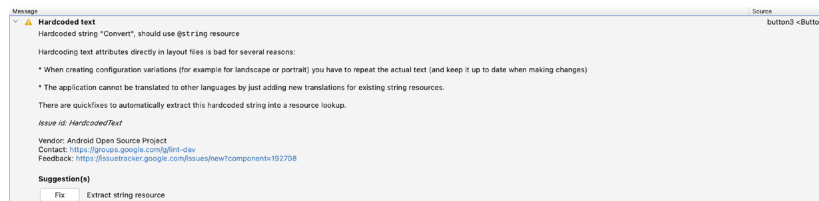


Figure 3-14

Currently, the only warning listed reads as follows:

Hardcoded string "Convert", should use @string resource

This I18N message is informing us that a potential issue exists with regard to the future internationalization of the project ("I18N" comes from the fact that the word "internationalization" begins with an "I", ends with an "N" and has 18 letters in between). The warning is reminding us that when developing Android applications, attributes and values such as text strings should be stored in the form of *resources* wherever possible. Doing so enables changes to the appearance of the application to be made by modifying resource files instead of changing the application source code. This can be especially valuable when translating a user interface to a different spoken language. If all of the text in a user interface is contained in a single resource file, for example, that file can be given to a translator who will then perform the translation work and return the translated file for inclusion in the application. This enables multiple languages to be targeted without the necessity for any source code changes to be made. In this instance, we are going to create a new resource named *convert_string* and assign to it the string "Convert".

Click on the *Fix* button in the Issue Explanation panel to display the *Extract Resource* panel (Figure 3-15). Within this panel, change the resource name field to *convert_string* and leave the resource value set to *Convert* before clicking on the OK button.

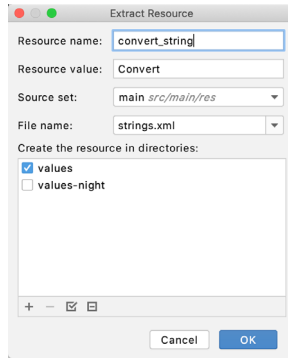


Figure 3-15

The next widget to be added is an EditText widget into which the user will enter the dollar amount to be converted. From the Palette panel, select the Text category and click and drag a Number (Decimal) component onto the layout so that it is centered horizontally and positioned above the existing TextView widget. With the widget selected, use the Attributes tools window to set the *hint* property to “dollars”. Click on the warning icon and extract the string to a resource named *dollars_hint*.

The code written later in this chapter will need to access the dollar value entered by the user into the EditText field. It will do this by referencing the id assigned to the widget in the user interface layout. The default id assigned to the widget by Android Studio can be viewed and changed from within the Attributes tool window when the widget is selected in the layout as shown in Figure 3-16:

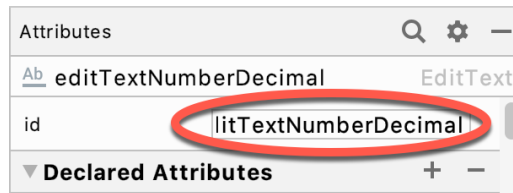


Figure 3-16

Change the id to *dollarText* and, in the Rename dialog, click on the *Refactor* button. This ensures that any references elsewhere within the project to the old id are automatically updated to use the new id:

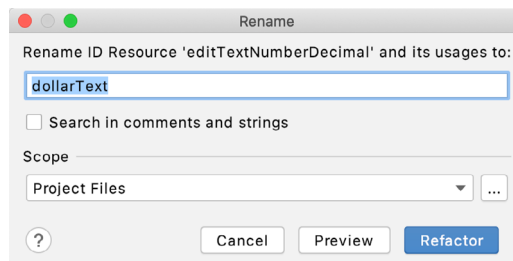


Figure 3-17

Add any missing layout constraints by clicking on the *Infer constraints* button. At this point the layout should resemble that shown in Figure 3-18:

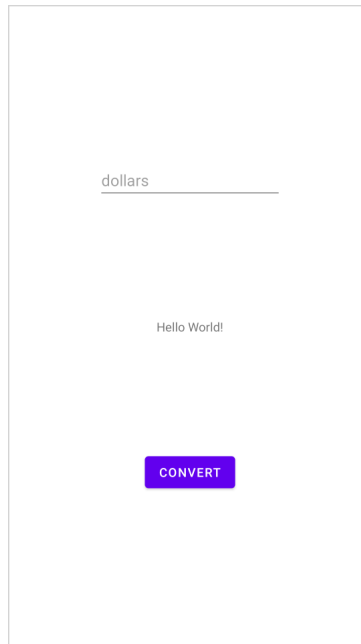


Figure 3-18

3.7 Reviewing the Layout and Resource Files

Before moving on to the next step, we are going to look at some of the internal aspects of user interface design and resource handling. In the previous section, we made some changes to the user interface by modifying the *activity_main.xml* file using the Layout Editor tool. In fact, all that the Layout Editor was doing was providing a user-friendly way to edit the underlying XML content of the file. In practice, there is no reason why you cannot modify the XML directly to make user interface changes and, in some instances, this may actually be quicker than using the Layout Editor tool. In the top right-hand corner of the Layout Editor panel are three buttons as highlighted in Figure 3-19 below:

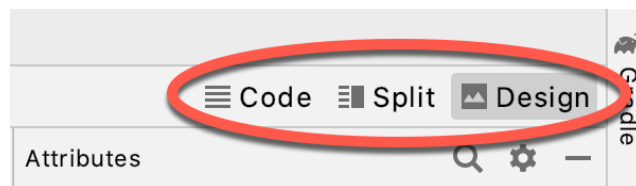


Figure 3-19

By default, the editor will be in *Design* mode whereby just the visual representation of the layout is displayed. The left-most button will switch to *Code* mode to display the XML for the layout, while the middle button enters *Split* mode where both the layout and XML are displayed, as shown in Figure 3-20:

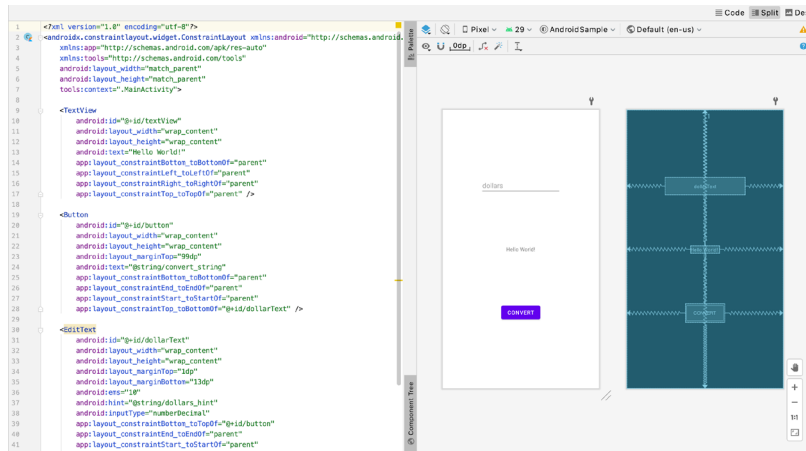


Figure 3-20

As can be seen from the structure of the XML file, the user interface consists of the `ConstraintLayout` component, which in turn, is the parent of the `TextView`, `Button` and `EditText` objects. We can also see, for example, that the `text` property of the `Button` is set to our `convert_string` resource. Although varying in complexity and content, all user interface layouts are structured in this hierarchical, XML based way.

As changes are made to the XML layout, these will be reflected in the layout canvas. The layout may also be modified visually from within the layout canvas panel with the changes appearing in the XML listing. To see this in action, switch to Split mode and modify the XML layout to change the background color of the `ConstraintLayout` to a shade of red as follows:

```
<?xml version="1.0" encoding="utf-8"?>
<androidx.constraintlayout.widget.ConstraintLayout xmlns:android="http://schemas.
android.com/apk/res/android"
    xmlns:app="http://schemas.android.com/apk/res-auto"
    xmlns:tools="http://schemas.android.com/tools"
    android:layout_width="match_parent"
    android:layout_height="match_parent"
    tools:context=".MainActivity"
    android:background="#ff2438" >
    .
    .
</androidx.constraintlayout.widget.ConstraintLayout>
```

Note that the color of the layout changes in real-time to match the new setting in the XML file. Note also that a small red square appears in the left-hand margin (also referred to as the *gutter*) of the XML editor next to the line containing the color setting. This is a visual cue to the fact that the color red has been set on a property. Clicking on the red square will display a color chooser allowing a different color to be selected:

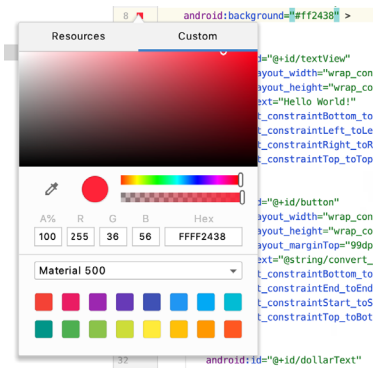


Figure 3-21

Before proceeding, delete the background property from the layout file so that the background returns to the default setting.

Finally, use the Project panel to locate the *app -> res -> values -> strings.xml* file and double-click on it to load it into the editor. Currently the XML should read as follows:

```
<resources>
    <string name="app_name">AndroidSample</string>
    <string name="convert_string">Convert</string>
    <string name="dollars_hint">dollars</string>
</resources>
```

As a demonstration of resources in action, change the string value currently assigned to the *convert_string* resource to “Convert to Euros” and then return to the Layout Editor tool by selecting the tab for the layout file in the editor panel. Note that the layout has picked up the new resource value for the string.

There is also a quick way to access the value of a resource referenced in an XML file. With the Layout Editor tool in Split or Code mode, click on the “@string/convert_string” property setting so that it highlights and then press Ctrl-B on the keyboard (Cmd-B on macOS). Android Studio will subsequently open the *strings.xml* file and take you to the line in that file where this resource is declared. Use this opportunity to revert the string resource back to the original “Convert” text and to add the following additional entry for a string resource that will be referenced later in the app code:

```
<resources>
.
.
    <string name="convert_string">Convert</string>
    <string name="dollars_hint">dollars</string>
    <string name="no_value_string">No Value</string>
</resources>
```

Resource strings may also be edited using the Android Studio Translations Editor. To open this editor, right-click on the *app -> res -> values -> strings.xml* file and select the *Open editor* menu option. This will display the Translation Editor in the main panel of the Android Studio window:

Creating an Example Android App in Android Studio

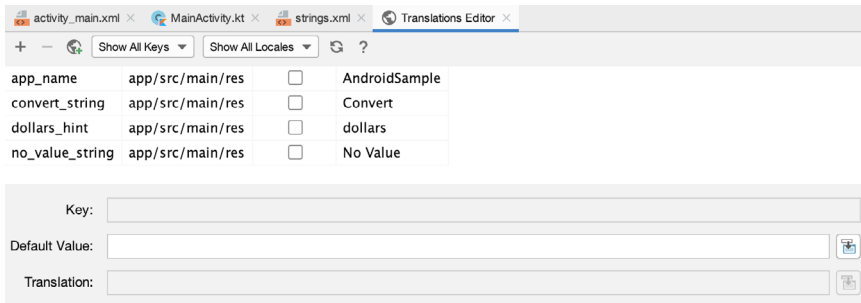


Figure 3-22

This editor allows the strings assigned to resource keys to be edited and for translations for multiple languages to be managed.

3.8 Adding the Kotlin Extensions Plugin

The next section will add some code to the project so that a currency conversion occurs when the button is tapped and the result displayed to the user. Before adding this code, however, we first need to add a plugin to the project build configuration which will make it easier for us to reference the user interface widgets from within the Kotlin code. To do this, begin by opening the module level *build.gradle* file located in the project tool window (*app* -> *Gradle Scripts* -> *build.gradle (Module: AndroidSample.app)*) as shown in :

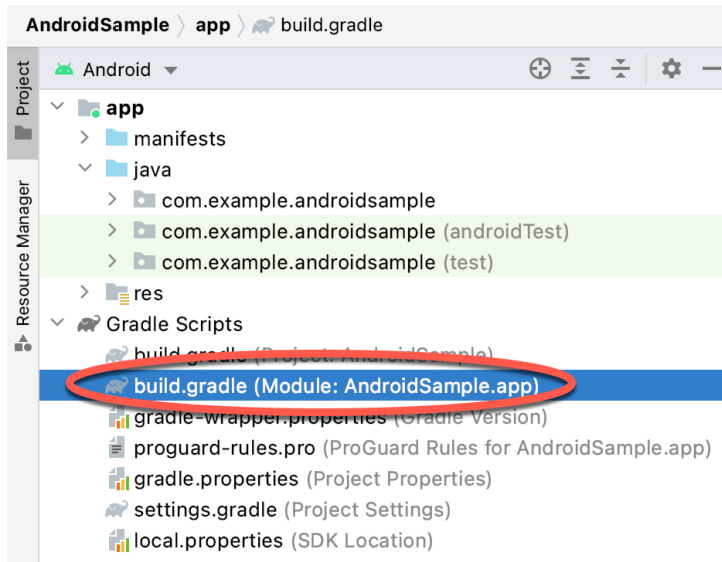


Figure 3-23

Once opened, modify the plugins section so that it reads as follows:

```
plugins {  
    id 'com.android.application'  
    id 'org.jetbrains.kotlin.android'  
    id '-extensions'  
}
```

Finally, click on the *Sync Now* link highlighted in below to commit the change and update the project:

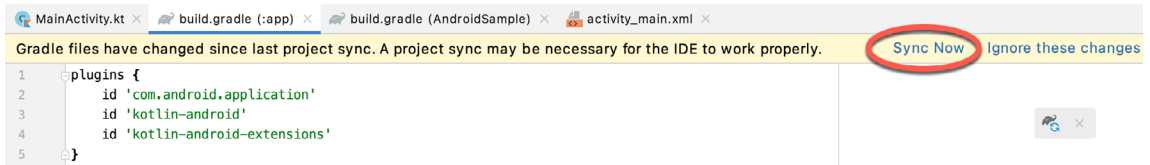


Figure 3-24

The topic of accessing widgets from within code using this technique, together with some useful alternatives, will be covered in the chapter entitled “*An Overview of Android View Binding*”.

3.9 Adding Interaction

The final step in this example project is to make the app interactive so that when the user enters a dollar value into the EditText field and clicks the convert button the converted euro value appears on the TextView. This involves the implementation of some event handling on the Button widget. Specifically, the Button needs to be configured so that a method in the app code is called when an *onClick* event is triggered. Event handling can be implemented in a number of different ways and is covered in detail in a later chapter entitled “*An Overview and Example of Android Event Handling*”. Return the layout editor to Design mode, select the Button widget in the layout editor, refer to the Attributes tool window and specify a method named *convertCurrency* as shown below:

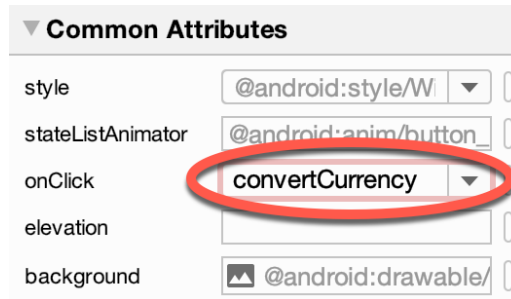


Figure 3-25

Note that the text field for the *onClick* property is now highlighted with a red border to warn us that the button has been configured to call a method which does not yet exist. To address this, double-click on the *MainActivity.kt* file in the Project tool window (*app* -> *java* -> *<package name>* -> *MainActivity*) to load it into the code editor and add the code for the *convertCurrency* method to the class file so that it reads as follows, noting that it is also necessary to import some additional Android packages:

```
package com.example.androidsample

import androidx.appcompat.app.AppCompatActivity
import android.os.Bundle
import android.view.View

import kotlinx.android.synthetic.main.activity_main.*

class MainActivity : AppCompatActivity() {

    override fun onCreate(savedInstanceState: Bundle?) {
        super.onCreate(savedInstanceState)
        setContentView(R.layout.activity_main)
    }
}
```

```

    }

    fun convertCurrency(view: View) {

        if (dollarText.text.isNotEmpty()) {

            val dollarValue = dollarText.text.toString().toFloat()

            val euroValue = dollarValue * 0.85f

            textView.text = euroValue.toString()
        } else {
            textView.text = getString(R.string.no_value_string)
        }
    }
}

```

The method begins by checking the text property of the dollarText EditText view to make sure that it is not empty (in other words that the user has entered a dollar value). If a value has not been entered, a “No Value” string is displayed on the TextView using the string resource declared earlier in the chapter. If, on the other hand, a dollar amount has been entered, it is converted into a floating point value and the equivalent euro value calculated. This floating point value is then converted into a string and displayed on the TextView. If any of this is unclear, rest assured that these concepts will be covered in greater detail in later chapters.

3.10 Summary

While not excessively complex, a number of steps are involved in setting up an Android development environment. Having performed those steps, it is worth working through an example to make sure the environment is correctly installed and configured. In this chapter, we have created an example application and then used the Android Studio Layout Editor tool to modify the user interface layout. In doing so, we explored the importance of using resources wherever possible, particularly in the case of string values, and briefly touched on the topic of layouts. Next we looked at the underlying XML that is used to store the user interface designs of Android applications.

Finally, an onClick event was added to a Button connected to a method that was implemented to extract the user input from the EditText component, convert from dollars to euros and then display the result on the TextView.

With the app ready for testing, the steps necessary to set up an emulator for testing purposes will be covered in detail in the next chapter.

4. Creating an Android Virtual Device (AVD) in Android Studio

Although the Android Studio Preview panel allows us to see the layout we are designing and test basic functionality using interactive mode, it be will necessary to compile and run an entire app to fully test that it works. An Android application may be tested by installing and running it either on a physical device or in an *Android Virtual Device (AVD)* emulator environment. Before an AVD can be used, it must first be created and configured to match the specifications of a particular device model. In this chapter, we will work through the creation of such a virtual device using the Pixel 4 phone as a reference example.

4.1 About Android Virtual Devices

AVDs are essentially emulators that allow Android applications to be tested without the necessity to install the application on a physical Android-based device. An AVD may be configured to emulate a variety of hardware features including options such as screen size, memory capacity, and the presence or otherwise of features such as a camera, GPS navigation support, or an accelerometer. As part of the standard Android Studio installation, several emulator templates are installed allowing AVDs to be configured for a range of different devices. Custom configurations may be created to match any physical Android device by specifying properties such as processor type, memory capacity, and the size and pixel density of the screen.

An AVD session can appear either as a separate window or embedded within the Android Studio window.

New AVDs are created and managed using the Android Virtual Device Manager, which may be used either in command-line mode or with a more user-friendly graphical user interface. To create a new AVD, the first step is to launch the AVD Manager. This can be achieved from within the Android Studio environment by selecting the *Tools -> Device Manager* menu option from within the main window.

Once launched, the manager will appear as a tool window as shown in Figure 4-1:

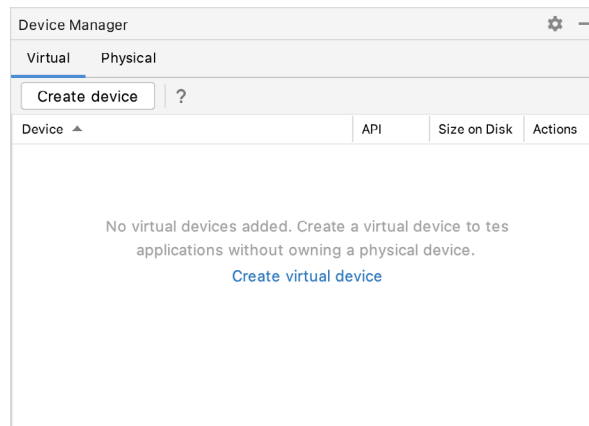


Figure 4-1

To add a new AVD, begin by making sure that the Virtual tab is selected before clicking on the *Create device*

Creating an Android Virtual Device (AVD) in Android Studio

button to open the *Virtual Device Configuration* dialog:

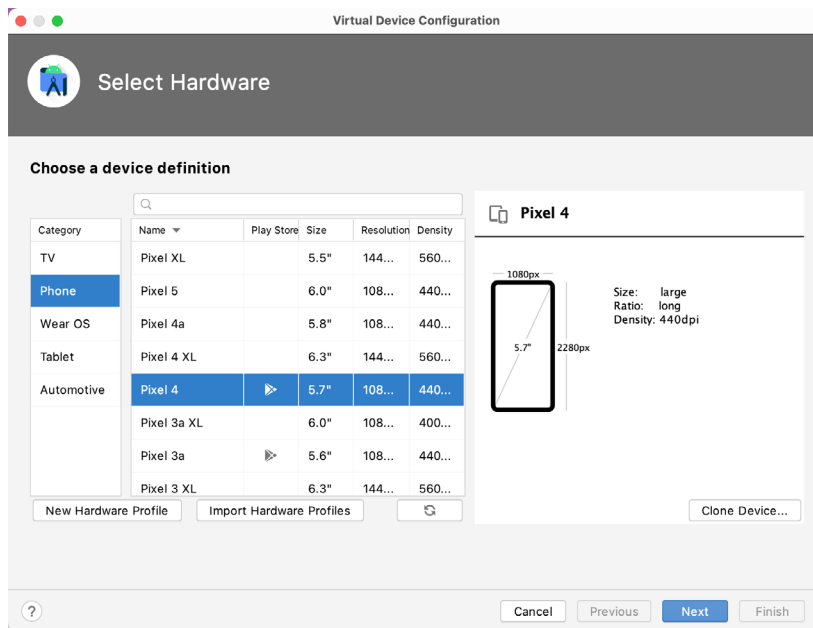


Figure 4-2

Within the dialog, perform the following steps to create a Pixel 4 compatible emulator:

1. From the *Category* panel, select the *Phone* option to display the list of available Android phone AVD templates.
2. Select the *Pixel 4* device option and click *Next*.
3. On the System Image screen, select the latest version of Android. Note that if the system image has not yet been installed a *Download* link will be provided next to the Release Name. Click this link to download and install the system image before selecting it. If the image you need is not listed, click on the *x86 Images* (or *ARM images* if you are running a Mac with Apple Silicon) and *Other images* tabs to view alternative lists.
4. Click *Next* to proceed and enter a descriptive name (for example *Pixel 4 API 32*) into the name field or simply accept the default name.
5. Click *Finish* to create the AVD.
6. With the AVD created, the Device Manager may now be closed. If future modifications to the AVD are necessary, simply re-open the Device Manager, select the AVD from the list, and click on the pencil icon in the Actions column to edit the settings.

4.2 Starting the Emulator

To perform a test run of the newly created AVD emulator, simply select the emulator from the Device Manager and click on the launch button (the triangle in the Actions column). The emulator will appear embedded into the main Android Studio window and begin the startup process. The amount of time it takes for the emulator to start will depend on the configuration of both the AVD and the system on which it is running:

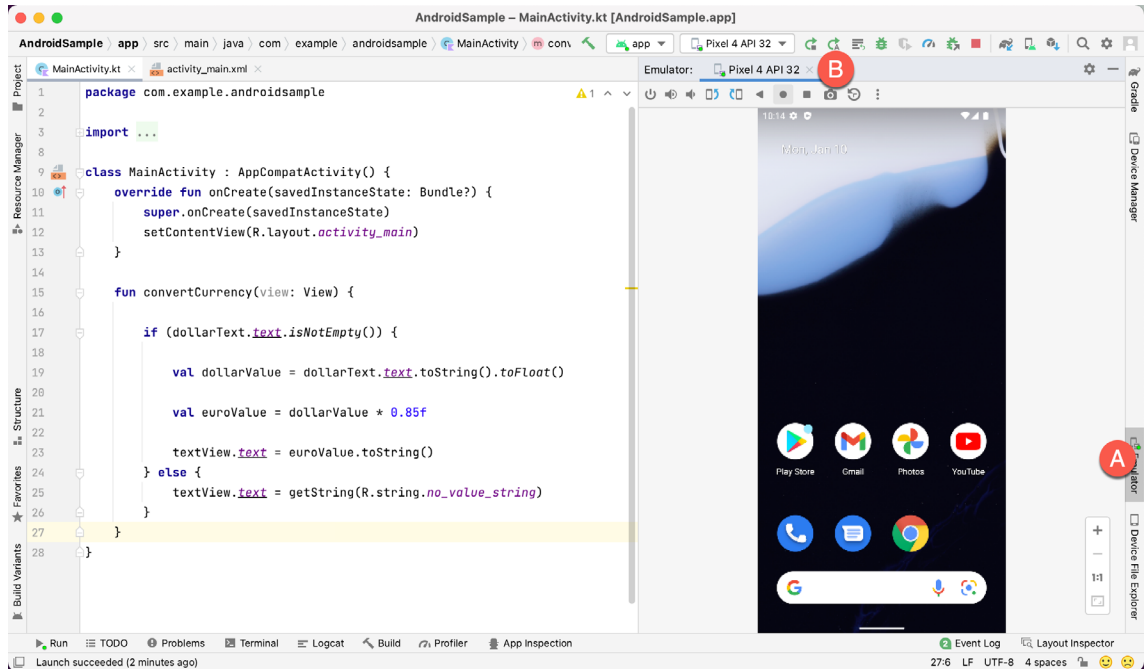


Figure 4-3

To hide and show the emulator tool window, click on the Emulator tool window button (marked A above). Click on the “x” close button next to the tab (B) to exit the emulator. The emulator tool window can accommodate multiple emulator sessions, with each session represented by a tab. Figure 4-4, for example, shows a tool window with two emulator sessions:

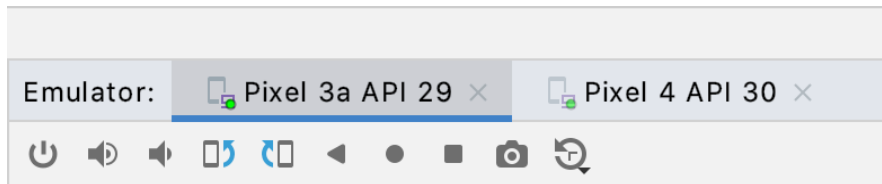


Figure 4-4

To switch between sessions, simply click on the corresponding tab.

Although the emulator probably defaulted to appearing in portrait orientation, this and other default options can be changed. Within the Device Manager, select the new Pixel 4 entry and click on the pencil icon in the *Actions* column of the device row. In the configuration screen, locate the *Startup orientation* section and change the orientation setting. Exit and restart the emulator session to see this change take effect. More details on the emulator are covered in the next chapter (“Using and Configuring the Android Studio AVD Emulator”).

To save time in the next section of this chapter, leave the emulator running before proceeding.

4.3 Running the Application in the AVD

With an AVD emulator configured, the example AndroidSample application created in the earlier chapter now can be compiled and run. With the AndroidSample project loaded into Android Studio, make sure that the newly created Pixel 4 AVD is displayed in the device menu (marked A in Figure 4-5 below), then either click on the run button represented by a green triangle (B), select the *Run -> Run ‘app’* menu option or use the Ctrl-R

Creating an Android Virtual Device (AVD) in Android Studio

keyboard shortcut:

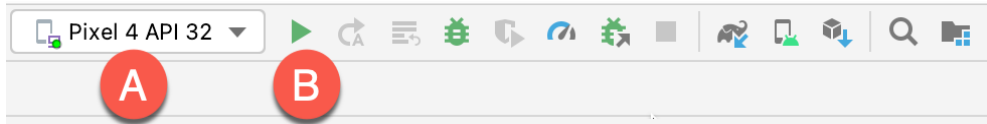


Figure 4-5

The device menu (A) may be used to select a different AVD instance or physical device as the run target, and also to run the app on multiple devices. The menu also provides access to the Device Manager as well as device connection configuration and troubleshooting options:

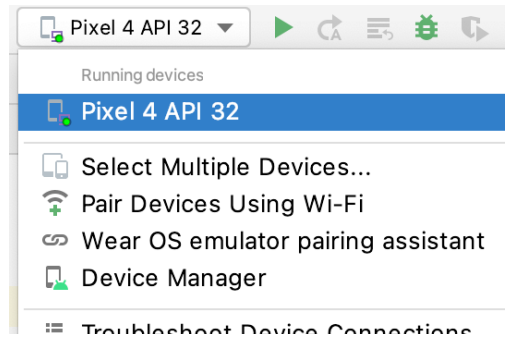


Figure 4-6

Once the application is installed and running, the user interface for the first fragment will appear within the emulator (a fragment is a reusable section of an Android project typically consisting of a user interface layout and some code, a topic which will be covered later in the chapter entitled “*An Introduction to Android Fragments*”):

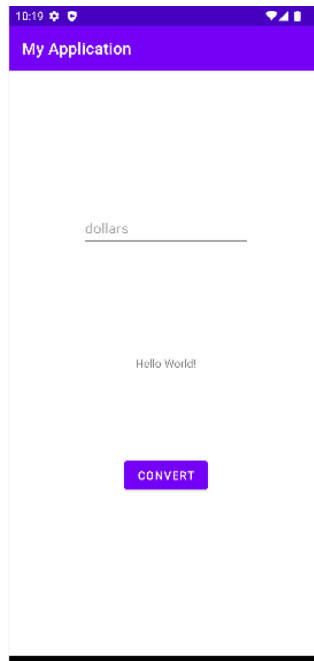


Figure 4-7

If the activity does not automatically launch, check to see if the launch icon has appeared among the apps on the emulator. If it has, simply click on it to launch the application. Once the run process begins, the Run tool window will become available. The Run tool window will display diagnostic information as the application package is installed and launched. Figure 4-8 shows the Run tool window output from a typical successful application launch:



Figure 4-8

If problems are encountered during the launch process, the Run tool window will provide information that will hopefully help to isolate the cause of the problem.

Assuming that the application loads into the emulator and runs as expected, we have safely verified that the Android development environment is correctly installed and configured. With the app now running, try performing a temperature conversion to verify that the app works as intended.

4.4 Running on Multiple Devices

The run menu shown in Figure 4-6 above includes an option to run the app on multiple emulators and devices in parallel. When selected, this option displays the dialog shown in Figure 4-9 providing a list of both the AVDs configured on the system and any attached physical devices. Enable the checkboxes next to the emulators or devices to be targeted before clicking on the Run button:



Figure 4-9

After the Run button is clicked, Android Studio will launch the app on the selected emulators and devices.

4.5 Stopping a Running Application

To stop a running application, simply click on the stop button located in the main toolbar as shown in Figure 4-10:

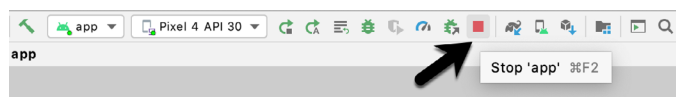


Figure 4-10

An app may also be terminated using the Run tool window. Begin by displaying the *Run* tool window using the window bar button that becomes available when the app is running. Once the Run tool window appears, click

Creating an Android Virtual Device (AVD) in Android Studio

the stop button highlighted in Figure 4-11 below:

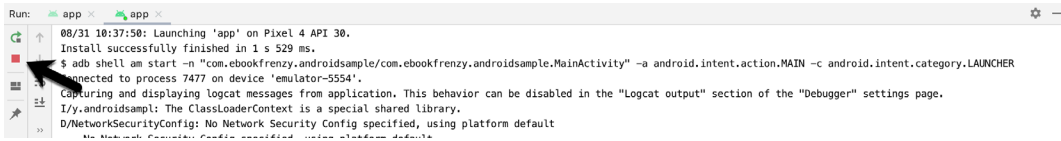


Figure 4-11

4.6 Supporting Dark Theme

Android 10 introduced the much-awaited dark theme, support for which is enabled by default in Android Studio app projects. To test dark theme in the AVD emulator, open the Settings app within the running Android instance in the emulator. Within the Settings app, choose the *Display* category and enable the *Dark theme* option as shown in Figure 4-12 so that the screen background turns black:

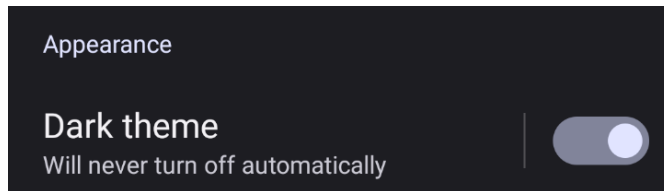


Figure 4-12

With dark theme enabled, run the AndroidSample app and note that it appears using a dark theme including a black background and a purple background color on the button as shown in Figure 4-13:

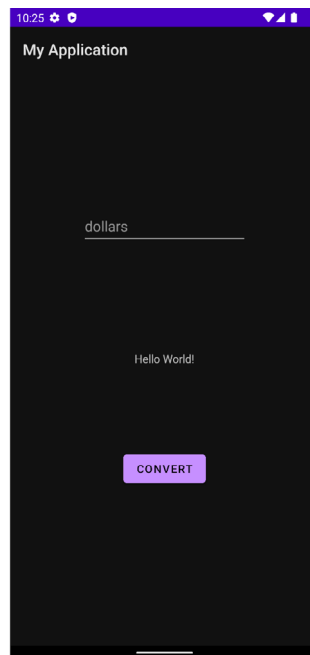


Figure 4-13

Return to the Settings app and turn off Dark theme mode before continuing.

4.7 Running the Emulator in a Separate Window

So far in this chapter, we have only used the emulator as a tool window embedded within the main Android Studio window. To run the emulator in a separate window, select the *File -> Settings...* menu option (*Android Studio -> Preferences...* on macOS), navigate to *Tools -> Emulator* in the left-hand navigation panel of the preferences dialog, and disable the *Launch in a tool window* option:

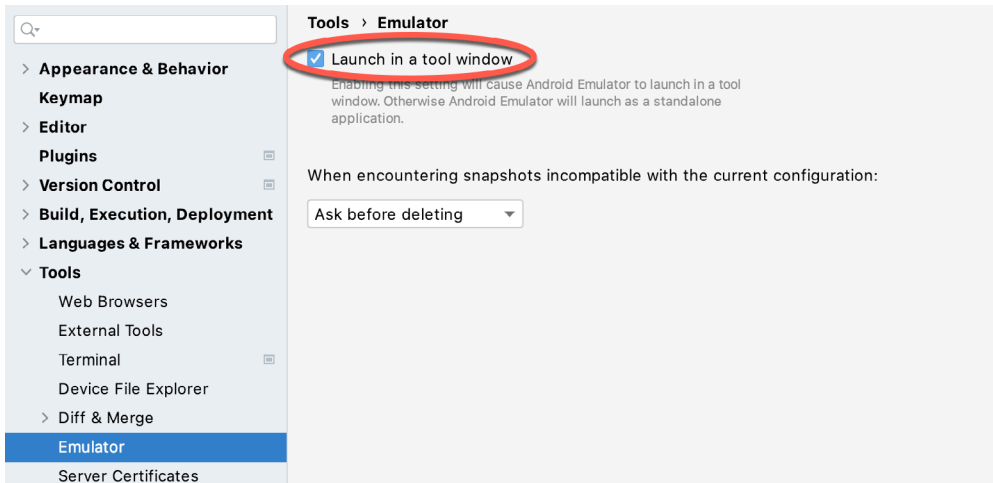


Figure 4-14

With the option disabled, click the Apply button followed by OK to commit the change, then exit the current emulator session by clicking on the close button on the tab marked B in Figure 4-3 above.

Run the sample app once again, at which point the emulator will appear as a separate window as shown below:

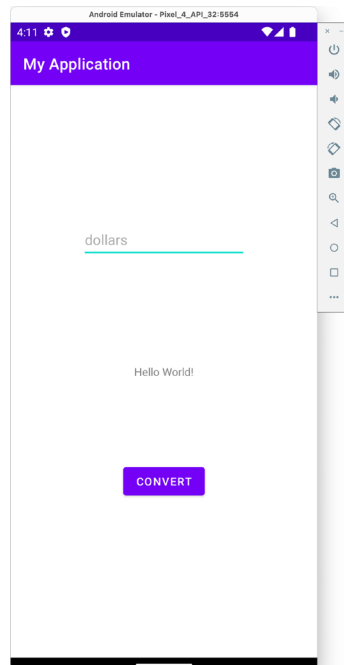


Figure 4-15

Creating an Android Virtual Device (AVD) in Android Studio

The choice of standalone or tool window mode is a matter of personal preference. If you prefer the emulator running in a tool window, return to the settings screen and re-enable the *Launch in a tool window* option. Before committing to standalone mode, however, keep in mind that the emulator tool window may also be detached from the main Android Studio window by clicking on the settings button (represented by the gear icon) in the tool emulator toolbar and selecting the *View Mode -> Float* menu option:

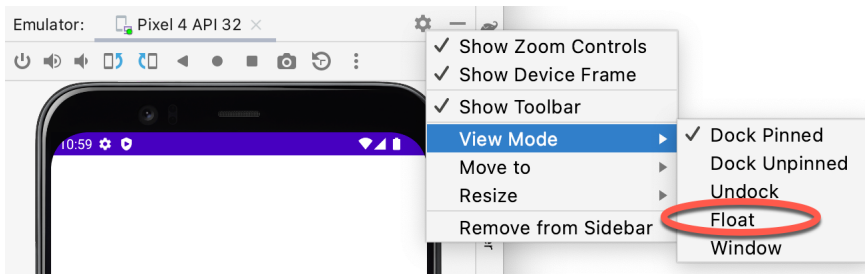


Figure 4-16

4.8 Enabling the Device Frame

The emulator can be configured to appear with (Figure 4-17) or without the device frame (Figure 4-15).

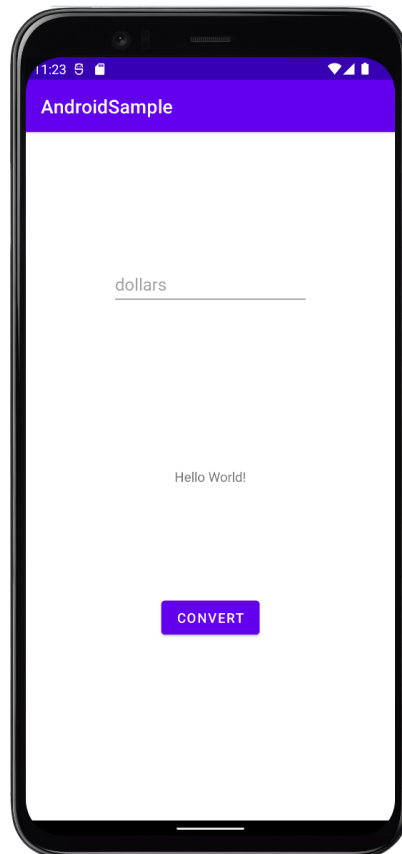


Figure 4-17

To change the setting, open the Device Manager, select the AVD from the list, and click on the pencil icon in the Actions column to edit the settings. In the settings screen, locate and change the Enable Device Frame option:

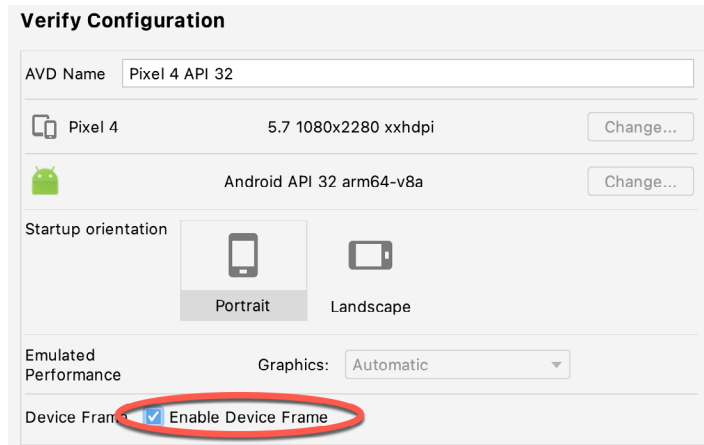


Figure 4-18

4.9 AVD Command-line Creation

As previously discussed, in addition to the graphical user interface it is also possible to create a new AVD directly from the command-line. This is achieved using the *avdmanager* tool in conjunction with some command-line options. Once initiated, the tool will prompt for additional information before creating the new AVD.

The *avdmanager* tool requires access to the Java Runtime Environment (JRE) to run. If, when attempting to run *avdmanager*, an error message appears indicating that the 'java' command cannot be found, the command prompt or terminal window within which you are running the command can be configured to use the OpenJDK environment bundled with Android Studio. Begin by identifying the location of the OpenJDK JRE as follows:

1. Launch Android Studio and open the ComposeDemo project created earlier in the book.
2. Select the *File -> Settings...* menu option (*Android Studio -> Preferences...* on macOS).
3. Navigate to the Build, Execution, Deployment section and select the Gradle option listed under the Build Tools category.
4. Click on the *Gradle JDK* setting and make a note of the path for *Android Studio default JDK*:

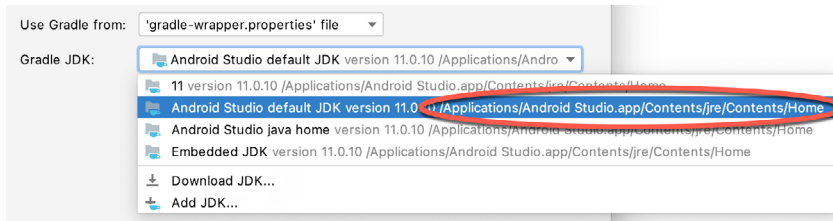


Figure 4-19

On Windows, execute the following command within the command prompt window from which *avdmanager* is to be run (where *<path to jre>* is replaced by the path copied from the Project Structure dialog above):

```
set JAVA_HOME=<path to jre>
```

On macOS or Linux, execute the following command:

```
export JAVA_HOME="<path to jre>"
```

If you expect to use the *avdmanager* tool frequently, follow the environment variable steps for your operating

Creating an Android Virtual Device (AVD) in Android Studio

system outlined in the chapter entitled “*Setting up an Android Studio Development Environment*” to configure `JAVA_HOME` on a system-wide basis.

Assuming that the system has been configured such that the Android SDK *tools* directory is included in the `PATH` environment variable, a list of available targets for the new AVD may be obtained by issuing the following command in a terminal or command window:

```
avdmanager list targets
```

The resulting output from the above command will contain a list of Android SDK versions that are available on the system. For example:

```
Available Android targets:
```

```
-----
```

```
id: 1 or "android-29"
```

```
    Name: Android API 29
```

```
    Type: Platform
```

```
    API level: 29
```

```
    Revision: 1
```

```
-----
```

```
id: 2 or "android-26"
```

```
    Name: Android API 26
```

```
    Type: Platform
```

```
    API level: 26
```

```
    Revision: 1
```

The `avdmanager` tool also allows new AVD instances to be created from the command-line. For example, to create a new AVD named *myAVD* using the target ID for the Android API level 29 device using the x86 ABI, the following command may be used:

```
avdmanager create avd -n myAVD -k "system-images;android-29;google_apis_
playstore;x86"
```

The `avdmanager` tool will create the new AVD to the specifications required for a basic Android 8 device, also providing the option to create a custom configuration to match the specification of a specific device if required. Once a new AVD has been created from the command-line, it may not show up in the Android Device Manager tool until the *Refresh* button is clicked.

In addition to the creation of new AVDs, several other tasks may be performed from the command-line. For example, a list of currently available AVDs may be obtained using the *list avd* command-line arguments:

```
avdmanager list avd
```

```
Available Android Virtual Devices:
```

```
    Name: Pixel_XL_API_28_No_Play
```

```
    Device: pixel_xl (Google)
```

```
    Path: /Users/neilsmyth/.android/avd/Pixel_XL_API_28_No_Play.avd
```

```
    Target: Google APIs (Google Inc.)
```

```
        Based on: Android API 28 Tag/ABI: google_apis/x86
```

```
    Skin: pixel_xl_silver
```

```
    Sdcard: 512M
```

Similarly, to delete an existing AVD, simply use the *delete* option as follows:

```
avdmanager delete avd -n <avd name>
```

4.10 Android Virtual Device Configuration Files

By default, the files associated with an AVD are stored in the *.android/avd* sub-directory of the user's home directory, the structure of which is as follows (where *<avd name>* is replaced by the name assigned to the AVD):

```
<avd name>.avd/config.ini
<avd name>.avd/userdata.img
<avd name>.ini
```

The *config.ini* file contains the device configuration settings such as display dimensions and memory specified during the AVD creation process. These settings may be changed directly within the configuration file and will be adopted by the AVD when it is next invoked.

The *<avd name>.ini* file contains a reference to the target Android SDK and the path to the AVD files. Note that a change to the *image.sysdir* value in the *config.ini* file will also need to be reflected in the *target* value of this file.

4.11 Moving and Renaming an Android Virtual Device

The current name or the location of the AVD files may be altered from the command-line using the *avdmanager* tool's *move avd* argument. For example, to rename an AVD named Pixel4 to Pixel4a, the following command may be executed:

```
avdmanager move avd -n Pixel4 -r Pixel4a
```

To physically relocate the files associated with the AVD, the following command syntax should be used:

```
avdmanager move avd -n <avd name> -p <path to new location>
```

For example, to move an AVD from its current file system location to */tmp/Pixel4Test*:

```
avdmanager move avd -n Pixel4 -p /tmp/Pixel4Test
```

Note that the destination directory must not already exist before executing the command to move an AVD.

4.12 Summary

A typical application development process follows a cycle of coding, compiling, and running in a test environment. Android applications may be tested on either a physical Android device or using an Android Virtual Device (AVD) emulator. AVDs are created and managed using the Android Studio Device Manager tool which may be used either as a command-line tool or via a graphical user interface. When creating an AVD to simulate a specific Android device model, the virtual device should be configured with a hardware specification matching that of the physical device.

The AVD emulator session may be displayed as a standalone window or embedded into the main Android Studio user interface.

5. Using and Configuring the Android Studio AVD Emulator

Before the next chapter explores testing on physical Android devices, this chapter will take some time to provide an overview of the Android Studio AVD emulator and highlight many of the configuration features that are available to customize the environment in both standalone and tool window modes.

5.1 The Emulator Environment

When launched in standalone mode, the emulator displays an initial splash screen during the loading process. Once loaded, the main emulator window appears containing a representation of the chosen device type (in the case of Figure 5-1 this is a Pixel 4 device):

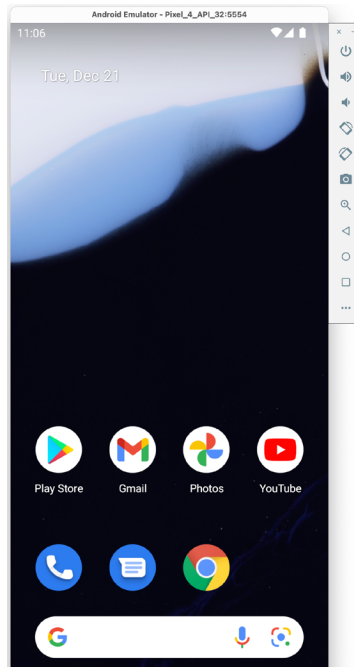


Figure 5-1

Positioned along the right-hand edge of the window is the toolbar providing quick access to the emulator controls and configuration options.

5.2 Emulator Toolbar Options

The emulator toolbar (Figure 5-2) provides access to a range of options relating to the appearance and behavior of the emulator environment.

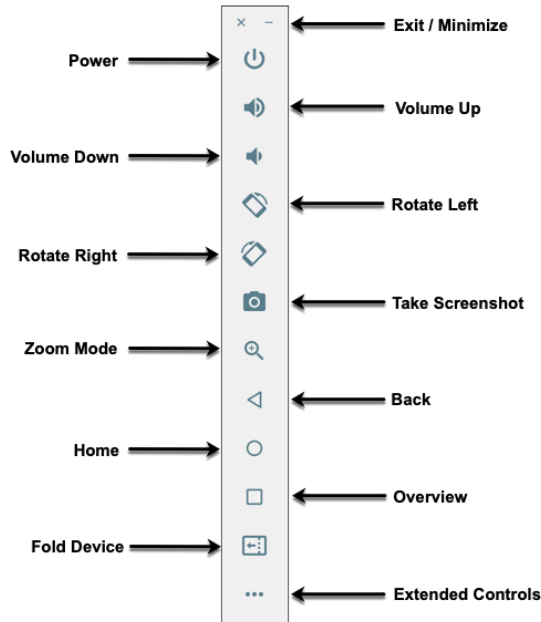


Figure 5-2

Each button in the toolbar has associated with it a keyboard accelerator which can be identified either by hovering the mouse pointer over the button and waiting for the tooltip to appear or via the help option of the extended controls panel.

Though many of the options contained within the toolbar are self-explanatory, each option will be covered for the sake of completeness:

- **Exit / Minimize** – The uppermost ‘x’ button in the toolbar exits the emulator session when selected while the ‘-’ option minimizes the entire window.
- **Power** – The Power button simulates the hardware power button on a physical Android device. Clicking and releasing this button will lock the device and turn off the screen. Clicking and holding this button will initiate the device “Power off” request sequence.
- **Volume Up / Down** – Two buttons that control the audio volume of playback within the simulator environment.
- **Rotate Left/Right** – Rotates the emulated device between portrait and landscape orientations.
- **Take Screenshot** – Takes a screenshot of the content currently displayed on the device screen. The captured image is stored at the location specified in the Settings screen of the extended controls panel as outlined later in this chapter.
- **Zoom Mode** – This button toggles in and out of zoom mode, details of which will be covered later in this chapter.
- **Back** – Performs the standard Android “Back” navigation to return to a previous screen.
- **Home** – Displays the device home screen.
- **Overview** – Simulates selection of the standard Android “Overview” navigation which displays the currently running apps on the device.

- **Fold Device** – Simulates the folding and unfolding of a foldable device. This option is only available if the emulator is running a foldable device system image.
- **Extended Controls** – Displays the extended controls panel, allowing for the configuration of options such as simulated location and telephony activity, battery strength, cellular network type, and fingerprint identification.

5.3 Working in Zoom Mode

The zoom button located in the emulator toolbar switches in and out of zoom mode. When zoom mode is active the toolbar button is depressed and the mouse pointer appears as a magnifying glass when hovering over the device screen. Clicking the left mouse button will cause the display to zoom in relative to the selected point on the screen, with repeated clicking increasing the zoom level. Conversely, clicking the right mouse button decreases the zoom level. Toggling the zoom button off reverts the display to the default size.

Clicking and dragging while in zoom mode will define a rectangular area into which the view will zoom when the mouse button is released.

While in zoom mode the visible area of the screen may be panned using the horizontal and vertical scrollbars located within the emulator window.

5.4 Resizing the Emulator Window

The size of the emulator window (and the corresponding representation of the device) can be changed at any time by clicking and dragging on any of the corners or sides of the window.

5.5 Extended Control Options

The extended controls toolbar button displays the panel illustrated in Figure 5-3. By default, the location settings will be displayed. Selecting a different category from the left-hand panel will display the corresponding group of controls:

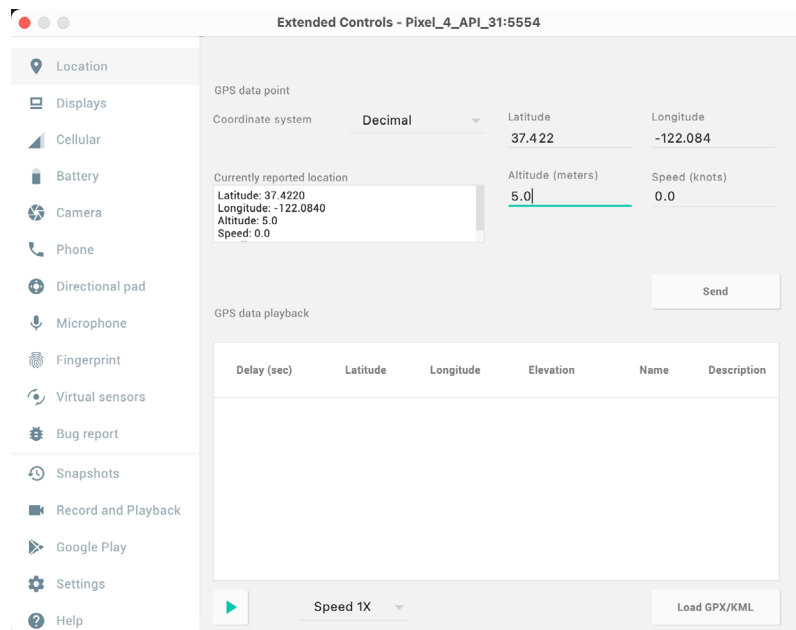


Figure 5-3

5.5.1 Location

The location controls allow simulated location information to be sent to the emulator in the form of decimal or sexagesimal coordinates. Location information can take the form of a single location, or a sequence of points representing movement of the device, the latter being provided via a file in either GPS Exchange (GPX) or Keyhole Markup Language (KML) format. Alternatively, the integrated Google Maps panel may be used to visually select single points or travel routes.

5.5.2 Displays

In addition to the main display shown within the emulator screen, the Displays option allows additional displays to be added running within the same Android instance. This can be useful for testing apps for dual-screen devices such as the Microsoft Surface Duo. These additional screens can be configured to be any required size and appear within the same emulator window as the main screen.

5.5.3 Cellular

The type of cellular connection being simulated can be changed within the cellular settings screen. Options are available to simulate different network types (CSM, EDGE, HSDPA, etc) in addition to a range of voice and data scenarios such as roaming and denied access.

5.5.4 Battery

A variety of battery state and charging conditions can be simulated on this panel of the extended controls screen, including battery charge level, battery health, and whether the AC charger is currently connected.

5.5.5 Camera

The emulator simulates a 3D scene when the camera is active. This takes the form of the interior of a virtual building through which you can navigate by holding down the Option key (Alt on Windows) while using the mouse pointer and keyboard keys when recording video or before taking a photo within the emulator. This extended configuration option allows different images to be uploaded for display within the virtual environment.

5.5.6 Phone

The phone extended controls provide two very simple but useful simulations within the emulator. The first option allows for the simulation of an incoming call from a designated phone number. This can be of particular use when testing how an app handles high-level interrupts of this nature.

The second option allows the receipt of text messages to be simulated within the emulator session. As in the real world, these messages appear within the Message app and trigger the standard notifications within the emulator.

5.5.7 Directional Pad

A directional pad (D-Pad) is an additional set of controls either built into an Android device or connected externally (such as a game controller) that provides directional controls (left, right, up, down). The directional pad settings allow D-Pad interaction to be simulated within the emulator.

5.5.8 Microphone

The microphone settings allow the microphone to be enabled and virtual headset and microphone connections to be simulated. A button is also provided to launch the Voice Assistant on the emulator.

5.5.9 Fingerprint

Many Android devices are now supplied with built-in fingerprint detection hardware. The AVD emulator makes it possible to test fingerprint authentication without the need to test apps on a physical device containing a fingerprint sensor. Details on how to configure fingerprint testing within the emulator will be covered in detail later in this chapter.

5.5.10 Virtual Sensors

The virtual sensors option allows the accelerometer and magnetometer to be simulated to emulate the effects of the physical motion of a device such as rotation, movement, and tilting through yaw, pitch and roll settings.

5.5.11 Snapshots

Snapshots contain the state of the currently running AVD session to be saved and rapidly restored making it easy to return the emulator to an exact state. Snapshots are covered in later in this chapter.

5.5.12 Record and Playback

Allows the emulator screen and audio to be recorded and saved in either WebM or animated GIF format.

5.5.13 Google Play

If the emulator is running a version of Android with Google Play Services installed, this option displays the current Google Play version and provides the option to update the emulator to the latest version.

5.5.14 Settings

The settings panel provides a small group of configuration options. Use this panel to choose a darker theme for the toolbar and extended controls panel, specify a file system location into which screenshots are to be saved, configure OpenGL support levels, and configure the emulator window to appear on top of other windows on the desktop.

5.5.15 Help

The Help screen contains three sub-panels containing a list of keyboard shortcuts, links to access the emulator online documentation, file bugs and send feedback, and emulator version information.

5.6 Working with Snapshots

When an emulator starts for the very first time it performs a *cold boot* much like a physical Android device when it is powered on. This cold boot process can take some time to complete as the operating system loads and all the background processes are started. To avoid the necessity of going through this process every time the emulator is started, the system is configured to automatically save a snapshot (referred to as a *quick-boot snapshot*) of the emulator's current state each time it exits. The next time the emulator is launched, the quick-boot snapshot is loaded into memory and execution resumes from where it left off previously, allowing the emulator to restart in a fraction of the time needed for a cold boot to complete.

The Snapshots screen of the extended controls panel can be used to store additional snapshots at any point during the execution of the emulator. This saves the exact state of the entire emulator allowing the emulator to be restored to the exact point in time that the snapshot was taken. From within the screen, snapshots can be taken using the *Take Snapshot* button (marked A in Figure 5-4). To restore an existing snapshot, select it from the list (B) and click the run button (C) located at the bottom of the screen. Options are also provided to edit (D) the snapshot name and description and to delete (E) the currently selected snapshot:

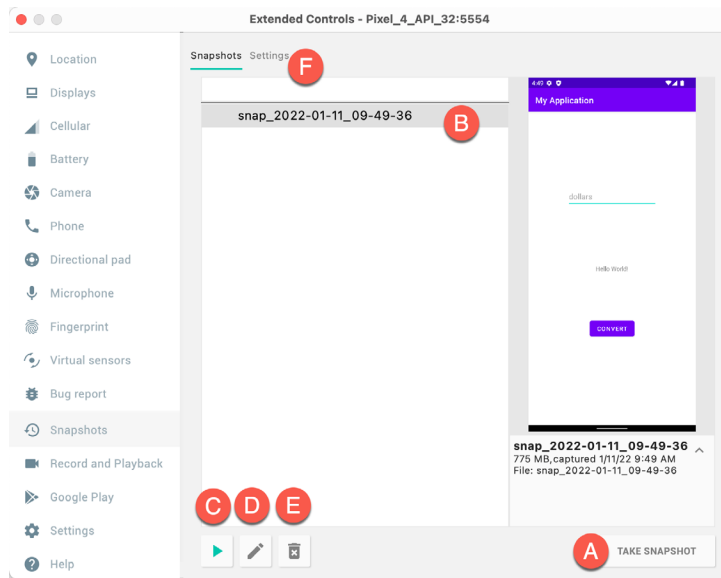


Figure 5-4

The Settings option (F) provides the option to configure the automatic saving of quick-boot snapshots (by default the emulator will ask whether to save the quick boot snapshot each time the emulator exits) and to reload the most recent snapshot. To force an emulator session to perform a cold boot instead of using a previous quick-boot snapshot, open the AVD Manager (*Tools -> AVD Manager*), click on the down arrow in the Actions column for the emulator and select the Cold Boot Now menu option.

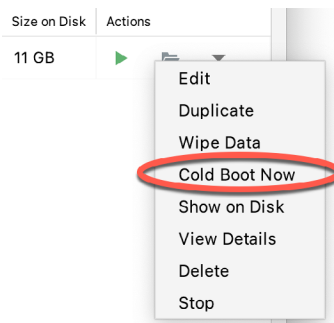


Figure 5-5

5.7 Configuring Fingerprint Emulation

The emulator allows up to 10 simulated fingerprints to be configured and used to test fingerprint authentication within Android apps. To configure simulated fingerprints begin by launching the emulator, opening the Settings app, and selecting the *Security & Location* option.

Within the Security settings screen, select the *Use fingerprint* option. On the resulting information screen click on the *Next* button to proceed to the Fingerprint setup screen. Before fingerprint security can be enabled a backup screen unlocking method (such as a PIN) must be configured. Click on the *Fingerprint + PIN* button and, when prompted, choose not to require the PIN on device startup. Enter and confirm a suitable PIN and complete the PIN entry process by accepting the default notifications option.

Proceed through the remaining screens until the Settings app requests a fingerprint on the sensor. At this point display the extended controls dialog, select the *Fingerprint* category in the left-hand panel and make sure that

Finger 1 is selected in the main settings panel:

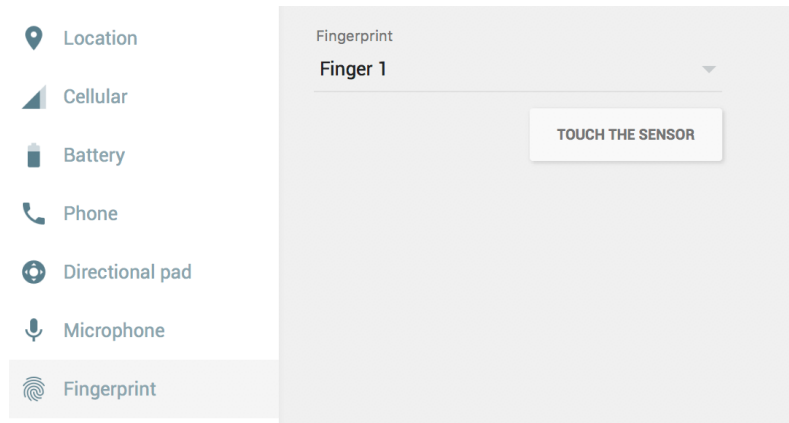


Figure 5-6

Click on the *Touch the Sensor* button to simulate Finger 1 touching the fingerprint sensor. The emulator will report the successful addition of the fingerprint:

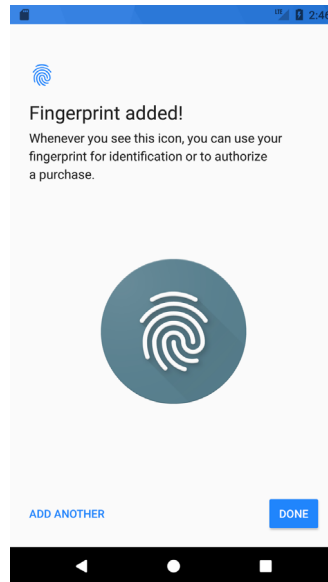


Figure 5-7

To add additional fingerprints click on the *Add Another* button and select another finger from the extended controls panel menu before clicking on the *Touch the Sensor* button once again.

5.8 The Emulator in Tool Window Mode

As outlined in the previous chapter (*“Creating an Android Virtual Device (AVD) in Android Studio”*), Android Studio can be configured to launch the emulator as an embedded tool window so that it does not appear in a separate window. When running in this mode, the same controls available in standalone mode are provided in the toolbar as shown in Figure 5-8:

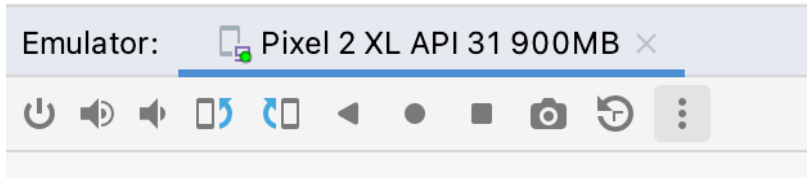


Figure 5-8

From left to right, these buttons perform the following tasks (details of which match those for standalone mode):

- Power
- Volume Up
- Volume Down
- Rotate Left
- Rotate Right
- Back
- Home
- Overview
- Screenshot
- Snapshots
- Extended Controls

5.9 Summary

Android Studio contains an Android Virtual Device emulator environment designed to make it easier to test applications without the need to run on a physical Android device. This chapter has provided a brief tour of the emulator and highlighted key features that are available to configure and customize the environment to simulate different testing conditions.

6. A Tour of the Android Studio User Interface

While it is tempting to plunge into running the example application created in the previous chapter, doing so involves using aspects of the Android Studio user interface which are best described in advance.

Android Studio is a powerful and feature rich development environment that is, to a large extent, intuitive to use. That being said, taking the time now to gain familiarity with the layout and organization of the Android Studio user interface will considerably shorten the learning curve in later chapters of the book. With this in mind, this chapter will provide an initial overview of the various areas and components that make up the Android Studio environment.

6.1 The Welcome Screen

The welcome screen (Figure 6-1) is displayed any time that Android Studio is running with no projects currently open (open projects can be closed at any time by selecting the *File -> Close Project* menu option). If Android Studio was previously exited while a project was still open, the tool will by-pass the welcome screen next time it is launched, automatically opening the previously active project.

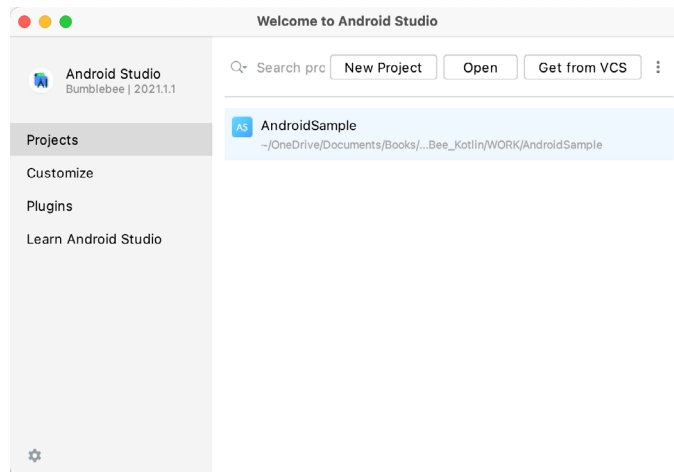


Figure 6-1

In addition to a list of recent projects, the welcome screen provides a range of options for performing tasks such as opening and creating projects along with access to projects currently under version control. In addition, the *Customize* screen provides options to change the theme and font settings used by both the IDE and the editor. Android Studio plugins may be viewed, installed and managed using via the *Plugins* option.

Additional options are available by clicking on the menu button as shown in Figure 6-2:

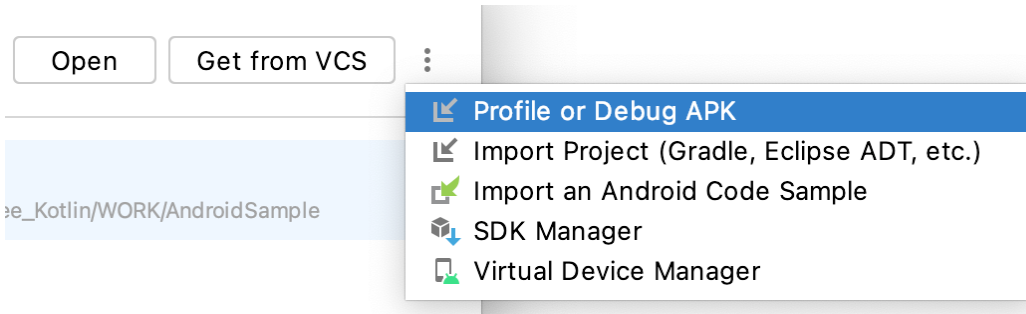


Figure 6-2

6.2 The Main Window

When a new project is created, or an existing one opened, the Android Studio *main window* will appear. When multiple projects are open simultaneously, each will be assigned its own main window. The precise configuration of the window will vary depending on which tools and panels were displayed the last time the project was open, but will typically resemble that of Figure 6-3.

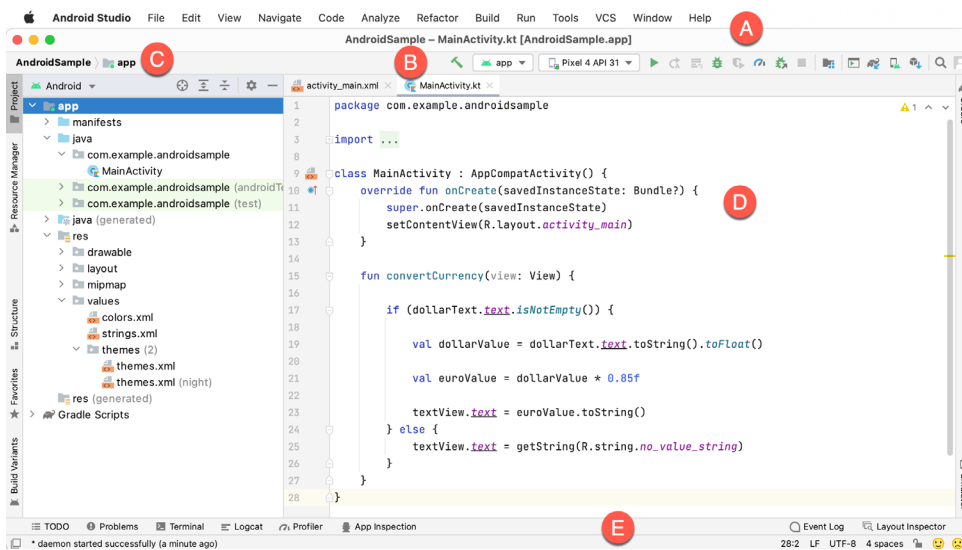


Figure 6-3

The various elements of the main window can be summarized as follows:

A – Menu Bar – Contains a range of menus for performing tasks within the Android Studio environment.

B – Toolbar – A selection of shortcuts to frequently performed actions. The toolbar buttons provide quicker access to a select group of menu bar actions. The toolbar can be customized by right-clicking on the bar and selecting the *Customize Menus and Toolbars...* menu option. If the toolbar is not visible, it can be displayed using the *View -> Appearance -> Toolbar* menu option.

C – Navigation Bar – The navigation bar provides a convenient way to move around the files and folders that make up the project. Clicking on an element in the navigation bar will drop down a menu listing the sub-folders and files at that location ready for selection. Similarly, clicking on a class name displays a menu listing methods contained within that class. Select a method from the list to be taken to the corresponding location within the code editor. Hide and display this bar using the *View -> Appearance -> Navigation Bar* menu option.

D – Editor Window – The editor window displays the content of the file on which the developer is currently working. What gets displayed in this location, however, is subject to context. When editing code, for example, the code editor will appear. When working on a user interface layout file, on the other hand, the user interface Layout Editor tool will appear. When multiple files are open, each file is represented by a tab located along the top edge of the editor as shown in Figure 6-4.

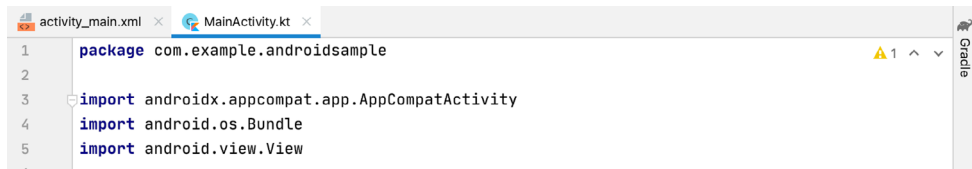


Figure 6-4

E – Status Bar – The status bar displays informational messages about the project and the activities of Android Studio together with the tools menu button located in the far left corner. Hovering over items in the status bar will provide a description of that field. Many fields are interactive, allowing the user to click to perform tasks or obtain more detailed status information.

F – Project Tool Window – The project tool window provides a hierarchical overview of the project file structure allowing navigation to specific files and folders to be performed. The toolbar can be used to display the project in a number of different ways. The default setting is the *Android* view which is the mode primarily used in the remainder of this book.

The project tool window is just one of a number of tool windows available within the Android Studio environment.

6.3 The Tool Windows

In addition to the project view tool window, Android Studio also includes a number of other windows which, when enabled, are displayed along the bottom and sides of the main window. The tool window quick access menu can be accessed by hovering the mouse pointer over the button located in the far left-hand corner of the status bar (Figure 6-5) without clicking the mouse button.

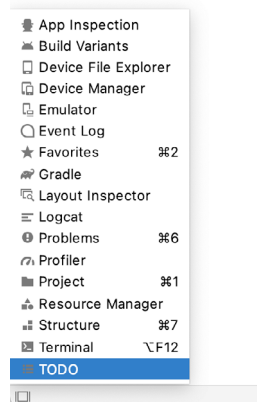


Figure 6-5

Selecting an item from the quick access menu will cause the corresponding tool window to appear within the main window.

Alternatively, a set of *tool window bars* can be displayed by clicking on the quick access menu icon in the status bar. These bars appear along the left, right and bottom edges of the main window (as indicated by the arrows in

A Tour of the Android Studio User Interface

Figure 6-6) and contain buttons for showing and hiding each of the tool windows. When the tool window bars are displayed, a second click on the button in the status bar will hide them.

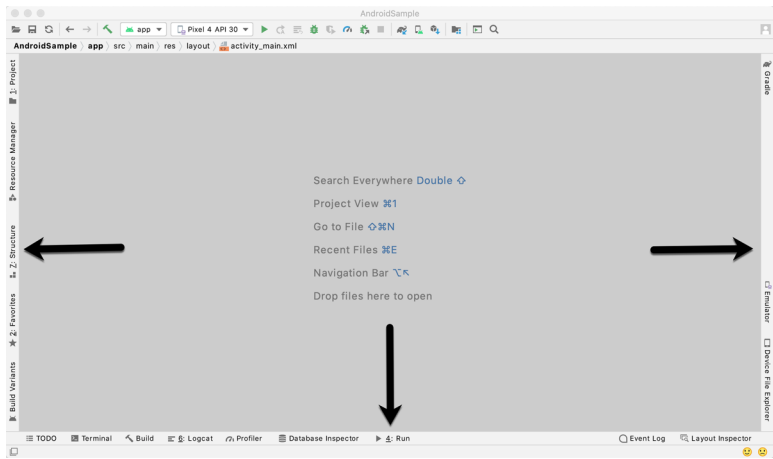


Figure 6-6

Clicking on a button will display the corresponding tool window while a second click will hide the window. Buttons prefixed with a number (for example 1: Project) indicate that the tool window may also be displayed by pressing the Alt key on the keyboard (or the Command key for macOS) together with the corresponding number.

The location of a button in a tool window bar indicates the side of the window against which the window will appear when displayed. These positions can be changed by clicking and dragging the buttons to different locations in other window tool bars.

Each tool window has its own toolbar along the top edge. The buttons within these toolbars vary from one tool to the next, though all tool windows contain a settings option, represented by the cog icon, which allows various aspects of the window to be changed. Figure 6-7 shows the settings menu for the project view tool window. Options are available, for example, to undock a window and to allow it to float outside of the boundaries of the Android Studio main window and to move and resize the tool panel.

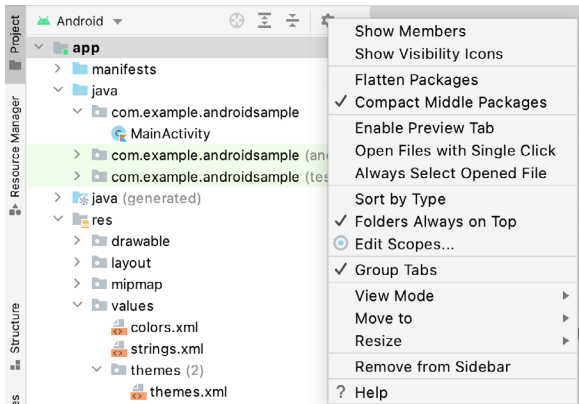


Figure 6-7

All of the windows also include a far right button on the toolbar providing an additional way to hide the tool window from view. A search of the items within a tool window can be performed simply by giving that window focus by clicking in it and then typing the search term (for example the name of a file in the Project tool window).

A search box will appear in the window's tool bar and items matching the search highlighted.

Android Studio offers a wide range of tool windows, the most commonly used of which are as follows:

- **App Inspector** - Provides access to the Database and Background Task inspectors. The Database Inspector allows you to inspect, query, and modify your app's databases while the app is running. The Background Task Inspector allows background worker tasks created using WorkManager to be monitored and managed.
- **Build** - The build tool window displays information about the build process while a project is being compiled and packaged and displays details of any errors encountered.
- **Build Variants** – The build variants tool window provides a quick way to configure different build targets for the current application project (for example different builds for debugging and release versions of the application, or multiple builds to target different device categories).
- **Device File Explorer** – Available via the *View -> Tool Windows -> Device File Explorer* menu, this tool window provides direct access to the filesystem of the currently connected Android device or emulator allowing the filesystem to be browsed and files copied to the local filesystem.
- **Device Manager** - Provides access to the Device Manager tool window where physical Android device connections and emulators may be added, removed, and managed.
- **Emulator** - Contains the AVD emulator if the option has been enabled to run the emulator in a tool window as outlined in the chapter entitled “*Creating an Android Virtual Device (AVD) in Android Studio*”.
- **Event Log** – The event log window displays messages relating to events and activities performed within Android Studio. The successful build of a project, for example, or the fact that an application is now running will be reported within this tool window.
- **Favorites** – A variety of project items can be added to the favorites list. Right-clicking on a file in the project view, for example, provides access to an *Add to Favorites* menu option. Similarly, a method in a source file can be added as a favorite by right-clicking on it in the Structure tool window. Anything added to a Favorites list can be accessed through this Favorites tool window.
- **Gradle** – The Gradle tool window provides a view of the Gradle tasks that make up the project build configuration. The window lists the tasks that are involved in compiling the various elements of the project into an executable application. Right-click on a top-level Gradle task and select the *Open Gradle Config* menu option to load the Gradle build file for the current project into the editor. Gradle will be covered in greater detail later in this book.
- **Layout Inspector** - Provides a visual 3D rendering of the hierarchy of components that make up a user interface layout.
- **Logcat** – The Logcat tool window provides access to the monitoring log output from a running application in addition to options for taking screenshots and videos of the application and stopping and restarting a process.
- **Problems** - A central location in which to view all of the current errors or warnings within the project. Double-clicking on an item in the problem list will take you to the problem file and location.
- **Profiler** – The Android Profiler tool window provides real-time monitoring and analysis tools for identifying performance issues within running apps, including CPU, memory and network usage. This option becomes available when an app is currently running.
- **Project** – The project view provides an overview of the file structure that makes up the project allowing for quick navigation between files. Generally, double-clicking on a file in the project view will cause that file to be

loaded into the appropriate editing tool.

- **Resource Manager** - A tool for adding and managing resources and assets such as images, colors, and layout files contained with the project.
- **Run** - The run tool window becomes available when an application is currently running and provides a view of the results of the run together with options to stop or restart a running process. If an application is failing to install and run on a device or emulator, this window will typically provide diagnostic information relating to the problem.
- **Structure** - The structure tool provides a high-level view of the structure of the source file currently displayed in the editor. This information includes a list of items such as classes, methods, and variables in the file. Selecting an item from the structure list will take you to that location in the source file in the editor window.
- **Terminal** - Provides access to a terminal window on the system on which Android Studio is running. On Windows systems, this is the Command Prompt interface, while on Linux and macOS systems this takes the form of a Terminal prompt.
- **TODO** - As the name suggests, this tool provides a place to review items that have yet to be completed on the project. Android Studio compiles this list by scanning the source files that make up the project to look for comments that match specified TODO patterns. These patterns can be reviewed and changed by selecting the *File -> Settings...* menu option (*Android Studio -> Preferences...* on macOS) and navigating to the *TODO* page listed under *Editor*.

6.4 Android Studio Keyboard Shortcuts

Android Studio includes an abundance of keyboard shortcuts designed to save time when performing common tasks. A full keyboard shortcut keymap listing can be viewed and printed from within the Android Studio project window by selecting the *Help -> Keymap Reference* menu option. You may also list and modify the keyboard shortcuts by selecting the *File -> Settings...* menu option (*Android Studio -> Preferences...* on macOS) and clicking on the Keymap entry as shown in Figure 6-8 below:

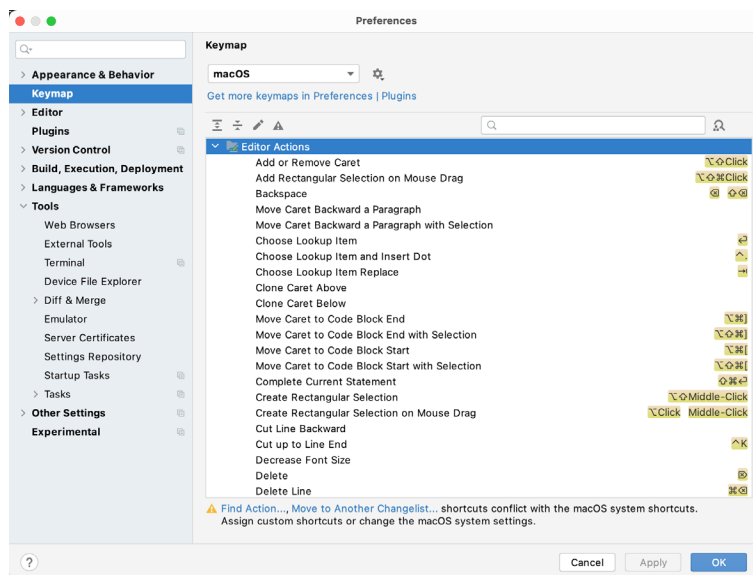


Figure 6-8

6.5 Switcher and Recent Files Navigation

Another useful mechanism for navigating within the Android Studio main window involves the use of the *Switcher*. Accessed via the Ctrl-Tab keyboard shortcut, the switcher appears as a panel listing both the tool windows and currently open files (Figure 6-9).

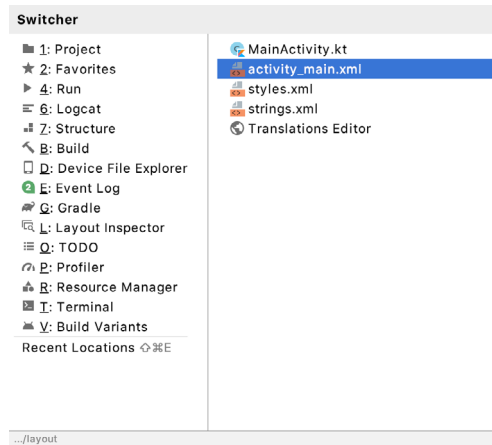


Figure 6-9

Once displayed, the switcher will remain visible for as long as the Ctrl key remains depressed. Repeatedly tapping the Tab key while holding down the Ctrl key will cycle through the various selection options, while releasing the Ctrl key causes the currently highlighted item to be selected and displayed within the main window.

In addition to the switcher, navigation to recently opened files is provided by the Recent Files panel (Figure 6-10). This can be accessed using the Ctrl-E keyboard shortcut (Cmd-E on macOS). Once displayed, either the mouse pointer can be used to select an option or, alternatively, the keyboard arrow keys used to scroll through the file name and tool window options. Pressing the Enter key will select the currently highlighted item.

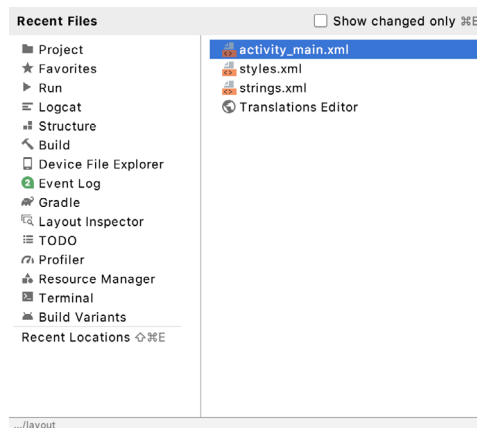


Figure 6-10

6.6 Changing the Android Studio Theme

The overall theme of the Android Studio environment may be changed either from the welcome screen using the *Configure -> Settings* option, or via the *File -> Settings...* menu option (*Android Studio -> Preferences...* on macOS) of the main window.

A Tour of the Android Studio User Interface

Once the settings dialog is displayed, select the *Appearance & Behavior* option followed by *Appearance* in the left-hand panel and then change the setting of the *Theme* menu before clicking on the *Apply* button. The themes available will depend on the platform but usually include options such as Light, IntelliJ, Windows, High Contrast and Darcula. Figure 6-11 shows an example of the main window with the Darcula theme selected:

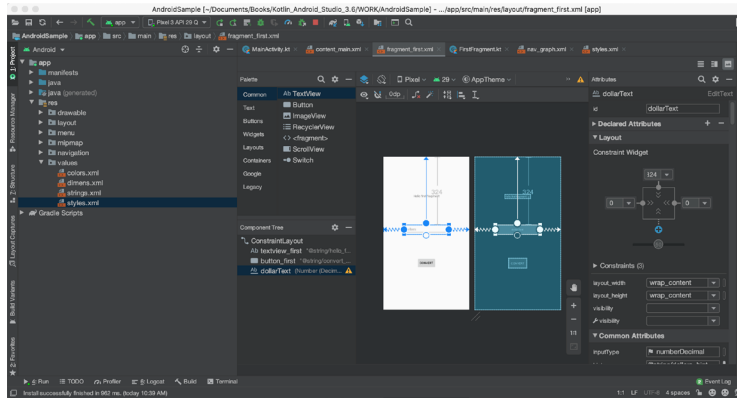


Figure 6-11

To synchronize the Android Studio theme with the operating system light and dark mode setting, enable the *Sync with OS* option and use the drop-down menu to control which theme to use for each mode:

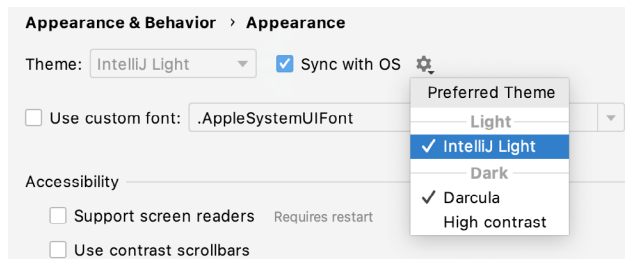


Figure 6-12

6.7 Summary

The primary elements of the Android Studio environment consist of the welcome screen and main window. Each open project is assigned its own main window which, in turn, consists of a menu bar, toolbar, editing and design area, status bar and a collection of tool windows. Tool windows appear on the sides and bottom edges of the main window and can be accessed either using the quick access menu located in the status bar, or via the optional tool window bars.

There are very few actions within Android Studio which cannot be triggered via a keyboard shortcut. A keymap of default keyboard shortcuts can be accessed at any time from within the Android Studio main window.

7. Testing Android Studio Apps on a Physical Android Device

While much can be achieved by testing applications using an Android Virtual Device (AVD), there is no substitute for performing real-world application testing on a physical Android device and there are some Android features that are only available on physical Android devices.

Communication with both AVD instances and connected Android devices is handled by the *Android Debug Bridge (ADB)*. In this chapter, we explain how to configure the adb environment to enable application testing on an Android device with macOS, Windows, and Linux-based systems.

7.1 An Overview of the Android Debug Bridge (ADB)

The primary purpose of the ADB is to facilitate interaction between a development system, in this case, Android Studio, and both AVD emulators and Android devices to run and debug applications. ADB allows you to connect to devices either over a WiFi network or directly using a USB cable.

The ADB consists of a client, a server process running in the background on the development system, and a daemon background process running in either AVDs or real Android devices such as phones and tablets.

The ADB client can take a variety of forms. For example, a client is provided in the form of a command-line tool named *adb* located in the Android SDK *platform-tools* sub-directory. Similarly, Android Studio also has a built-in client.

A variety of tasks may be performed using the *adb* command-line tool. For example, a listing of currently active virtual or physical devices may be obtained using the *devices* command-line argument. The following command output indicates the presence of an AVD on the system but no physical devices:

```
$ adb devices
List of devices attached
emulator-5554    device
```

7.2 Enabling USB Debugging ADB on Android Devices

Before ADB can connect to an Android device, that device must first be configured to allow the connection. On phone and tablet devices running Android 6.0 or later, the steps to achieve this are as follows:

1. Open the Settings app on the device and select the *About tablet* or *About phone* option (on some versions of Android this can be found on the *System* page of the Settings app).
2. On the *About* screen, scroll down to the *Build number* field (Figure 7-1) and tap on it seven times until a message appears indicating that developer mode has been enabled. If the Build number is not listed on the About screen it may be available via the *Software information* option. Alternatively, unfold the Advanced section of the list if available.

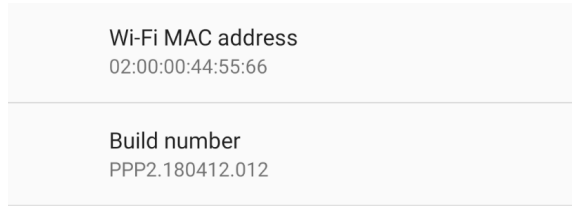


Figure 7-1

3. Return to the main Settings screen and note the appearance of a new option titled Developer options (on newer versions of Android this option is listed on the System settings screen). Select this option and on the resulting screen, locate the USB debugging option as illustrated in Figure 7-2:

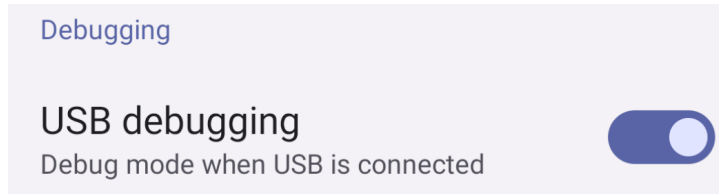


Figure 7-2

4. Enable the USB debugging option and tap the Allow button when confirmation is requested.

At this point, the device is now configured to accept debugging connections from adb on the development system over a USB connection. All that remains is to configure the development system to detect the device when it is attached. While this is a relatively straightforward process, the steps involved differ depending on whether the development system is running Windows, macOS, or Linux. Note that the following steps assume that the Android SDK *platform-tools* directory is included in the operating system PATH environment variable as described in the chapter entitled “*Setting up an Android Studio Development Environment*”.

7.2.1 macOS ADB Configuration

To configure the ADB environment on a macOS system, connect the device to the computer system using a USB cable, open a terminal window and execute the following command to restart the adb server:

```
$ adb kill-server
$ adb start-server
* daemon not running. starting it now on port 5037 *
* daemon started successfully *
```

Once the server is successfully running, execute the following command to verify that the device has been detected:

```
$ adb devices
List of devices attached
74CE000600000001      offline
```

If the device is listed as *offline*, go to the Android device and check for the presence of the dialog shown in Figure 7-3 seeking permission to *Allow USB debugging*. Enable the checkbox next to the option that reads *Always allow from this computer*, before clicking on OK.

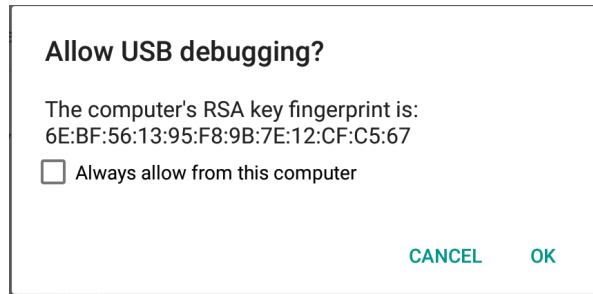


Figure 7-3

Repeating the `adb devices` command should now list the device as being available:

```
List of devices attached
015d41d4454bf80c    device
```

If the device is not listed, try logging out and then back into the macOS desktop and, if the problem persists, rebooting the system.

7.2.2 Windows ADB Configuration

The first step in configuring a Windows-based development system to connect to an Android device using ADB is to install the appropriate USB drivers on the system. The USB drivers to install will depend on the model of the Android Device. If you have a Google device such as a Pixel phone, then it will be necessary to install and configure the Google USB Driver package on your Windows system. Detailed steps to achieve this are outlined on the following web page:

<https://developer.android.com/sdk/win-usb.html>

For Android devices not supported by the Google USB driver, it will be necessary to download the drivers provided by the device manufacturer. A listing of drivers together with download and installation information can be obtained online at:

<https://developer.android.com/tools/extras/oem-usb.html>

With the drivers installed and the device now being recognized as the correct device type, open a Command Prompt window and execute the following command:

```
adb devices
```

This command should output information about the connected device similar to the following:

```
List of devices attached
HT4CTJT01906    offline
```

If the device is listed as *offline* or *unauthorized*, go to the device display and check for the dialog shown in Figure 7-3 seeking permission to *Allow USB debugging*. Enable the checkbox next to the option that reads *Always allow from this computer*, before clicking on *OK*. Repeating the `adb devices` command should now list the device as being ready:

```
List of devices attached
HT4CTJT01906    device
```

If the device is not listed, execute the following commands to restart the ADB server:

```
adb kill-server
adb start-server
```

Testing Android Studio Apps on a Physical Android Device

If the device is still not listed, try executing the following command:

```
android update adb
```

Note that it may also be necessary to reboot the system.

7.2.3 Linux adb Configuration

For this chapter, we will once again use Ubuntu Linux as a reference example in terms of configuring adb on Linux to connect to a physical Android device for application testing.

Physical device testing on Ubuntu Linux requires the installation of a package named *android-tools-adb* which, in turn, requires that the Android Studio user be a member of the *plugdev* group. This is the default for user accounts on most Ubuntu versions and can be verified by running the *id* command. If the *plugdev* group is not listed, run the following command to add your account to the group:

```
sudo usermod -aG plugdev $LOGNAME
```

After the group membership requirement has been met, the *android-tools-adb* package can be installed by executing the following command:

```
sudo apt-get install android-tools-adb
```

Once the above changes have been made, reboot the Ubuntu system. Once the system has restarted, open a Terminal window, start the adb server and check the list of attached devices:

```
$ adb start-server
* daemon not running. starting it now on port 5037 *
* daemon started successfully *
$ adb devices
List of devices attached
015d41d4454bf80c      offline
```

If the device is listed as *offline* or *unauthorized*, go to the Android device and check for the dialog shown in Figure 7-3 seeking permission to *Allow USB debugging*.

7.3 Resolving USB Connection Issues

If you are unable to successfully connect to the device using the above steps, display the run target menu (Figure 7-4) and select the *Troubleshoot Device Connections* option:

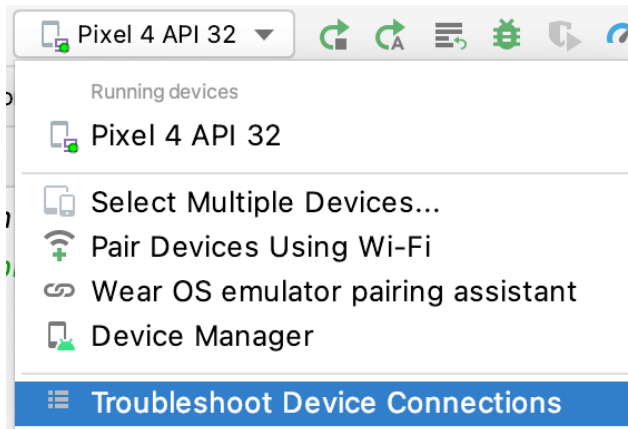


Figure 7-4

The connection assistant will scan for devices and report problems and possible solutions.

7.4 Enabling Wireless Debugging on Android Devices

Follow steps 1 through 3 from section 7.2 above, this time enabling the Wireless Debugging option as shown in Figure 7-5:

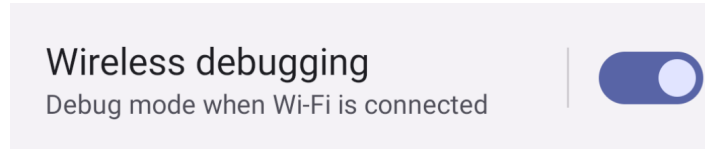


Figure 7-5

Next, tap the above Wireless debugging entry to display the screen shown in Figure 7-6:

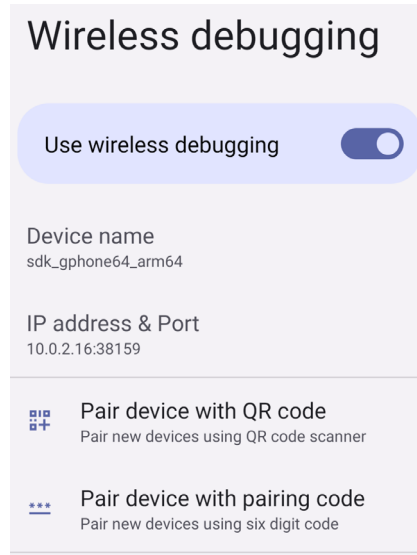


Figure 7-6

If the device you are using has a camera, select *Pair device with QR code*, otherwise select the *Pair device with pairing code* option. Depending on your selection, the Settings app will either start a camera session or display a pairing code as shown in Figure 7-7:

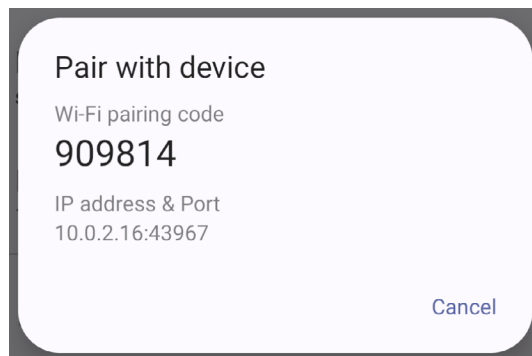


Figure 7-7

With an option selected, return to Android Studio and select the *Pair Devices Using WiFi* option from the run target menu as illustrated in Figure 7-8:

Testing Android Studio Apps on a Physical Android Device

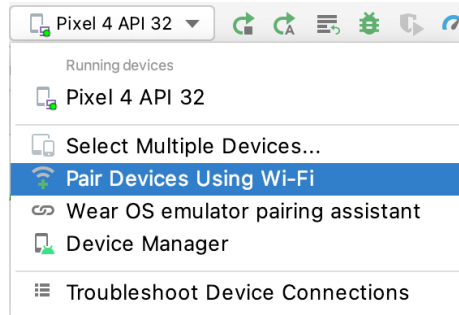


Figure 7-8

In the pairing dialog, select either *Pair using QR code* or *Pair using pairing code* depending on your previous selection in the Settings app on the device:

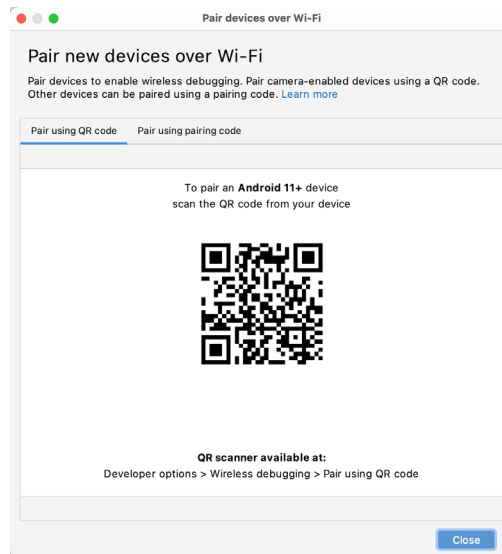


Figure 7-9

Either scan the QR code using the Android device or enter the pairing code displayed on the device screen into the Android Studio dialog (Figure 7-10) to complete the pairing process:

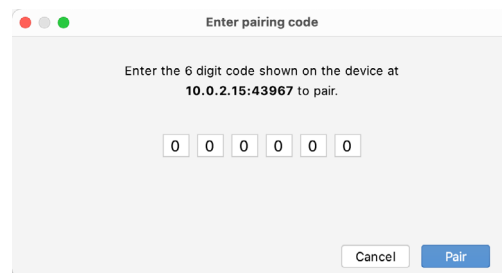


Figure 7-10

If the pairing process fails, try rebooting both the development system and Android device and try again.

7.5 Testing the adb Connection

Assuming that the adb configuration has been successful on your chosen development platform, the next step is to try running the test application created in the chapter entitled “*Creating an Example Android App in Android Studio*” on the device. Launch Android Studio, open the AndroidSample project, and verify that the device appears in the device selection menu as highlighted in Figure 7-11:

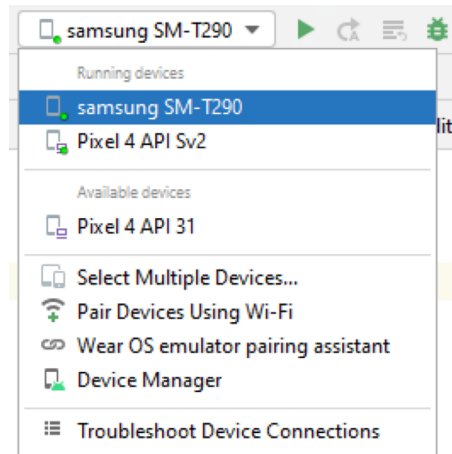


Figure 7-11

Select the device from the list and click on the run button (the green arrow button located immediately to the right of the device menu) to install and run the app.

7.6 Summary

While the Android Virtual Device emulator provides an excellent testing environment, it is important to keep in mind that there is no real substitute for making sure an application functions correctly on a physical Android device. This, after all, is where the application will be used in the real world.

By default, however, the Android Studio environment is not configured to detect Android devices as a target testing device. It is necessary, therefore, to perform some steps to be able to load applications directly onto an Android device from within the Android Studio development environment either via a USB cable or over a WiFi network. The exact steps to achieve this goal differ depending on the development platform being used. In this chapter, we have covered those steps for Linux, macOS, and Windows-based platforms.

8. The Basics of the Android Studio Code Editor

Developing applications for Android involves a considerable amount of programming work which, by definition, involves typing, reviewing and modifying lines of code. It should come as no surprise that the majority of a developer's time spent using Android Studio will typically involve editing code within the editor window.

The modern code editor needs to go far beyond the original basics of typing, deleting, cutting and pasting. Today the usefulness of a code editor is generally gauged by factors such as the amount by which it reduces the typing required by the programmer, ease of navigation through large source code files and the editor's ability to detect and highlight programming errors in real-time as the code is being written. As will become evident in this chapter, these are just a few of the areas in which the Android Studio editor excels.

While not an exhaustive overview of the features of the Android Studio editor, this chapter aims to provide a guide to the key features of the tool. Experienced programmers will find that some of these features are common to most code editors available today, while a number are unique to this particular editing environment.

8.1 The Android Studio Editor

The Android Studio editor appears in the center of the main window when a Java, Kotlin, XML or other text based file is selected for editing. Figure 8-1, for example, shows a typical editor session with a Kotlin source code file loaded:

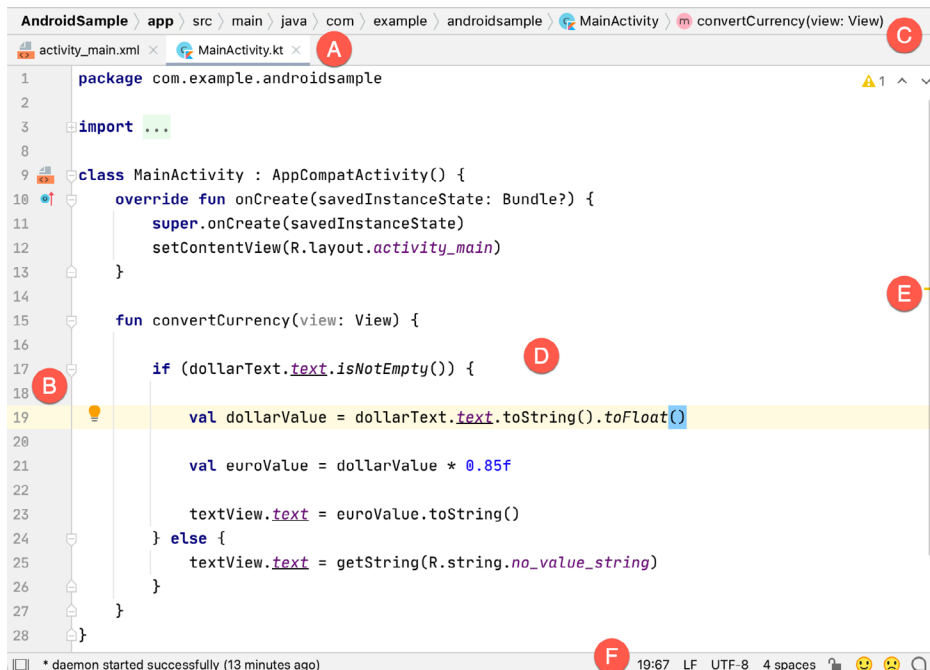


Figure 8-1

The elements that comprise the editor window can be summarized as follows:

A – Document Tabs – Android Studio is capable of holding multiple files open for editing at any one time. As each file is opened, it is assigned a document tab displaying the file name in the tab bar located along the top edge of the editor window. A small drop-down menu will appear in the far right-hand corner of the tab bar when there is insufficient room to display all of the tabs. Clicking on this menu will drop down a list of additional open files. A wavy red line underneath a file name in a tab indicates that the code in the file contains one or more errors that need to be addressed before the project can be compiled and run.

Switching between files is simply a matter of clicking on the corresponding tab or using the Alt-Left and Alt-Right keyboard shortcuts. Navigation between files may also be performed using the Switcher mechanism (accessible via the Ctrl-Tab keyboard shortcut).

To detach an editor panel from the Android Studio main window so that it appears in a separate window, click on the tab and drag it to an area on the desktop outside of the main window. To return the editor to the main window, click on the file tab in the separated editor window and drag and drop it onto the original editor tab bar in the main window.

B – The Editor Gutter Area - The gutter area is used by the editor to display informational icons and controls. Some typical items, among others, which appear in this gutter area are debugging breakpoint markers, controls to fold and unfold blocks of code, bookmarks, change markers and line numbers. Line numbers are switched on by default but may be disabled by right-clicking in the gutter and selecting the Show Line Numbers menu option.

C – Code Structure Location - This bar at the bottom of the editor displays the current position of the cursor as it relates to the overall structure of the code. In the following figure, for example, the bar indicates that the `convertCurrency` method is currently being edited, and that this method is contained within the `MainActivity` class.

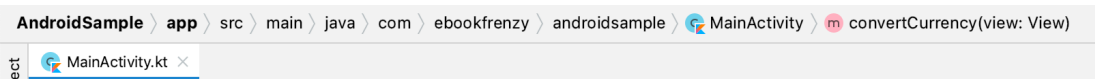


Figure 8-2

Double-clicking an element within the bar will move the cursor to the corresponding location within the code file. For example, double-clicking on the `convertCurrency` entry will move the cursor to the top of the `convertCurrency` method within the source code. Similarly clicking on the `MainActivity` entry will drop down a list of available code navigation points for selection:

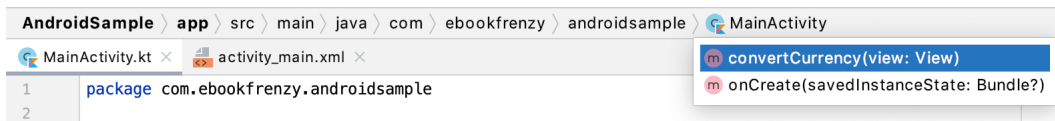


Figure 8-3

D – The Editor Area – This is the main area where the code is displayed, entered and edited by the user. Later sections of this chapter will cover the key features of the editing area in detail.

E – The Validation and Marker Sidebar – Android Studio incorporates a feature referred to as “on-the-fly code analysis”. What this essentially means is that as you are typing code, the editor is analyzing the code to check for warnings and syntax errors. The indicators at the top of the validation sidebar will update in real-time to indicate the number of errors and warnings found as code is added. Clicking on this indicator will display a popup containing a summary of the issues found with the code in the editor as illustrated in Figure 8-4:

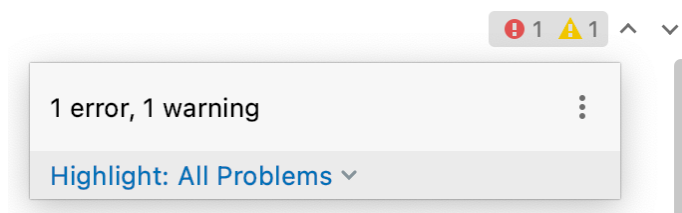


Figure 8-4

The up and down arrows may be used to move between the error locations within the code. A green check mark indicates that no warnings or errors have been detected.

The sidebar also displays markers at the locations where issues have been detected using the same color coding. Hovering the mouse pointer over a marker when the line of code is visible in the editor area will display a popup containing a description of the issue:

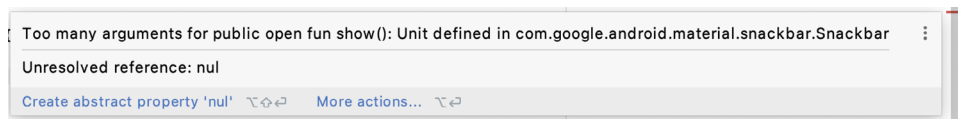


Figure 8-5

Hovering the mouse pointer over a marker for a line of code which is currently scrolled out of the viewing area of the editor will display a “lens” overlay containing the block of code where the problem is located (Figure 8-6) allowing it to be viewed without the necessity to scroll to that location in the editor:

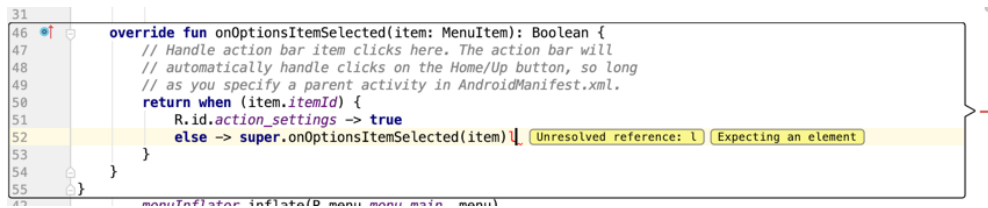


Figure 8-6

It is also worth noting that the lens overlay is not limited to warnings and errors in the sidebar. Hovering over any part of the sidebar will result in a lens appearing containing the code present at that location within the source file.

F – The Status Bar – Though the status bar is actually part of the main window, as opposed to the editor, it does contain some information about the currently active editing session. This information includes the current position of the cursor in terms of lines and characters and the encoding format of the file (UTF-8, ASCII etc.). Clicking on these values in the status bar allows the corresponding setting to be changed. Clicking on the line number, for example, displays the Go to Line dialog.

Having provided an overview of the elements that comprise the Android Studio editor, the remainder of this chapter will explore the key features of the editing environment in more detail.

8.2 Splitting the Editor Window

By default, the editor will display a single panel showing the content of the currently selected file. A particularly useful feature when working simultaneously with multiple source code files is the ability to split the editor into multiple panes. To split the editor, right-click on a file tab within the editor window and select either the Split Vertically or Split Horizontally menu option. Figure 8-7, for example, shows the splitter in action with the editor

split into three panels:

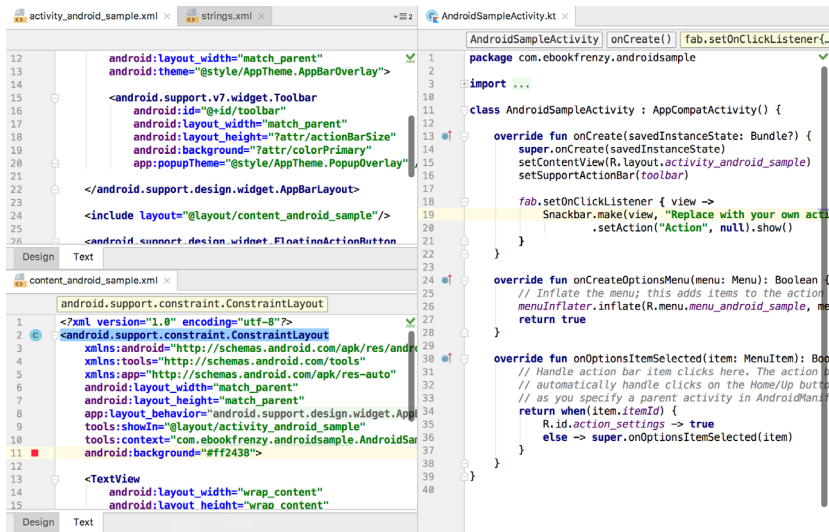


Figure 8-7

The orientation of a split panel may be changed at any time by right-clicking on the corresponding tab and selecting the Change Splitter Orientation menu option. Repeat these steps to unsplit a single panel, this time selecting the Unsplit option from the menu. All of the split panels may be removed by right-clicking on any tab and selecting the Unsplit All menu option.

Window splitting may be used to display different files, or to provide multiple windows onto the same file, allowing different areas of the same file to be viewed and edited concurrently.

8.3 Code Completion

The Android Studio editor has a considerable amount of built-in knowledge of Kotlin programming syntax and the classes and methods that make up the Android SDK, as well as knowledge of your own code base. As code is typed, the editor scans what is being typed and, where appropriate, makes suggestions with regard to what might be needed to complete a statement or reference. When a completion suggestion is detected by the editor, a panel will appear containing a list of suggestions. In Figure 8-8, for example, the editor is suggesting possibilities for the beginning of a String declaration:

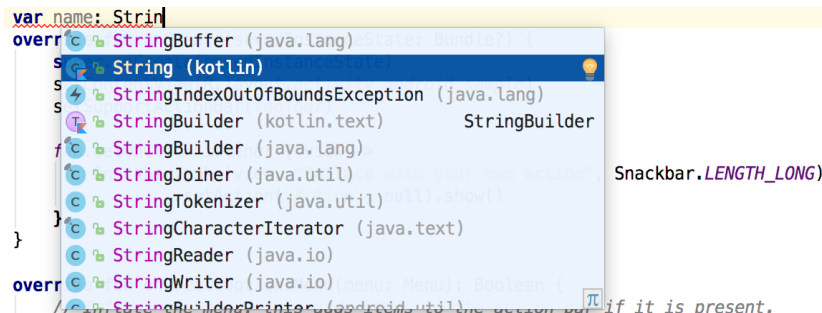


Figure 8-8

If none of the auto completion suggestions are correct, simply keep typing and the editor will continue to refine the suggestions where appropriate. To accept the top most suggestion, simply press the Enter or Tab key on the keyboard. To select a different suggestion, use the arrow keys to move up and down the list, once again using the

Enter or Tab key to select the highlighted item.

Completion suggestions can be manually invoked using the Ctrl-Space keyboard sequence. This can be useful when changing a word or declaration in the editor. When the cursor is positioned over a word in the editor, that word will automatically highlight. Pressing Ctrl-Space will display a list of alternate suggestions. To replace the current word with the currently highlighted item in the suggestion list, simply press the Tab key.

In addition to the real-time auto completion feature, the Android Studio editor also offers a system referred to as Smart Completion. Smart completion is invoked using the Shift-Ctrl-Space keyboard sequence and, when selected, will provide more detailed suggestions based on the current context of the code. Pressing the Shift-Ctrl-Space shortcut sequence a second time will provide more suggestions from a wider range of possibilities.

Code completion can be a matter of personal preference for many programmers. In recognition of this fact, Android Studio provides a high level of control over the auto completion settings. These can be viewed and modified by selecting the *File -> Settings...* menu option (or *Android Studio -> Preferences...* on macOS) and choosing *Editor -> General -> Code Completion* from the settings panel as shown in Figure 8-9:

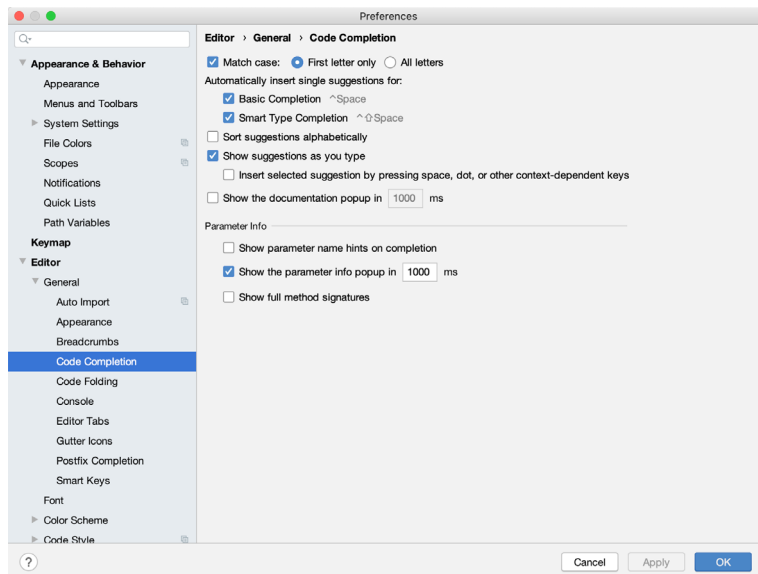


Figure 8-9

8.4 Statement Completion

Another form of auto completion provided by the Android Studio editor is statement completion. This can be used to automatically fill out the parentheses and braces for items such as methods and loop statements. Statement completion is invoked using the *Shift-Ctrl-Enter* (*Shift-Cmd-Enter* on macOS) keyboard sequence. Consider for example the following code:

```
fun myMethod()
```

Having typed this code into the editor, triggering statement completion will cause the editor to automatically add the braces to the method:

```
fun myMethod() {  
  
}
```

8.5 Parameter Information

It is also possible to ask the editor to provide information about the argument parameters accepted by a method. With the cursor positioned between the brackets of a method call, the Ctrl-P (Cmd-P on macOS) keyboard sequence will display the parameters known to be accepted by that method, with the most likely suggestion highlighted in bold:

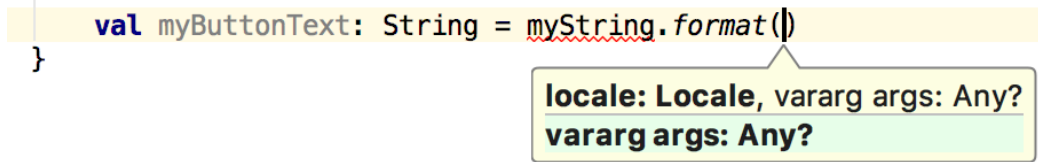


Figure 8-10

8.6 Parameter Name Hints

The code editor may be configured to display parameter name hints within method calls. Figure 8-11, for example, highlights the parameter name hints within the calls to the `make()` and `setAction()` methods of the `Snackbar` class:



Figure 8-11

The settings for this mode may be configured by selecting the *File -> Settings* menu (*Android Studio -> Preferences* on macOS) option followed by *Editor -> Inlay Hints -> Kotlin* in the left-hand panel. On the resulting screen, select the *Parameter Hints* item from the list and enable or disable the *Show parameter hints* option. To adjust the hint settings, click on the *Exclude list...* link and make any necessary adjustments.

8.7 Code Generation

In addition to completing code as it is typed the editor can, under certain conditions, also generate code for you. The list of available code generation options shown in Figure 8-12 can be accessed using the Alt-Insert (Cmd-N on macOS) keyboard shortcut when the cursor is at the location in the file where the code is to be generated.

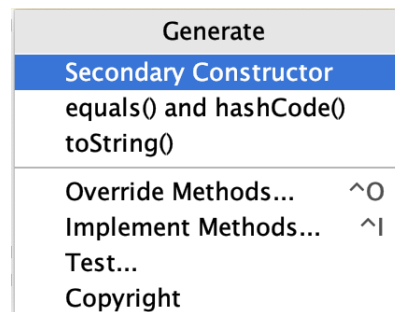


Figure 8-12

For the purposes of an example, consider a situation where we want to be notified when an Activity in our project is about to be destroyed by the operating system. As will be outlined in a later chapter of this book, this can be achieved by overriding the `onStop()` lifecycle method of the Activity superclass. To have Android Studio

generate a stub method for this, simply select the *Override Methods...* option from the code generation list and select the *onStop()* method from the resulting list of available methods:

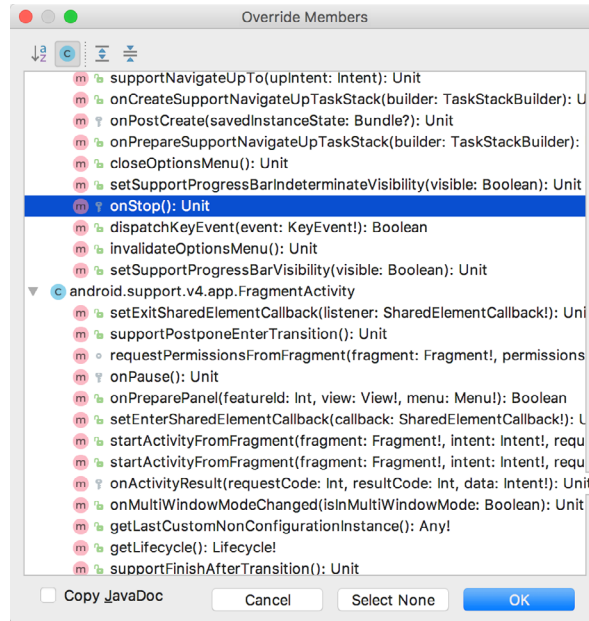


Figure 8-13

Having selected the method to override, clicking on OK will generate the stub method at the current cursor location in the Kotlin source file as follows:

```
override fun onStop() {
    super.onStop()
}
```

8.8 Code Folding

Once a source code file reaches a certain size, even the most carefully formatted and well organized code can become overwhelming and difficult to navigate. Android Studio takes the view that it is not always necessary to have the content of every code block visible at all times. Code navigation can be made easier through the use of the code folding feature of the Android Studio editor. Code folding is controlled using markers appearing in the editor gutter at the beginning and end of each block of code in a source file. Figure 8-14, for example, highlights the start and end markers for a method declaration which is not currently folded:

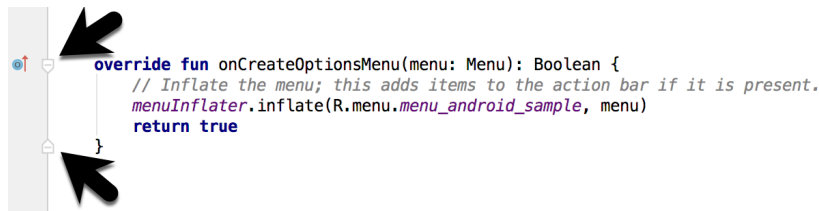


Figure 8-14

Clicking on either of these markers will fold the statement such that only the signature line is visible as shown in Figure 8-15:

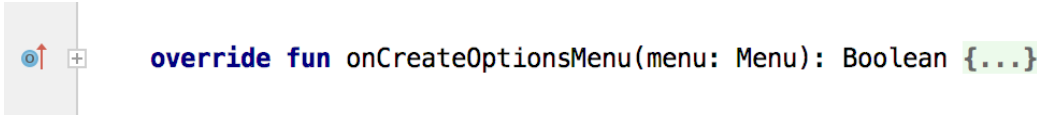


Figure 8-15

To unfold a collapsed section of code, simply click on the '+' marker in the editor gutter. To see the hidden code without unfolding it, hover the mouse pointer over the "{...}" indicator as shown in Figure 8-16. The editor will then display the lens overlay containing the folded code block:

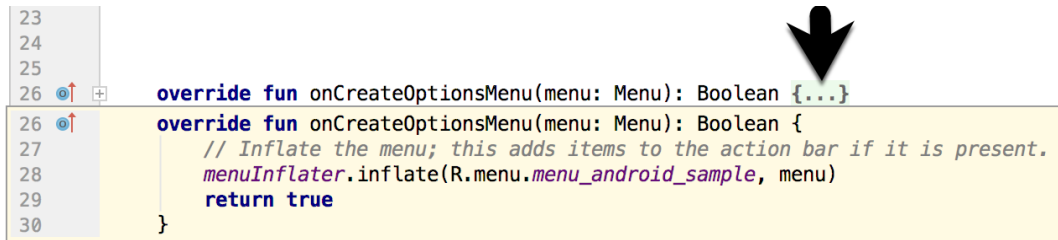


Figure 8-16

All of the code blocks in a file may be folded or unfolded using the Ctrl-Shift-Plus and Ctrl-Shift-Minus keyboard sequences.

By default, the Android Studio editor will automatically fold some code when a source file is opened. To configure the conditions under which this happens, select File -> Settings... (Android Studio -> Preferences... on macOS) and choose the Editor -> General -> Code Folding entry in the resulting settings panel (Figure 8-17):

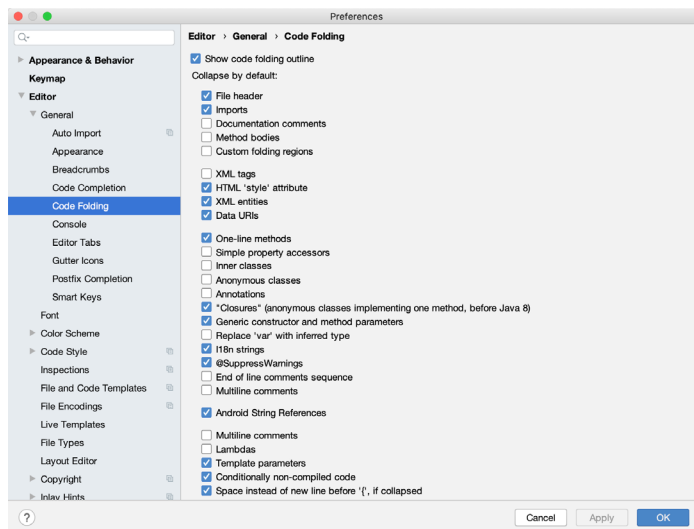


Figure 8-17

8.9 Quick Documentation Lookup

Context sensitive Kotlin and Android documentation can be accessed by placing the cursor over the declaration for which documentation is required and pressing the Ctrl-Q keyboard shortcut (Ctrl-J on macOS). This will display a popup containing the relevant reference documentation for the item. Figure 8-18, for example, shows the documentation for the Android Menu class.

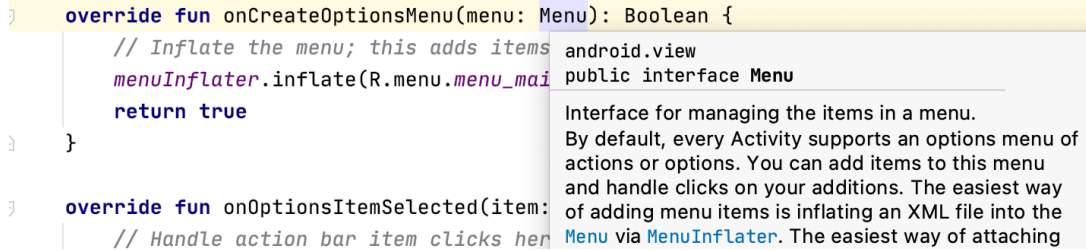


Figure 8-18

Once displayed, the documentation popup can be moved around the screen as needed.

8.10 Code Reformatting

In general, the Android Studio editor will automatically format code in terms of indenting, spacing and nesting of statements and code blocks as they are added. In situations where lines of code need to be reformatted (a common occurrence, for example, when cutting and pasting sample code from a website), the editor provides a source code reformatting feature which, when selected, will automatically reformat code to match the prevailing code style.

To reformat source code, press the Ctrl-Alt-L (Cmd-Opt-L on macOS) keyboard shortcut sequence. To display the Reformat Code dialog (Figure 8-19) use the Ctrl-Alt-Shift-L (Cmd-Opt-Shift-L on macOS). This dialog provides the option to reformat only the currently selected code, the entire source file currently active in the editor or only code that has changed as the result of a source code control update.

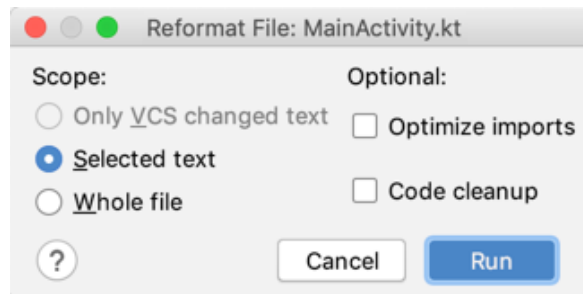


Figure 8-19

The full range of code style preferences can be changed from within the project settings dialog. Select the *File* -> *Settings* menu option (*Android Studio* -> *Preferences...* on macOS) and choose Code Style in the left-hand panel to access a list of supported programming and markup languages. Selecting a language will provide access to a vast array of formatting style options, all of which may be modified from the Android Studio default to match your preferred code style. To configure the settings for the Rearrange code option in the above dialog, for example, unfold the Code Style section, select Kotlin and, from the Kotlin settings, select the Arrangement tab.

8.11 Finding Sample Code

The Android Studio editor provides a way to access sample code relating to the currently highlighted entry within the code listing. This feature can be useful for learning how a particular Android class or method is used. To find sample code, highlight a method or class name in the editor, right-click on it and select the *Find Sample Code* menu option. The Find Sample Code panel (Figure 8-20) will appear beneath the editor with a list of matching samples. Selecting a sample from the list will load the corresponding code into the right-hand panel:

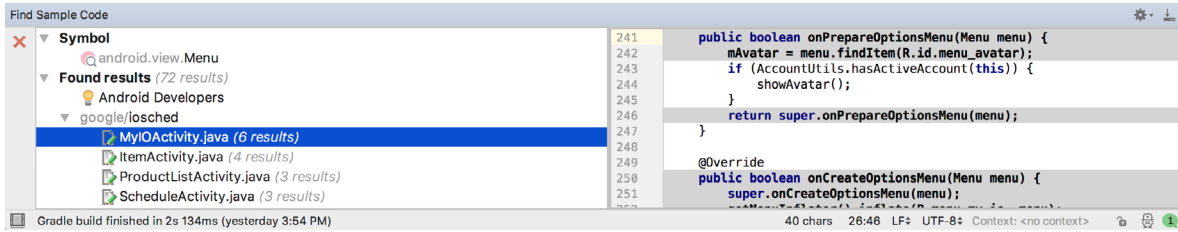


Figure 8-20

8.12 Live Templates

As you write Android code you will find that there are common constructs that are used frequently. For example, a common requirement is to display a popup message to the user using the Android Toast class. Live templates are a collection of common code constructs that can be entered into the editor by typing the initial characters followed by a special key (set to the Tab key by default) to insert template code. To experience this in action, type toast in the code editor followed by the Tab key and Android Studio will insert the following code at the cursor position ready for editing:

```
Toast.makeText(, "", Toast.LENGTH_SHORT).show()
```

To list and edit existing templates, change the special key, or add your own templates, open the Preferences dialog and select Live Templates from the Editor section of the left-hand navigation panel:

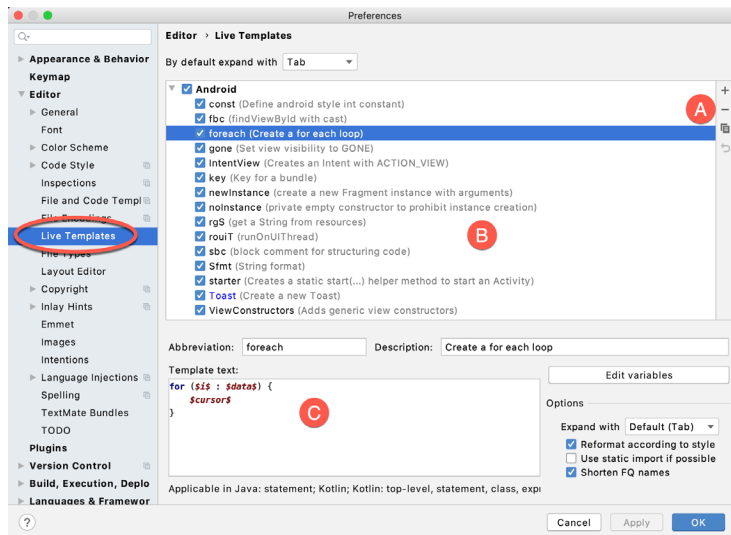


Figure 8-21

Add, remove, duplicate or reset templates using the buttons marked A in Figure 8-21 above. To modify a template, select it from the list (B) and change the settings in the panel marked C.

8.13 Summary

The Android Studio editor goes to great length to reduce the amount of typing needed to write code and to make that code easier to read and navigate. In this chapter we have covered a number of the key editor features including code completion, code generation, editor window splitting, code folding, reformatting, documentation lookup and live templates.

9. An Overview of the Android Architecture

So far in this book, steps have been taken to set up an environment suitable for the development of Android applications using Android Studio. An initial step has also been taken into the process of application development through the creation of an Android Studio application project.

Before delving further into the practical matters of Android application development, however, it is important to gain an understanding of some of the more abstract concepts of both the Android SDK and Android development in general. Gaining a clear understanding of these concepts now will provide a sound foundation on which to build further knowledge.

Starting with an overview of the Android architecture in this chapter, and continuing in the next few chapters of this book, the goal is to provide a detailed overview of the fundamentals of Android development.

9.1 The Android Software Stack

Android is structured in the form of a software stack comprising applications, an operating system, run-time environment, middle-ware, services and libraries. This architecture can, perhaps, best be represented visually as outlined in Figure 9-1. Each layer of the stack, and the corresponding elements within each layer, are tightly integrated and carefully tuned to provide the optimal application development and execution environment for mobile devices. The remainder of this chapter will work through the different layers of the Android stack, starting at the bottom with the Linux Kernel.

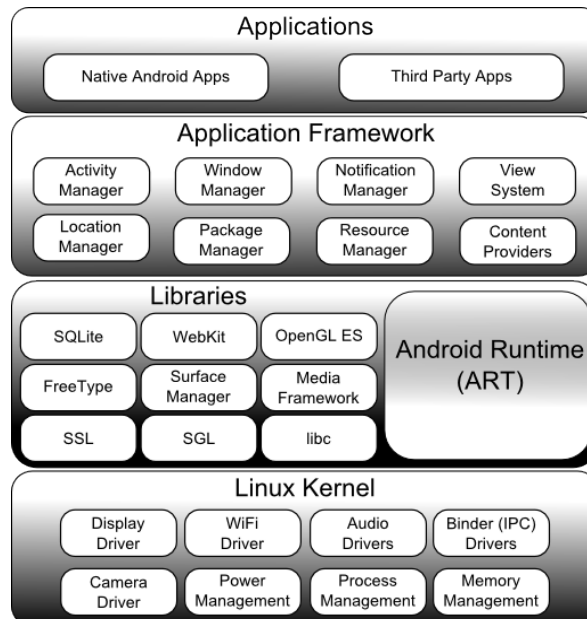


Figure 9-1

9.2 The Linux Kernel

Positioned at the bottom of the Android software stack, the Linux Kernel provides a level of abstraction between the device hardware and the upper layers of the Android software stack. Based on Linux version 2.6, the kernel provides preemptive multitasking, low-level core system services such as memory, process and power management in addition to providing a network stack and device drivers for hardware such as the device display, WiFi and audio.

The original Linux kernel was developed in 1991 by Linus Torvalds and was combined with a set of tools, utilities and compilers developed by Richard Stallman at the Free Software Foundation to create a full operating system referred to as GNU/Linux. Various Linux distributions have been derived from these basic underpinnings such as Ubuntu and Red Hat Enterprise Linux.

It is important to note, however, that Android uses only the Linux kernel. That said, it is worth noting that the Linux kernel was originally developed for use in traditional computers in the form of desktops and servers. In fact, Linux is now most widely deployed in mission critical enterprise server environments. It is a testament to both the power of today's mobile devices and the efficiency and performance of the Linux kernel that we find this software at the heart of the Android software stack.

9.3 Android Runtime – ART

When an Android app is built within Android Studio it is compiled into an intermediate bytecode format (referred to as DEX format). When the application is subsequently loaded onto the device, the Android Runtime (ART) uses a process referred to as Ahead-of-Time (AOT) compilation to translate the bytecode down to the native instructions required by the device processor. This format is known as Executable and Linkable Format (ELF).

Each time the application is subsequently launched, the ELF executable version is run, resulting in faster application performance and improved battery life.

This contrasts with the Just-in-Time (JIT) compilation approach used in older Android implementations whereby the bytecode was translated within a virtual machine (VM) each time the application was launched.

9.4 Android Libraries

In addition to a set of standard Java development libraries (providing support for such general purpose tasks as string handling, networking and file manipulation), the Android development environment also includes the Android Libraries. These are a set of Java-based libraries that are specific to Android development. Examples of libraries in this category include the application framework libraries in addition to those that facilitate user interface building, graphics drawing and database access.

A summary of some key core Android libraries available to the Android developer is as follows:

- **android.app** – Provides access to the application model and is the cornerstone of all Android applications.
- **android.content** – Facilitates content access, publishing and messaging between applications and application components.
- **android.database** – Used to access data published by content providers and includes SQLite database management classes.
- **android.graphics** – A low-level 2D graphics drawing API including colors, points, filters, rectangles and canvases.
- **android.hardware** – Presents an API providing access to hardware such as the accelerometer and light sensor.

- **android.opengl** – A Java interface to the OpenGL ES 3D graphics rendering API.
- **android.os** – Provides applications with access to standard operating system services including messages, system services and inter-process communication.
- **android.media** – Provides classes to enable playback of audio and video.
- **android.net** – A set of APIs providing access to the network stack. Includes *android.net.wifi*, which provides access to the device's wireless stack.
- **android.print** – Includes a set of classes that enable content to be sent to configured printers from within Android applications.
- **android.provider** – A set of convenience classes that provide access to standard Android content provider databases such as those maintained by the calendar and contact applications.
- **android.text** – Used to render and manipulate text on a device display.
- **android.util** – A set of utility classes for performing tasks such as string and number conversion, XML handling and date and time manipulation.
- **android.view** – The fundamental building blocks of application user interfaces.
- **android.widget** – A rich collection of pre-built user interface components such as buttons, labels, list views, layout managers, radio buttons etc.
- **android.webkit** – A set of classes intended to allow web-browsing capabilities to be built into applications.

Having covered the Java-based libraries in the Android runtime, it is now time to turn our attention to the C/C++ based libraries contained in this layer of the Android software stack.

9.4.1 C/C++ Libraries

The Android runtime core libraries outlined in the preceding section are Java-based and provide the primary APIs for developers writing Android applications. It is important to note, however, that the core libraries do not perform much of the actual work and are, in fact, essentially Java “wrappers” around a set of C/C++ based libraries. When making calls, for example, to the *android.opengl* library to draw 3D graphics on the device display, the library actually ultimately makes calls to the *OpenGL ES C++* library which, in turn, works with the underlying Linux kernel to perform the drawing tasks.

C/C++ libraries are included to fulfill a wide and diverse range of functions including 2D and 3D graphics drawing, Secure Sockets Layer (SSL) communication, SQLite database management, audio and video playback, bitmap and vector font rendering, display subsystem and graphic layer management and an implementation of the standard C system library (libc).

In practice, the typical Android application developer will access these libraries solely through the Java based Android core library APIs. If direct access to these libraries is needed, this can be achieved using the Android Native Development Kit (NDK), the purpose of which is to call the native methods of non-Java or Kotlin programming languages (such as C and C++) from within Java code using the Java Native Interface (JNI).

9.5 Application Framework

The Application Framework is a set of services that collectively form the environment in which Android applications run and are managed. This framework implements the concept that Android applications are constructed from reusable, interchangeable and replaceable components. This concept is taken a step further in that an application is also able to *publish* its capabilities along with any corresponding data so that they can be

found and reused by other applications.

The Android framework includes the following key services:

- **Activity Manager** – Controls all aspects of the application lifecycle and activity stack.
- **Content Providers** – Allows applications to publish and share data with other applications.
- **Resource Manager** – Provides access to non-code embedded resources such as strings, color settings and user interface layouts.
- **Notifications Manager** – Allows applications to display alerts and notifications to the user.
- **View System** – An extensible set of views used to create application user interfaces.
- **Package Manager** – The system by which applications are able to find out information about other applications currently installed on the device.
- **Telephony Manager** – Provides information to the application about the telephony services available on the device such as status and subscriber information.
- **Location Manager** – Provides access to the location services allowing an application to receive updates about location changes.

9.6 Applications

Located at the top of the Android software stack are the applications. These comprise both the native applications provided with the particular Android implementation (for example web browser and email applications) and the third party applications installed by the user after purchasing the device.

9.7 Summary

A good Android development knowledge foundation requires an understanding of the overall architecture of Android. Android is implemented in the form of a software stack architecture consisting of a Linux kernel, a runtime environment and corresponding libraries, an application framework and a set of applications. Applications are predominantly written in Java or Kotlin and compiled down to bytecode format within the Android Studio build environment. When the application is subsequently installed on a device, this bytecode is compiled down by the Android Runtime (ART) to the native format used by the CPU. The key goals of the Android architecture are performance and efficiency, both in application execution and in the implementation of reuse in application design.