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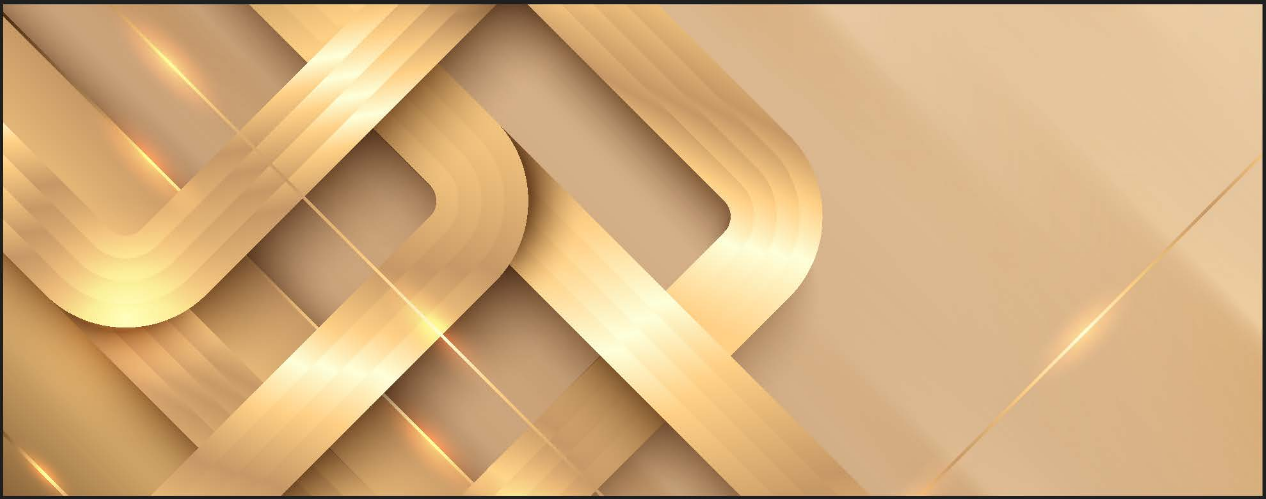

3RD EDITION

Flutter for Beginners

Cross-platform mobile development
from Hello, World! to app release with Flutter 3.10+ and Dart 3.x

THOMAS BAILEY | ALESSANDRO BIESSEK

Foreword by Trevor Wills, Managing Director Life Ninja

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Cross-platform mobile development from Hello, World! to app release with Flutter 3.10+ and Dart 3.x

Thomas Bailey

Alessandro Biessek

BIRMINGHAM—MUMBAI

Flutter for Beginners

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To my long-suffering wife, Laura Bailey, who allows me to embark on all manner of crazy projects, and my two lovely (most of the time) children, Lottie and Bobby, who keep life exciting and fresh. Love you all so much!

– Tom Bailey

Foreword

I have known and worked with Tom for more than 12 years. We met at an antenatal class as we both embarked on our journey into parenthood and have been close friends ever since.

Together, we founded our education apps company, and from the very start, we decided to go all-in on Flutter for all our apps. At the time, Flutter was in beta, and I must admit, I questioned Tom's decision to put all our eggs into such a new and untested basket.

Three years later, we have created a suite of high-quality education apps across Android, iOS, and, to some degree, the web, allowing us to keep development costs incredibly low relative to our competitors while creating apps that are very high quality.

In *Flutter for Beginners*, Tom shares his learnings from those five years of development. This book is written from the point of view of someone who has been there all the way from justifying the use of the framework to the wider business team, learning the basics of the framework, and implementing the user experience defined by our designers through to testing and, ultimately, releasing to the iOS App Store and Google Play Store.

His latest project creating a Flutter Web website for the cutting-edge NHS prescription service Vyne has allowed him to further extend his knowledge of Flutter and how it services the needs of a different demographic.

Why not join Tom and build some epic Flutter apps using this awesome framework?

Trevor Wills

Managing Director, Life Ninja

Contributors

About the authors

Thomas Bailey has an extensive background in tech, working for high-profile companies as a senior developer, solutions architect, and IT director. His education company used Flutter as the sole technology powering their education apps and he has guided the Vyne prescription service onto Flutter web. He has enjoyed watching Flutter move from beta to the fully-fledged and highly popular framework we see today. He loves to talk tech over a hot chocolate with anyone who will listen and is constantly exploring the cutting edge of tech and how it will shape our industry in the future.

I want to thank the people who have supported me, especially my wife Laura, and my colleagues across Ocado, IBM, Life Ninja, Rappi, and Optimum Medical, whose wisdom I have learned from.

Alessandro Biessek was born in the beautiful city of Chapecó, in the state of Santa Catarina, southern Brazil, in 1993. He is currently working on mobile application development for Android and iOS in his hometown. He has more than 9 years of experience in development, from desktop development with Delphi to backend with PHP, Node.js, Golang, mobile development with Apache Flex, and Java/Kotlin. Most of his time is devoted to the development of Android apps. Always interested in new technologies, he has been following the Flutter framework for a long time, through its growth and adoption in recent months.

About the reviewers

Kefeh Collins is a seasoned Flutter engineer with 5+ years of experience. Their expertise in Flutter and Dart, combined with a strong UI/UX understanding, enables them to translate designs into elegant UIs. They have led successful mobile initiatives, processed over 1 billion transactions, and are an avid technical writer. With a keen eye for detail and a collaborative approach, their reviews offer valuable insights to the Flutter community.

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Preface

Flutter for Beginners introduces you to the Flutter framework world and how you can use it to build awesome mobile applications. We'll start by looking at the reasons why Flutter was created; we'll then explore the elegance of the Dart language, and then move on to an in-depth examination of the Flutter structures and concepts needed to make a high-level app. Together, we will study the whole Flutter life cycle, from project creation to app release. With clear code examples, you will learn how to start a small Flutter project, add some widgets, apply styles and themes, connect with remote services such as Firebase, get user input, add some animations to improve the user experience, and more. In addition, you will learn about why you should choose Flutter, how to test your app, how to monitor your app, and some common gotchas you may experience in the release process. In short, this book will prepare you for the future of mobile development with the amazing Flutter framework.

Who this book is for

This book is for developers who are either looking to learn about the Flutter framework from scratch or who have started coding in Flutter and want to advance their knowledge. No knowledge of Flutter or Dart is required. However, basic programming language knowledge will be helpful, especially experience of an object-oriented language.

Alternatively, this book can be a guide for a manager, solution architect, or team leader who wants to validate the decision by their development team to use the Flutter framework.

What this book covers

Chapter 1, *What Is Flutter and Why Should I Use It?*, gives a gentle introduction to the world of Flutter and an exploration of the reasons why it may fit your development process.

Chapter 2, *An Introduction to Dart*, starts to develop the basic syntax of the Dart programming language that is fundamental to Flutter.

Chapter 3, *Flutter versus Other Frameworks*, compares and contrasts Flutter to other existing mobile app development frameworks so that you can make an informed decision and explain that decision to your colleagues.

Chapter 4, *Dart Classes and Constructs*, advances your knowledge of the Dart programming language along with object-orientation concepts.

Chapter 5, *Building Your User Interface through Widgets*, explains the idea of the widget, a concept that is at the heart of the Flutter framework, and how it can be used to create basic user interfaces.

Chapter 6, *Handling User Input and Gestures*, shows you how to handle user input with Flutter widgets.

Chapter 7, *Let's Get Graphical!*, builds on your widget knowledge to show how styling and decoration can be added to your widgets.

Chapter 8, *Routing – Navigating between Screens*, explores how to add navigation to your app so that a user can transition from one part of your app to another.

Chapter 9, *Flutter Plugins – Get Great Functionality for Free*, explores what the plugin or package concept is and how you can use it to turbo-charge your app functionality.

Chapter 10, *Popular Third-Party Plugins*, teaches you about the most popular third-party plugins and how to use them in Flutter apps.

Chapter 11, *Using Widget Manipulations and Animations*, gets into how to create unique visuals with graphic manipulations and gives you an insight into how to add animations to your Flutter widgets.

Chapter 12, *Testing and Debugging*, delves into the excellent Flutter tools that will help you ensure your app is ready for public use.

Chapter 13, *Releasing Your App to the World*, guides you through the steps and potential pitfalls of deploying your app to the world.

To get the most out of this book

To get started, all you need is to have access to a browser so you can use the DartPad website and play with Dart code. However, to develop a full Flutter app, you will need an **integrated development environment** (**IDE**) such as Android Studio or Visual Studio Code.

To professionally develop and publish iOS apps, you will need a developer license (paid annually), a Mac, and at least one physical iOS device to test the applications. Similarly, for Android, you will need a developer license (one-off payment) but can use any major operating system. All this is not strictly necessary for the purpose of learning Flutter, but if you aim to release an app at some point, then you will need to bear these requirements in mind.

The entire installation process and the requirements of the Flutter environment are available on the official Flutter website (`https://flutter.dev/docs/get-started/install`), but do not worry: you can start with the bare minimum and install any extras only when necessary.

Setup requirement	**Options**
Operating system – Android development	Windows, Linux, or macOS
Operating system – iOS development	macOS
Operating system – web development	Windows, Linux, or macOS
IDE	Android Studio or Visual Studio Code
SDK	Flutter

If you are using the digital version of this book, we advise you to type the code yourself or access the code from the book's GitHub repository (a link is available in the next section). Doing so will help you avoid any potential errors related to the copying and pasting of code.

Download the example code files

You can download the example code files for this book from GitHub at `https://github.com/PacktPublishing/Flutter-for-Beginners-Third-Edition`. If there's an update to the code, it will be updated in the GitHub repository.

We also have other code bundles from our rich catalog of books and videos available at `https://github.com/PacktPublishing/`. Check them out!

Conventions used

There are a number of text conventions used throughout this book.

`Code in text`: Indicates code words in text, database table names, folder names, filenames, file extensions, pathnames, dummy URLs, user input, and Twitter handles. Here is an example: "Anytime you want to change the color of a widget, you will need to understand how to use the `Color` class."

A block of code is set as follows:

```
ElevatedButton(
    onPressed: () {
      ScaffoldMessenger.of(context).showSnackBar(
        SnackBar(
          content: Text('The parmo is a famous food from Teesside.'),
        ),
      );
    },
    child: Text('Show SnackBar'),
  ),
```

When we wish to draw your attention to a particular part of a code block, the relevant lines or items are set in bold:

```
messages: {
  a3bdj2: {
    text: "Hello friends",
    deleted: true,
    …
  },
```

```
  4bajfasdf: {…}
}
```

Any command-line input or output is written as follows:

```
C:\src\flutter>flutter doctor
```

Bold: Indicates a new term, an important word, or words that you see onscreen. For instance, words in menus or dialog boxes appear in **bold**. Here is an example: "As we can see, the **Next** button has moved to the base of the screen as we hoped."

> **Tips or important notes**
> Appear like this.

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Part 1: Learning the Core Concepts

In this part, you will be introduced to the Flutter framework and start to understand what Flutter is. At the heart of Flutter is the Dart programming language, so this part will also give you a strong foundational knowledge of Dart ready for a deeper exploration of Flutter in later parts.

We will also look at why Flutter is a good choice for your mobile app development and compare and contrast it against other development options such as native and alternative cross-platform solutions.

This part contains the following chapters:

- *Chapter 1, What Is Flutter and Why Should I Use It?*
- *Chapter 2, An Introduction to Dart*
- *Chapter 3, Flutter versus Other Frameworks*
- *Chapter 4, Dart Classes and Constructs*

1

What Is Flutter and Why Should I Use It?

In this chapter, you will learn the basics of the Flutter framework, the reasons for its creation, and what the future of Flutter may hold. You will learn about the thriving Flutter community, how it is contributing to the continued evolution of Flutter, and how and why Flutter has grown so quickly in the last few years. Along the way, you will see how to build (and run!) your first Flutter project, experience the excellent Flutter documentation, and see how Flutter is designed to work across a range of platforms including iOS, Android, web, Windows, and macOS.

The following topics will be covered in this chapter:

- What is Flutter?
- Hello Flutter – a first glimpse of Flutter
- Widgets, widgets, everywhere
- Building and running Flutter

Technical requirements

In this chapter, we will create, build, and run a Flutter application. To do this, you will need to set up your system so that it can do this.

Specifically, you will need to set up your system so that it has the following:

- The latest stable Flutter **software development kit** (**SDK**) installed and added to your path
- An **integrated development environment** (**IDE**) where you can view and edit Flutter code
- Android Studio and/or Xcode so that you can use the Android and iOS development tools and iOS simulators/Android emulators

The chapter will give you some guidance on how to set up your system, but as you will discover, the Flutter documentation is excellent and includes very accurate and up-to-date getting started guides: `https://flutter.dev/docs/get-started/install`.

Feel free to set up your system now or at the specific points required during this chapter.

You can find the source code for this chapter on GitHub at `https://github.com/PacktPublishing/Flutter-for-Beginners-Third-Edition`.

What is Flutter?

Since the advent of the Apple App Store (and subsequently, the Google Play Store), there has been a way for organizations to share programs with mobile users in a very controlled and managed way. Much like websites on the internet, mobile apps have proliferated to encompass all aspects of our life. And much like websites, over the years, developers have iteratively discovered and learned the best ways to create reliable, scalable, and intuitive mobile apps.

As developers have learned to work within the mobile ecosystem, they have followed similar design patterns and framework ideas that were created to deal with the web ecosystem. Much like the complications of developing code for multiple browsers on the web, in the mobile ecosystem, there has been the challenge of developing code that can work on both iOS and Android devices, with the dream always being to have one code base that works across all devices, and even the web.

Flutter is a framework that is the culmination of this learning. Like most other frameworks, developers use a programming language specified by the framework and structure their code in a way that aligns with the needs of the framework so that ultimately, the developer creates the least amount of "boilerplate" code and can focus on their business needs. Examples of "boilerplate" code would be how to manage touch input, how to connect to the internet, and how to package the app code so that it works with the App Store, Play Store, or web hosting service.

Flutter is a relatively new framework, yet on Google Trends, Flutter comes out above all of its competitor frameworks such as React Native, Xamarin, Swift, and Kotlin, and the outlook for the next few years is highly positive.

When choosing a new programming language or framework, developers and software companies need to assess certain key aspects of the language or framework to ensure it is easy to pick up and that it has a bright, long-term future. Investing time and money into the learning of a new solution, and then developing a code base and development processes around that language and framework, is incredibly expensive. If that solution becomes outdated after a short period, there is poor support and documentation, there is a lack of new developers available to take the product forward, or the solution has scaling issues or usability problems, then that investment is wasted. For a small start-up or a low-funded project, it can even be terminal. With that in mind, let's look at some of the aspects that suggest Flutter may be a good long-term investment.

Backed by Google

Flutter, and the **Dart** programming language it depends on, were created by Google, and although they are open source, they continue to be strongly backed by Google. This ensures the framework has all the tools it needs to succeed in the community, with support from the Google team, presence at big events such as **Google I/O**, Flutter Forward, and investment into continuous improvement in the code base.

From the launch of the first stable release during the **Flutter Live Event** at the end of 2018, the growth of Flutter is evident:

- Flutter apps have been installed on hundreds of millions of devices
- More than 700,000 Flutter apps have been released
- Flutter has been used by more than 5 million developers
- It is the 18th most popular software repository on GitHub

Not only has Google backed Flutter, but they have also put it at the heart of their plans. Important Google apps such as Google Ads and Google Pay are Flutter apps, and Google's future replacement for Android, Fuchsia OS, is built around Flutter.

Fuchsia OS and Flutter

It's not a secret anymore that Google has been working on a new **operating system** (**OS**) called Fuchsia OS, which has long been rumored as a potential future replacement for the Android OS. One thing to pay attention to is that Fuchsia OS may be a universal Google OS that runs on more than just mobile phones, and this would directly affect Flutter adoption. This is because Flutter will be the primary method of developing mobile apps for the new Fuchsia OS, and, not only this, Fuchsia also uses Flutter as its UI rendering engine. With the system targeting more devices than just smartphones, as seems to be the case, Flutter will certainly have a lot of improvements.

The growth of the framework's adoption is directly related to the new Fuchsia OS. As it gets closer to launch, Google needs to have mobile apps targeting the new system. For example, Google has announced that Android apps will be compatible with the new OS, making the transition to and adoption of Flutter significantly easier.

However, a framework, no matter how good, benefits from a well-designed and elegant programming language that allows developers to focus on the "what" of their app rather than the "how." The success of Flutter is very much linked to the Dart programming language that the framework uses throughout.

Dart

The Dart programming language was first unveiled by Google at the **GOTO** conference in 2011, and Dart 1.0 was released at the end of 2013. Initially viewed as a replacement for JavaScript (the main web programming language), the uptake of Dart by developers was relatively low. However, thanks to the emergence of Flutter and its reliance on Dart, the Dart programming language has seen a huge rise in usage.

So, why did the Flutter project choose the Dart programming language? Since its inception, one of Flutter's main goals was to be a high-performance alternative to existing cross-platform frameworks and also to significantly improve the mobile developer's experience.

With this in mind, Flutter needed a programming language that allowed it to accomplish these goals, and Dart is the perfect match for the following reasons:

- **Dart compilation**: Dart is flexible enough to provide different ways of executing the app code depending on the circumstances. Flutter uses Dart **ahead-of-time** (**AOT**) compilation with performance in mind when compiling a *production-ready* version of the application, and it uses **just-in-time** (**JIT**) compilation with a sub-second compilation of code in development time, aiming for fast feedback for code changes. Dart JIT and AOT refer to when the compilation phase takes place. In AOT, code is compiled during the build process and before running the code; in JIT, code is compiled while running (check out the *Dart introduction* section in the next chapter).
- **High performance**: Due to Dart's support for AOT compilation, *Flutter does not require a slow bridge between realms (for example, non-native Flutter code to native device code)*, which makes Flutter apps responsive and allows a fast startup.
- **Garbage collection**: Flutter uses a functional-style flow with short-lived objects, and this means a lot of short-lived allocations. Dart garbage collection works without locks, helping with fast allocation.
- **Easy to learn**: Dart is a flexible, robust, modern, and advanced language. The language has been adapted as Flutter has become more popular, with lots of syntax improvements to simplify the development experience (syntactic sugar), and fundamental design changes that help with Flutter app creation. Although it is still evolving, the language has a well-defined object-oriented framework with familiar functionalities to dynamic and static languages, an active community, and very well-structured documentation.

- **Declarative UI**: In Flutter, you use a declarative style to lay out widgets, which means that widgets are immutable and are only lightweight "blueprints." To change the UI, a widget triggers a rebuild on itself and its subtree, creating a new blueprint that, for the most part, matches the previous blueprint with some changes. This is in contrast to the imperative style (the most common), where you explicitly change specific component properties through function calls after they are created Declarative UI.

  We will explore this a lot more throughout this book, but if you want to understand the concept of the Flutter declarative UI at this point, then take a look at the official introduction to declarative UI from Flutter: `https://flutter.dev/docs/get-started/flutter-for/declarative`.

- **Dart syntax for layout and styling**: Different from many frameworks that have separate syntax for layout and styling, in Flutter, the layout and styling are specified inline within the Dart code. This gives greater flexibility and reduces the developer's cognitive load. The use of HTML, JavaScript, and CSS for web page design is an example of the opposite approach where the functionality, layout, and styling are managed through different syntax. Developers need to know HTML, JavaScript, and CSS to create a complete web page. Flutter also has great tools for debugging layout, as well as investigating and refining the rendering performance of your code.

These are great reasons why Dart fits perfectly with Flutter. However, there is an area of Flutter that we haven't yet explored and is probably the main reason that you are learning and using it, and explains why it is a game-changer in the app development world: a single code base for multiple platforms. Let's take a look at that now.

One code base to rule them all

The primary goal of the Flutter framework is to be a toolkit for building apps that are equivalent in performance, usability, and features to native apps (apps created directly for iOS or Android) while using only a single code base. You may have heard it stated often that there are big advantages to having a single code base. Let's see why that is the case:

- **Multiple languages to learn**: If a developer wants to develop for multiple platforms, they must learn how to do something in one OS and programming language, and later, the same thing in another OS and programming language. The developer then needs to decide whether to focus on one platform for a certain period, causing a mismatch of features/bug fixes between the apps, or constantly switch between platforms, impacting productivity and potentially introducing bugs.
- **Long/more expensive development cycles**: If you decide to create multiple development teams to avoid the previous issues, there are consequences in terms of cost, multiple deadlines, different capabilities of native frameworks, and disparate sets of bug reports.

- **Inconsistency**: Different native capabilities, or different development teams developing features in slightly different ways, may lead to inconsistencies between apps, annoying users, and making bug reporting more complicated to diagnose.

Flutter is not the first attempt to create a single code base and there are existing frameworks available that have similar promises. However, they can suffer from some serious drawbacks:

- **Performance**: Some frameworks use workarounds to allow consistency of user experience across platforms. One of these is to have a web page running inside a native app using a **web view** (a built-in web browser). This tends to have much worse performance than native apps, leading to a poor user experience.
- **Design constraints**: Some frameworks are based on languages that were designed before the mobile experience was created. This can mean they are not designed well for certain user interactions or certain device capabilities, leading to complicated or obscure code, and the inherent maintenance issues this can cause.
- **Not quite one code base**: Although some frameworks suggest a single code base approach to app development, once you get into the details, you will find that you still need to write some platform-specific code, which causes code duplication and allows single platform bugs to creep in.

Now, let's see how Flutter solves these problems.

Bi-directional communication between Flutter to native

Bi-directional communication between Flutter and native refers to the ability of a Flutter application to communicate with a native application (for example, Android or iOS) and vice versa. Flutter is a mobile app SDK for building high-performance, high-fidelity apps for iOS, Android, and the web using a single code base. Native apps, on the other hand, are built specifically for one platform and are written using that platform's native language. With bi-directional communication, you can integrate Flutter widgets into an existing native app, or use native components within a Flutter app. This allows for a more seamless user experience and can improve performance by leveraging the strengths of both Flutter and native platforms.

For example, you can use Flutter to build a UI while using native code to access platform-specific features such as cameras, sensors, or storage. Flutter provides several mechanisms for bi-directional communication with native code, such as platform channels, method channels, and event channels.

Overall, bi-directional communication between Flutter and native is a powerful feature that allows developers to create sophisticated mobile applications that leverage the strengths of both Flutter and native platforms.

High performance

At the time of writing, it is hard to say that Flutter's performance is always better in practice than other frameworks, but it's safe to say that it aims to be. For example, its rendering layer was developed with a high frame rate in mind. As we will see in the *Flutter rendering* section, some of the existing frameworks rely on JavaScript and HTML rendering, which might cause overheads in performance because everything is drawn in a web view.

Some use **original equipment manufacturer** (**OEM**) widgets but rely on a bridge to request the OS API to render the components, which creates a bottleneck in the application because it needs an extra step to render the **user interface** (**UI**). See the *Flutter rendering* section for more details of the Flutter rendering approach compared to others.

Some points that make Flutter's performance great are as follows:

- **Flutter owns the pixels**: Flutter renders the application pixel by pixel (see the next section), *interacting directly with the Skia graphics engine or the new Impeller rendering engine*.
- **No extra layers or additional OS API calls**: As Flutter owns the app rendering, it does not need additional calls to use the OEM widgets, so there's no bottleneck.
- **Flutter is compiled to native code**: Flutter uses the Dart AOT compiler to produce native code. This means there's no overhead in setting up an environment to interpret Dart code on the fly, and it runs just like a native app, starting more quickly than frameworks that need some kind of interpreter.

Full control of the UI

The Flutter framework chooses to do all the UI by itself, rendering the visual components directly to the canvas and requiring nothing more than the canvas from the platform. Most of the time, frameworks just reproduce what the platform offers in another way. For example, other web view-based cross-platform frameworks reproduce visual components using HTML elements with CSS styling. Other frameworks emulate the creation of the visual components and pass them to the device platform, which will render the OEM widgets like a natively developed app. We are not talking about performance here, so what else does Flutter offer by not using the OEM widgets and doing the job all by itself?

Let's see:

- **Ruling all the pixels on the device**: Frameworks limited by OEM widgets will reproduce, at most, what a native-developed app would as they use only the platform's available components. On the other hand, frameworks based on web technologies may reproduce more than platform-specific components, but may also be limited by the mobile web engine available on the device. By getting control of the UI rendering, Flutter allows the developer to create the UI in their own way by exposing an extensible and rich Widgets API, which provides tools that can be used to create a unique UI with no drawbacks in performance and no limits in design.

- **Platform UI kits**: By not using OEM widgets, Flutter can break the platform design, but it does not. Flutter is equipped with packages that provide platform design widgets – the Material set in Android and Cupertino in iOS. We will learn more about platform UI kits in *Chapter 5, Building Your User Interface through Widgets*.
- **Achievable UI design requirements**: Flutter provides a clean and robust API with the ability to reproduce layouts that are faithful to the design requirements. Unlike web-based frameworks that rely on CSS layout rules that can be large and complicated and even conflicting, Flutter simplifies this by adding semantic rules that can be used to make complex but efficient and beautiful layouts.
- **Smoother look and feel**: In addition to native widget kits, Flutter seeks to provide a native platform experience where the application is running, so fonts, gestures, and interactions are implemented in a platform-specific way, bringing a natural feel to the user, similar to a native application.

We refer to visual components as widgets. This is also what Flutter calls them. We will discuss more about this in the *Widgets, widgets, everywhere* section in this chapter.

Open source framework

Having a big company such as Google behind it is a huge benefit to a framework such as Flutter (see React, for example, which is maintained by Facebook). In addition, community support becomes even more important as it becomes more popular.

By being open source, the community and Google can work together to do the following:

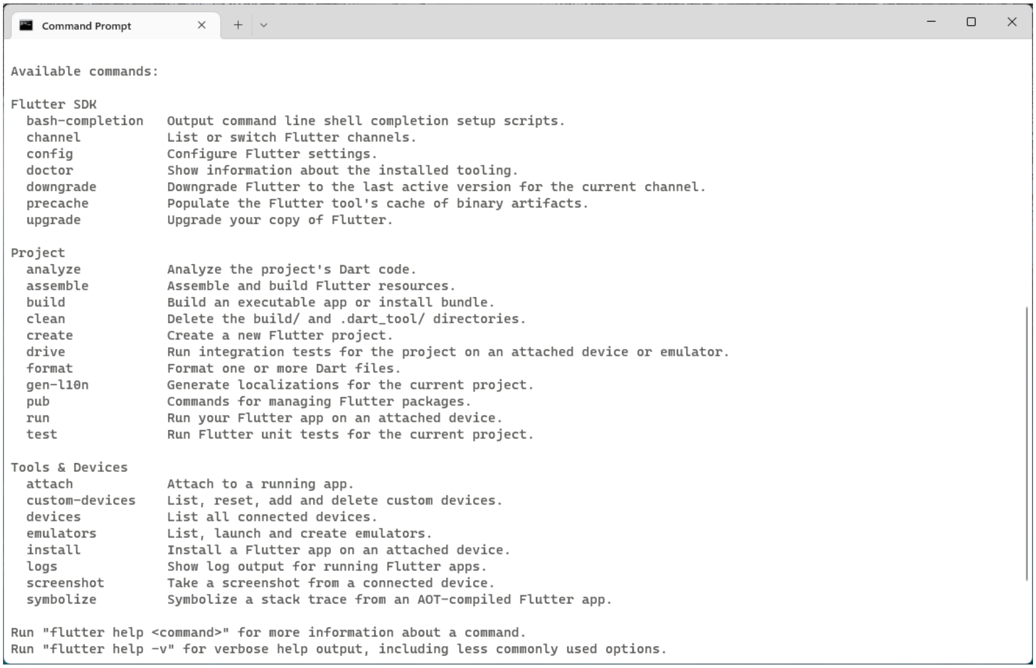
- Help with bug fixes and documentation through code collaboration
- Create new educational content about the framework
- Support documentation and usage
- Make improvement decisions based on real feedback
- Share resources to make bug fixes and develop new features

Improving the developer experience is one of the main goals of the framework. Therefore, in addition to being close to the community, the framework provides great tools and resources for developers. Let's take a look.

Developer resources and tooling

The focus on developers in the Flutter framework goes from documentation and learning resources to providing tools to help with productivity:

- **Documentation and learning resources**: Flutter websites are rich for developers coming from other platforms as they include many examples and use cases – for example, the famous Google Codelabs (`https://codelabs.developers.google.com/?cat=Flutter`).
- **IDE integration**: Flutter and Dart have a completed, integrated IDE experience with Android Studio, IntelliJ, and Visual Studio Code. Within this book, we will show examples from Visual Studio Code, but these examples will work very similarly in Android Studio and IntelliJ.
- **Command-line tools**: Dart has tools that help with analyzing, running, and managing dependencies and these are also part of Flutter. In addition, Flutter has commands to help with debugging, deploying, inspecting layout rendering, and integration with IDEs through Dart plugins. Here's a list of the various commands:



```
Command Prompt

Available commands:

Flutter SDK
  bash-completion   Output command line shell completion setup scripts.
  channel           List or switch Flutter channels.
  config            Configure Flutter settings.
  doctor            Show information about the installed tooling.
  downgrade         Downgrade Flutter to the last active version for the current channel.
  precache          Populate the Flutter tool's cache of binary artifacts.
  upgrade           Upgrade your copy of Flutter.

Project
  analyze           Analyze the project's Dart code.
  assemble          Assemble and build Flutter resources.
  build             Build an executable app or install bundle.
  clean             Delete the build/ and .dart_tool/ directories.
  create            Create a new Flutter project.
  drive             Run integration tests for the project on an attached device or emulator.
  format            Format one or more Dart files.
  gen-l10n          Generate localizations for the current project.
  pub               Commands for managing Flutter packages.
  run               Run your Flutter app on an attached device.
  test              Run Flutter unit tests for the current project.

Tools & Devices
  attach            Attach to a running app.
  custom-devices    List, reset, add and delete custom devices.
  devices           List all connected devices.
  emulators         List, launch and create emulators.
  install           Install a Flutter app on an attached device.
  logs              Show log output for running Flutter apps.
  screenshot        Take a screenshot from a connected device.
  symbolize         Symbolize a stack trace from an AOT-compiled Flutter app.

Run "flutter help <command>" for more information about a command.
Run "flutter help -v" for verbose help output, including less commonly used options.
```

Figure 1.1 – Available commands in Flutter

- **Quick setup**: Flutter has the `create` command, as shown in the preceding screenshot, which allows you to create a new and fully functional Flutter project with minimal input. IDEs also offer a Flutter project creation menu option, replicating the command-line functionality.

- **Environment issue diagnostics**: Flutter comes with the `flutter doctor` tool, which is a command-line tool that guides the developer through the system setup by indicating what they need to set up a Flutter environment. We will see this tool in action when we set up the project environment very soon. The `flutter doctor` command also identifies connected devices and whether there are any upgrades available.
- **Hot reload**: This is a huge benefit to developers and a feature that is getting a lot of attention. By combining the capabilities of the Dart language (such as JIT compilation) and the power of Flutter, it is possible for the developer to instantly see design changes made to code in the simulator or device. In Flutter, there is no specific tool for layout preview. Hot reload makes this unnecessary.

Now that we have learned about the benefits of Flutter, let's do some exploring.

Hello Flutter – a first glimpse of Flutter

It's about time we started getting our hands dirty with some code. Flutter comes with a simple Hello World app that we will get running and then look at in some detail. First of all, though, we need to get your system ready for some Flutter action!

Installing Flutter

Flutter is very easy to install. Head over to the Flutter docs web pages to install Flutter and Dart for your OS: `https://flutter.dev/docs/get-started/install`.

The installation documentation for Flutter is comprehensive, with explanations and any potential issues described there. Ensure that you read the installation documentation fully and complete all the steps so that your system is correctly prepared for our journey into Flutter.

Download the SDK and place it somewhere on your filesystem. Note that downloading Flutter will also download a compatible version of Dart and the relevant `dart` command-line tool. You should not need to download Dart separately.

> **Updating your PATH**
> The installation documentation also explains how to update your `PATH` so that you can run Flutter commands from your command line. Please follow these instructions – you will be using the command line regularly to interact with Flutter and Dart.

With everything installed and `PATH` set up, you should run the `flutter doctor` command to see how ready your system is for Flutter. You will do this from your command line/Terminal:

```
C:\src\flutter>flutter doctor
```

Here is an example of the output:

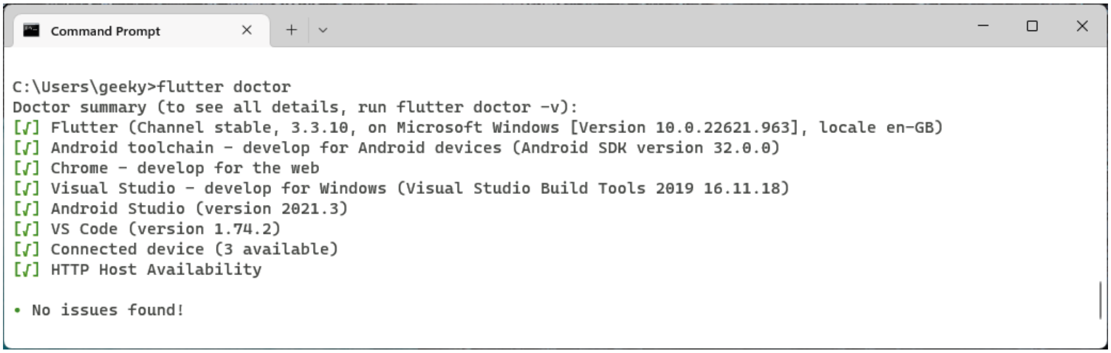


Figure 1.2 – flutter doctor command-line output

You are likely to see errors in the `flutter doctor` report at this point because we haven't set up our development environment yet.

If you are unable to run `flutter doctor`, then it is likely an issue with your `PATH`, as mentioned previously. Double-check that the path to your Flutter folder is correct and points to the `flutter/bin` subfolder. Also, try closing your command line/Terminal and opening it again because `PATH`, in some situations, is only updated when the command line/Terminal is opened.

Development environment

As mentioned previously, Flutter has excellent support in Android Studio, IntelliJ, and Visual Studio Code. This book will generally be agnostic of IDE, but where required, we will show examples from Visual Studio Code.

All three IDEs can be downloaded from the internet. Android Studio and Visual Studio Code are free, and IntelliJ has both a free **Community** Edition and a paid-for **Ultimate** Edition.

If you are planning to work with Android devices (and because Flutter is cross-platform I expect you will), then you will need to download and install Android Studio regardless of the IDE you decide to develop code with. This is because installing Android Studio also installs the Android SDK, Android SDK command-line tools, and Android SDK build tools. These are required by Flutter when interacting with Android devices, running Android emulators, and building the app ready for use on the Android Play Store.

On macOS devices, you will also need to install and configure Xcode so that you can build your app for iOS. Follow the instructions provided in the Flutter getting started documentation to ensure Xcode is configured correctly.

> **Important note**
>
> You can only build iOS apps on Macs. This is a restriction imposed by Apple and is imposed on all app development, not just Flutter. If this is an issue, then there are options such as cloud-based Mac instances you can use, or virtualization software that allows you to run a Mac virtual machine. Exploring this is beyond the scope of this book. However, when developing Flutter apps, you can build and test quite happily on Android for the vast majority of the time, only switching to iOS for late-stage testing.

Once you have both your IDE installed and Android Studio (or just Android Studio if that is your IDE of choice) and Xcode installed and configured (if you are on a Mac), then rerun `flutter doctor` to check everything is ready to go.

Hello world!

With the Flutter development environment configured, we can start using Flutter commands. The typical way to start a Flutter project is to run the following command:

```
flutter create <output_directory>
```

Here, `output_directory` will also be the Flutter project name if you do not specify it as an argument. By running the preceding command, the folder with the provided name will be generated with a sample Flutter project in it. We will analyze the project in a few moments. First, it is good to know that there are some useful options to manipulate the resulting project from the `flutter create` command.

To find out the options for any command, you can simply run the following:

```
flutter <command> -h
```

Therefore, by running the `-h` option on the `flutter create` command, you will be able to see which additional options are available, just like this:

```
flutter create -h
```

The main ones are as follows:

- `--org`: This can be used to change the owner organization of the project. If you already know Android or iOS development, this is a reverse domain name, and it is used to identify package names on Android and as a prefix in the iOS bundle identifier. The default value is `com.example`.
- `-s,--sample=<id>`: Most of the official examples for widget usage have a unique ID that you can use to quickly clone the example to your machine. Whenever you are exploring the Flutter docs website (`https://docs.flutter.dev`), you can take a sample ID from it and use it with this argument.

- `-i`, `--ios-language`, and `-a`, `--android-language`: These are used to specify the language for the native part code of the project, and are only used if you plan to write native platform code.
- `--project-name`: Use this to change the project's name. It must be a valid Dart package identifier. If you do not specify this parameter, it will try to use the same name as the output directory name.

> **Valid Dart package identifiers**
> As specified in the Dart documentation, "*Package names should be all lowercase, with underscores to separate words, `just_like_this`. Use only basic Latin letters and Arabic digits: [a- z0-9_]. Also, make sure the name is a valid Dart identifier – that it doesn't start with digits and isn't a reserved word.*"

Let's create a typical Flutter project with the following command:

```
flutter create hello_world
```

Once this command has finished running, open the newly created folder in your IDE; you should see a structure similar to this:

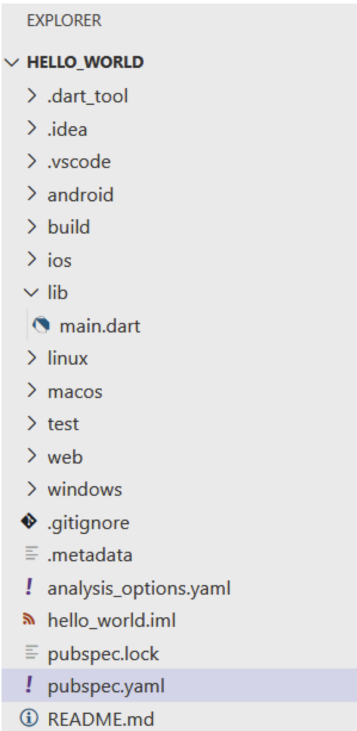


Figure 1.3 – Typical Flutter project structure

Upon listing the basic structure elements, we get the following:

- `android/ios`: This contains the platform-specific code. If you already know the Android project structure from Android Studio, there is no surprise here. The same goes for Xcode iOS projects. Similarly, there are `linux`, `macos`, `web`, and `windows` folders for the other platforms that Flutter supports. Although we will focus less on these platforms in this book, the concepts we are going explore apply across all the Flutter platforms.
- `hello_world.iml`: This is a typical IntelliJ project file that contains the `JAVA_MODULE` information used by the IDE. Similarly, there is a `.idea` folder containing IntelliJ settings, and a `.vscode` folder for Visual Studio Code settings.
- A `lib` folder: This is the main folder of a Flutter application and is where you will spend the vast majority of your time; the generated project will contain at least a `main.dart` file you can start working on. We will be checking this file in detail soon.
- `pubspec.yaml` and `pubspec.lock`: This `pubspec.yaml` file is what defines a Dart package. This is one of the main files of the project and defines the app build number. It also lists dependencies on external plugins, images, fonts, and more. We will be looking at this in more detail in *Chapter 5*, *Building Your User Interface through Widgets*.
- `README.md`: This is a standard `README` document that is very common in open source projects. It allows you to document how to set up and use your code so that other developers can easily get your code running.
- A `test` directory: This contains all the test-related files of the project. Here, we can add unit and widget tests to ensure we do not introduce bugs into our app as we develop it.
- `analysis_options.yaml`: This file configures an analyzer that will look into your code for common bugs. It also allows you to configure your default code styles (known as `lints`, which are enforced through `linter`) so that other developers adhere to your preferences, allowing easier code maintenance.

Now that you have created your first Flutter project (congratulations, by the way!), you should explore the IDE so that you can start to get a feel for the structure of a Flutter project.

Now, I'm sure you are keen to delve more into your shiny new Flutter project, especially this mysterious `main.dart` file. However, before we do, we need to look at a few key aspects of Flutter, starting with widgets.

Widgets, widgets, everywhere

Flutter widgets are a core part of the framework and are used constantly throughout your code. You will hear the saying "Everything is a widget," and that is almost true in Flutter. In this section, we will see how Flutter renders the user interface and then how Flutter applies the widgets idea to app development to create awesome UIs.

Widgets can be understood as the visual (but not only that) representation of parts of the application. Many widgets are put together to compose the UI of an application. Imagine it as a puzzle in which you define the pieces.

Widgets intend to provide a way for your application to be modular, scalable, and expressive with less code and without imposing limitations. The main characteristics of the widgets UI in Flutter are composability and immutability.

Flutter rendering

One of the main aspects that makes Flutter unique is the way that it draws the visual components to the screen. A key differentiator to existing frameworks is how the application communicates with the platform's SDK, what it asks the SDK to do, and what it does by itself:

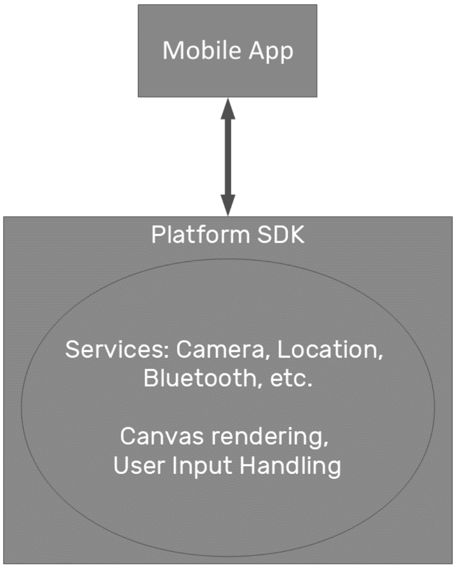


Figure 1.4 – How Flutter communicates with the platform's SDK

The platform SDK can be seen as the interface between applications and the OS and services. Each system provides its own SDK with capabilities and is based on a programming language (that is, Kotlin/Java for the Android SDK and Swift/Objective C for the iOS SDK).

Flutter – rendering by itself

Flutter chooses to do all the rendering work by itself. The only thing it needs from the platform's SDK is access to **Services** APIs and a canvas to draw the UI on:

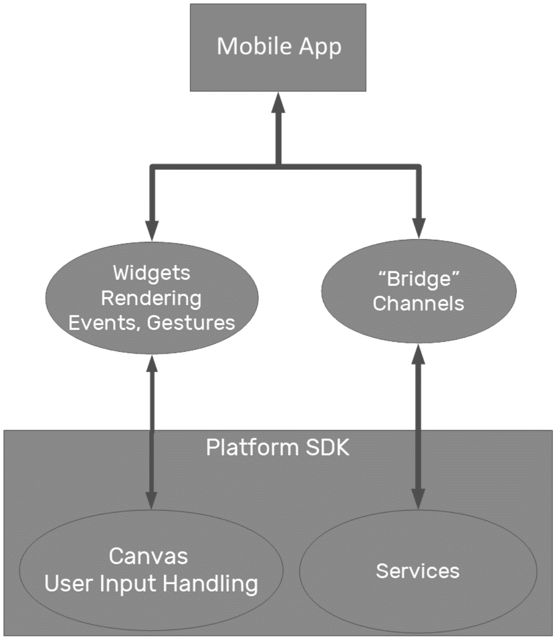


Figure 1.5 – Flutter access to services and the canvas

Flutter moves the widgets and rendering to the app, from where it gets its customization and extensibility. Through a canvas, it can draw anything and also access events to handle user inputs and gestures by itself.

Composability

For the widget user interface structures, Flutter chooses composition over inheritance, intending to keep each widget simple and with a well-defined purpose. Meeting one of the framework's goals, *flexibility*, Flutter allows the developer to make many combinations to achieve incredible results.

Composition versus inheritance

Inheritance derives one class from another. For example, you may have a class such as `Vehicle` and subclasses of `Car` and `Motorbike`. The `Car` and `Motorbike` classes would inherit the abilities of the `Vehicle` class and then add their own specializations. In this instance, `Car` **is a** Vehicle and `Motorbike` **is a** `Vehicle`.

Composition defines a class as the sum of its parts. For example, you may have an `Engine` class and a `Wheel` class. In this model, a `Car` is composed of an `Engine`, four Wheels, and other specializations; a `Car` **has an** `Engine` and a `Car` **has** Wheels. Composability is less rigid than inheritance and allows for things such as dependency injection and modifications at runtime.

Immutability

Flutter is based on the reactive style of programming, where the widget instances are short-lived and change their descriptions (whether visually or not) based on configuration changes, so it reacts to changes and propagates these changes to its composing widgets, and so on.

A Flutter widget may have a state associated with it, and when the associated state changes, it can be rebuilt to match the representation.

The terms **state** and **reactive** are well known in the React style of programming, disseminated by Facebook's famous React library.

Don't worry if this is a concept you have not experienced. It is surprisingly intuitive and we will explore it via many examples throughout this book.

Everything is a widget

Flutter widgets are everywhere in an application. Maybe not everything is a widget, but almost everything is. Even an app is a widget in Flutter, and that's why this concept is so important. A widget represents a part of a UI, but it does not mean it's just visible. It can be any of the following:

- A visual/structural element that is a basic structural element, such as the `Button` or `Text` widgets
- A layout-specific element that may define the position, margins, or padding, such as the `Padding` widget
- A style element that may help colorize and theme a visual/structural element, such as the `Theme` widget
- An interaction element that helps respond to user interactions in different ways, such as the `GestureDetector` widget

An example widget

OK, enough theory – let's have a quick look at a widget so that you can get a feel for what we are referring to. Open your IDE and take a look at that mysterious `lib/main.dart` file we mentioned earlier. Around line 7, you will see a section like this:

```
class MyApp extends StatelessWidget {
  @override
  Widget build(BuildContext context) {
    return MaterialApp(
      title: 'Flutter Demo',
      theme: ThemeData(
        primarySwatch: Colors.blue,
      ),
      home: const MyHomePage(title: 'Flutter Demo Home
        Page'),
    );
  }
}
```

Not only is this your first example of a Flutter widget, but it is also your first chance to see Dart. If you are from a Java, C++, or Objective-C background, then it should look relatively familiar to you. Components of code are held in class definitions that describe fields and methods, with inheritance through the `extends` keyword:

```
class MyApp extends StatelessWidget {
```

We will explore this syntax in a lot more detail in later chapters, but it is easiest to think of a class as a blueprint. This class blueprint says what information or data can be stored and how it can be accessed and manipulated. Extending another class, or blueprint, simply overlays the blueprint you are extending onto your new blueprint. If this is all new to you, then it is highly recommended that you explore object-oriented programming concepts after you complete this chapter as that will give you a strong foundation on which to build your Flutter knowledge.

The `MyApp` class runs the whole show and is itself a widget. In this instance, it is `StatelessWidget`, as you can see from the `extends` section. We will explore `StatelessWidget` (and its alter ego, `StatefulWidget`) in more detail later on, but for the moment, it's sufficient to know that `StatelessWidget` holds no state – it exists to compose other widgets that may or may not hold their own state.

You can see this composition in the `build` method, as defined by this piece of code:

```
Widget build(BuildContext context) {
```

In this `build` method, the `MyApp` widget simply returns another widget, `MaterialApp`, which itself will have a `build` method that may also return widgets. Ultimately, you will reach leaf widgets that will render graphics to the display. The `build` method updates the display and is called when some external activity happens – for example, the user interacts with the device, some data is sent from a database, or a timer is triggered at a set time.

Widgets are the basic building blocks of an interface. To build a UI properly, Flutter organizes the widgets in a widget tree.

The widget tree

This is another important concept in Flutter layouts. It's where widgets come to life. The widget tree is the logical representation of all the UI's widgets. It is computed during **layout** (measurements and structural information) and used during **rendering** (frame to screen) and **hit testing** (touch interactions), and this is the thing Flutter does best. By using a lot of optimization algorithms, it tries to manipulate the tree as little as possible, reducing the total amount of work spent on rendering, aiming for greater efficiency:

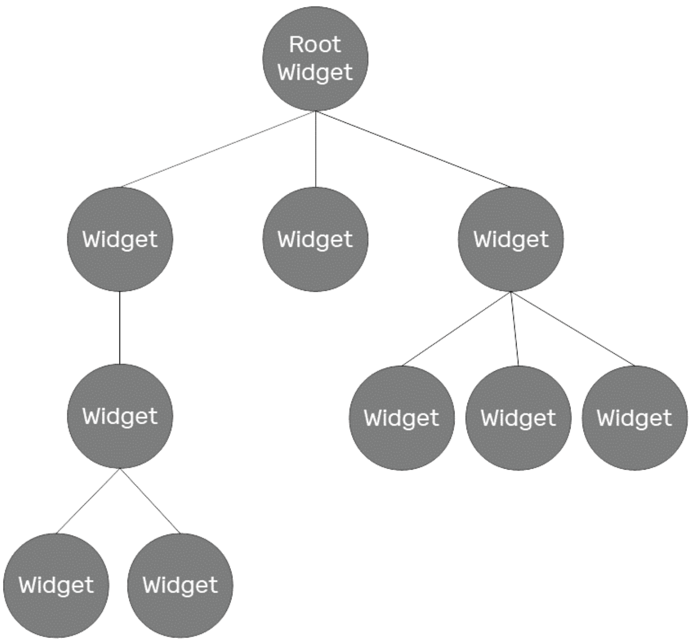


Figure 1.6 – Example widget tree

Widgets are represented in the tree as nodes. Each widget may have a state associated with it; every change to its state results in rebuilding the widget and the child involved.

As you can see, the tree's child structure is not static, and it's defined by the widget's description. The children relations in widgets are what makes the UI tree; it exists by composition, so it's common to see Flutter's built-in widgets exposing `child` or `children` properties, depending on the purpose of the widget.

The element tree

The widget tree does not work alone in the framework. It has the help of the element tree – a tree that relates to the widget tree by representing the built widget on the screen. This means every widget will have a corresponding element in the element tree after it is built.

The element tree has an important task in Flutter. It helps map onscreen elements to the widget tree. It also determines how widget rebuilding is done in update scenarios. When a widget changes and needs to be rebuilt, this will cause an update on the corresponding element. The element stores the type of the corresponding widget and a reference to its children elements. In the case of repositioning, for example, a widget, the element will check the type of the corresponding new widget, and if there is a match, it will update itself with the new widget description.

You have now learned the basics of how to put a Flutter app together. Before you learn how to run our `hello_world` Flutter app, let's look at the build process and options in some more detail.

Building and running Flutter

The way an application is built is fundamental to how it will perform on the target platform. This is an important step regarding performance. Even though you do not necessarily need to know this for every kind of application, knowing how the application is built helps you understand and measure possible improvements.

As we have already pointed out, Flutter relies on the AOT compilation of Dart for release mode and the JIT compilation of Dart for development/debug mode. Dart is one of only a few languages that are capable of being compiled to both AOT and JIT, and Flutter gets the most of this advantage. Let's look at the different build options available, why you should use each one, and how the capabilities of Dart lead to an optimal developer and user experience.

Debug mode

During development, Flutter uses JIT compilation in debug mode. Debug mode compilation is optimized for fast feedback, and therefore sacrifices execution speed and binary size (the size of the app when installed on a device). However, due to the power of Dart's compiler, interactions between the code and the simulator/device are still fast, and debugging tools allow developers to step into the source code and analyze the widget's layout.

Release mode

In release mode, debugging information is not necessary, and the focus is performance. Flutter uses a technique that is common to game engines. By using AOT mode, Dart code is compiled to native code, and the app loads the Flutter library and delegates rendering, input, and event handling to it through the Skia or Impeller rendering engines.

Skia versus Impeller

Skia is an open source library that provides APIs for 2D graphics. It is the primary rendering engine in Flutter and is used by Google Chrome, Android, Firefox, and many others. It is also backed by Google, similar to Dart and Flutter.

However, the unique way that Flutter uses Skia has led to some minor display issues. Additionally, Skia is solely a 2D rendering engine, which limits the potential domains that Flutter can be used for.

To solve these problems, the Flutter team has created a new rendering engine called Impeller, which removes the display issues, provides support for 3D, and is designed to harness the capabilities of modern graphics APIs.

At the time of writing, Impeller is the default rendering engine for iOS apps, with Android support being actively developed, and web support on the development roadmap.

Profile mode

Sometimes, you need to analyze the performance of your app. Profile mode retains just enough debugging ability to create a profile of your app's performance while attempting to be a true reflection of your app's real-world performance. This mode is only available on physical devices because emulators will not have representative performance characteristics.

Supported platforms

At the time of writing, Flutter supports ARM Android devices running at least on Jelly Bean 4.1.x version, and iOS devices from iPhone 4S or newer. As you would expect, Flutter apps can be run on device emulators, and debugging works equally well on physical and emulated devices.

Additionally, Flutter has web and desktop support (Windows, macOS, and Linux). As you can see, the vision for Flutter is to allow developers to have a single code base for mobile, web, and desktop!

We are not going to go into more detail on Flutter's compilation aspects as they are beyond the scope of this book. For more information, you can read `https://docs.flutter.dev/resources/faq#run-android` and `https://docs.flutter.dev/resources/faq#run-ios`.

The pubspec.yaml file

The `pubspec.yaml` file in Flutter is a file that is used to define Dart packages. Besides that, it contains an additional section for configurations specific to Flutter. Let's see the `pubspec.yaml` file's content in detail:

```
name: hello_flutter
description: A new Flutter project.
publish_to: 'none'
version: 1.0.0+1
```

The beginning of the file is simple. As we already know, the `name` property is defined when we execute the `pub create` command. Next is the default project's `description`; feel free to change this to something more interesting. Note that if you do so, your IDE may suddenly run the `flutter pub get` command. We'll see why in a bit.

> **Description during create**
> Like many parts of the `pubspec.yaml` file, you can specify the description while running the `flutter create` command by using the `–description` argument.

The `publish_to` property is used if you are creating a package that you wish to share with others. We will explore this notion in later chapters when we start to use plugins for our apps. By default, packages are published to the official Dart package repository, `pub.dev`.

If you set the `publish_to` field to `none`, this means that the package will not be published to, or listed in, the Dart package repository. This is useful for private packages that are only intended for internal use within an organization. If you are writing a mobile app instead of a package or plugin, then you would set this to `none`.

The `version` property follows the Dart package conventions: the version number, plus an optional build version number separated by `+`. In this example, the version number is 1.0.0 and the build number is 1.

In addition to this, Flutter allows you to override these values during the build. We will take a more detailed look at this in *Chapter 13*, *Releasing Your App to the World*.

Then, we have the `dependencies` section of the `pubspec` file:

```
environment:
  sdk: ">=3.1.0 <4.0.0"

dependencies:
  flutter:
    sdk: flutter
```

```
  cupertino_icons: ^1.0.2

dev_dependencies:
  flutter_test:
    sdk: flutter
  flutter_lints: ^2.0.0
```

We start with the `environment` property. This specifies the version of Dart that your code will work with. This entry is specifying that your code will need version 3.1.0 of Dart or above, but will not run on Dart 4.0.0. As per standard versioning, you would expect that if Dart 4.0.0 is released, it will have some backward-incompatible changes that may stop your code from compiling. This happened when Dart was updated from 1.x.x to 2.x.x. By restricting your allowed Dart versions, your code will not need to support Dart 3.x.x until you are ready to do so.

> **Important note**
>
> Dart 2.12 was a significant milestone for Dart because it introduced the concept of null safety. Code written before Dart 2.12 was released will have certain syntax differences and potentially be more prone to bugs around the nullness of variables. We will explore null safety in *Chapter 2*, *An Introduction to Dart*.

Additionally, Dart 3.0 introduced new language features such as interfaces and records, which will be used throughout this book. Ensure that any projects you create are using Dart 3.0 or later so that you can get full null safety and the latest Dart language features.

Then, we have the `dependencies` property. This starts with the main dependency of a Flutter application, the Flutter SDK itself, which contains many of Flutter's core packages.

As an additional dependency, the generator adds the `cupertino_icons` package, which contains icon assets that are used by the built-in Flutter Cupertino widgets (there's more on that in the next chapter). Cupertino is the name given to widgets that follow the iOS design guidelines.

As you add other dependencies (and I would bet my hat that you will add a lot of dependencies), they will also appear here.

The `dev_dependencies` property contains the `flutter_test` package dependency provided by the Flutter SDK itself, which contains Flutter-specific extensions to Dart's `test package`. We will explore this in *Chapter 12*, *Testing and Debugging*.

Additionally, it contains the `flutter_lints` dependency. As we mentioned in the *Hello World!* section, `linter` uses `lints` to enforce a recommended code style.

In the final block of the file, there's a dedicated `flutter` section:

```
flutter:
  uses-material-design: true

# To add assets to your application, add an assets section, like this:
# assets:
#     - images/a_dot_burr.jpeg
#     - images/a_dot_ham.jpeg
# ...
# To add custom fonts to your application, add a fonts section here,
# fonts:
#     - family: Schyler
#       fonts:
#         - asset: fonts/Schyler-Regular.ttf
#         - asset: fonts/Schyler-Italic.ttf
#           style: italic
```

This `flutter` section allows us to configure resources that are bundled in the application to be used during runtime, such as images, fonts, music, sound effects, and videos.

Let's have a closer look:

- `uses-material-design`: We will see the Material widgets provided by Flutter in the next chapter. Much like Cupertino is the name used for the iOS design guidelines, Material is the name given to the Android/Google design guidelines. In addition to them, we can use Material Design icons (`https://material.io/tools/icons/?style=baseline`), which are in a custom font format. For this to work properly, we need to activate this property (set it to `true`) so that the icons are included in the application.
- `assets`: This property is used to list the resource paths that will be bundled with the final application. The `assets` files and folders can be organized in any way; what matters for Flutter is the path to the files. You specify the path of the file relative to the project's root. This is used later in Dart code when you need to refer to an asset file. Here's an example of adding a single image:

  ```
  assets:
    images/home_background.jpeg
  ```

  Often, you will want to add many images, and listing them individually would be onerous. An alternative is to include a whole folder:

  ```
  assets:
    images/
  ```

You must add the / character at the end of the path, which is used to specify that you want to include all files in that folder. Note that this doesn't include subfolders; they would need to be listed as well:

```
assets:
  images/
  images/icons/
```

- `fonts`: This property allows us to add custom fonts to the application. More on this will be covered in *Chapter 6*, *Handling User Input and Gestures*, in the *Custom fonts* section.

We will learn how to load different assets throughout this book whenever we need to. You can read more about asset specification details on the Flutter docs website: `https://flutter.io/docs/development/ui/assets-and-images`.

Running the generated project

The `hello_world` application that we created earlier has a counter to demonstrate the React style of programming in Flutter. We will look at Dart code in more detail in the next chapter, but let's look at the `main.dart` file a little bit more before we try running the application.

The lib/main.dart file

We explored the `main.dart` file earlier to look at a widget. This file is also the entry point of the Flutter application:

```
void main() => runApp(MyApp());
```

The `main` function is the Dart entry point of an application; this is where the execution of your app will start. Flutter then takes over the execution in the `runApp` function, which is called by passing your top-level (or root) widget as a parameter. This is the widget we saw earlier – the `MyApp` widget.

Flutter run

To execute a Flutter application, we must have a connected device or simulator. You can see if your system has been set up correctly to use simulators or emulators by running the `flutter doctor` tool. The `flutter emulators` tool can then be run, which will show which emulators/simulators are on your system. The following command lets you know the existing Android and iOS emulators that can be used to run the project:

```
flutter emulators
```

You will get something similar to the following output:

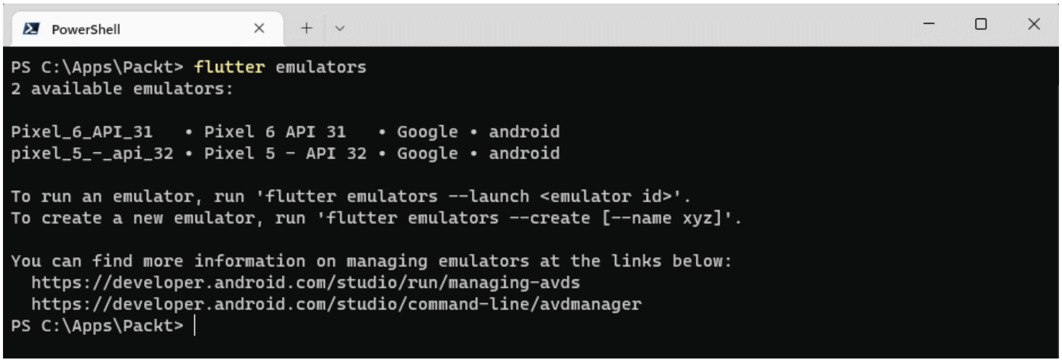


Figure 1.7 – Output from the flutter emulators command

You can then choose to run the emulator/simulator using the command shown in the output or start the emulator or simulator using the Android Studio or Xcode simulator functionality. In this scenario, you could run the following:

```
flutter emulators --launch Pixel_6_API_31
```

You can learn how to manage your Android emulators at `https://developer.android.com/studio/run/managing-avds`. For iOS device simulators, you should use the Xcode Simulator developer tool.

> **Emulator versus simulator**
>
> You will notice that Android has emulators and iOS has simulators. The Android emulator mimics the software and hardware of an Android device. In contrast, the iOS simulator only mimics the software of an iOS device, using the full hardware available on the machine it is running. Therefore, it is highly recommended that you test your app on a true iOS device before releasing it to the world to ensure there are no hardware issues, such as excessive memory consumption.

Alternatively, you can choose to run the app on a physical device. You will need to set up your device for development, so for the moment, it is probably easier to use an emulator or simulator.

After asserting that we have a device connected that can run the app, we can use the following command from the project folder to run the app on the device:

```
flutter run
```

You will see an output similar to the following:

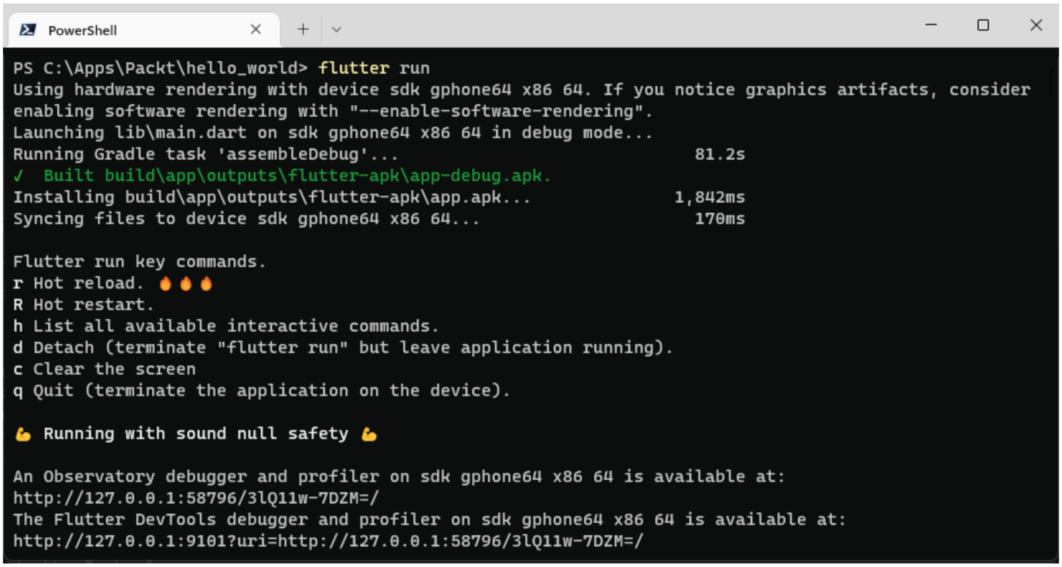


Figure 1.8 – Output from the flutter run command

This command starts the debugger and makes the hot reload functionality available. The first run of the application will generally take a little longer than subsequent executions.

The emulator or simulator should start up and after a pause to load the OS, it should run your Flutter application. If you see the following screen, then congratulations – you have just run your first-ever Flutter application and should be proud of yourself!

Figure 1.9 – Emulator displaying the Flutter app

The application is up and running; you can see a debug mark in the top-right corner. This shows that it's not a release version running; the app is in debug mode, which means you have all the debug mode goodies available to you, such as hot reload and code debug facilities.

The preceding example was run on a Pixel 6 emulator. The same result can be achieved using an iOS simulator, or any other **Android virtual device** (**AVD**).

Summary

In this chapter, we started playing with the Flutter framework. First, we learned some important concepts about Flutter, mainly the concepts of widgets. We saw that widgets are the central part of the Flutter world. This is because the widget concept is everywhere, from rendering performance to the final result on the screen.

We also saw how to start a Flutter application project with the framework tools, the basic project structure of files, and the peculiarities of the `pubspec.yaml` file. We also started exploring the `main.dart` file, our first foray into the world of Dart coding. In the end, we saw how to run a project on an emulator or simulator.

In the next chapter, we will dive deeper into Dart. You had a sneak peek when we looked at widgets and you saw how similar it is to other common programming languages, such as Java, C#, and Swift. Dart is a great language, and I must confess it is my favorite language to work with. Hopefully, you will share some of this love by the end of the next chapter.

Questions

At the end of each chapter, you'll find a set of questions like the ones in this section. These will focus on key pieces of information shared within each chapter to ensure you have retained the relevant knowledge.

If you are unable to answer any questions, then look back through this chapter for the relevant answers to refresh your knowledge:

1. Which programming language is used for Flutter apps?
2. Which company is the predominant backer of Flutter?
3. What are the two types of compilation available in Dart?
4. Name three reasons why having a single code base for multiple platforms is an advantage.
5. What is the tool that checks your Flutter setup is correct?
6. Which command will generate a new Flutter project?
7. What is the purpose of the `pubspec.yaml` file?
8. Name the three build modes available when building a Flutter app.

Further reading

At the end of each chapter, there will be references for further reading so that you can extend your knowledge of the topics discussed within each chapter. These may be web links, books, or podcasts.

For this chapter, I recommend that you get a feel for the potential of Flutter apps. A great place to do this is Flutter Showcase: `https://flutter.dev/showcase`.

Have a play with the apps shown there, view the case studies, and start to appreciate just how amazing Flutter will be for your future apps.

2
An Introduction to Dart

The Dart language is at the core of the Flutter framework. A modern framework such as Flutter requires a high-level modern language so that it can provide the best experience to developers and allow them to create awesome mobile applications. Understanding Dart is fundamental to working with Flutter.

To use an analogy, when you want to write a film script, you first need to have detailed knowledge of the language (for example, English) in which the script will be written. You need to know the syntax and grammar, how a sentence is structured, the use of symbols such as speech marks, and more. Given that knowledge, you can try to write the film script, but all film scripts require a certain structure on top of the base language structure. This includes character descriptions, scene information, character dialogue, additional details for the film director, and more.

The relationship between Dart and Flutter is very similar to the relationship between the English language and a film script. The language of your mobile app development is Dart, which gives the base syntax and structures the code you write, and it is Flutter that overlays the higher-level structure onto the base language; widgets, state management, routing, tooling, and so on.

To be a great film writer, you need to have detailed knowledge of the English language, and the same logic applies to great Flutter developers who need detailed knowledge of the Dart language. This includes knowing the origins of the Dart language, how the community works and develops it, the language's strengths and weaknesses, and what characteristics made it the chosen programming language for Flutter.

In this chapter, we will review the basics of the Dart language and identify resources that can help you on your Flutter journey. We will review Dart's built-in types and operators and how Dart works with **object-oriented programming** (**OOP**). By taking the time to understand what the Dart language has to offer, you will become increasingly comfortable using Dart, which will allow you to focus your attention more on the functionality of your app and less on how to write the code.

The following topics will be covered in this chapter:

- Getting started with Dart
- Variables and data types
- Control flows and looping
- Functions and methods

Technical requirements

In this chapter, we will explore the Dart language. You can do this via DartPad, which will be explained later in this chapter, or within your chosen **integrated development environment** (**IDE**), as discussed in the previous chapter.

Either option will allow you to experiment with your code. If you choose to use your IDE, then you will need to ensure your system has been configured correctly to run Dart programs. Please refer to *Chapter 1, What Is Flutter and Why Should I Use It?* for details on how to ensure your system is ready to do this.

You can find the source code for this chapter on GitHub at `https://github.com/PacktPublishing/Flutter-for-Beginners-Third-Edition`.

Getting started with Dart

Let's start by looking at some of the high-level aspects of the Dart language. Many languages borrow the best parts of languages that came before them, and Dart is no different in that regard. Dart aims to aggregate the benefits of many of the existing high-level languages that have mature language features, including the following:

- **Productive tooling**: This includes tools to analyze code, IDE plugins, and big package ecosystems. A language will struggle and fail if there isn't great tooling available to developers.
- **Garbage collection**: This manages or deals with memory deallocation (mainly memory occupied by objects that are no longer in use). Java was one of the first high-level languages to use this approach, and it is now a common approach for languages to take. The Dart garbage collector is designed to be fast and not impact the user experience.
- **Statically typed**: Dart is type-safe and uses both static type checking and runtime checking to continuously ensure the value of a variable matches its defined type. This feature is important to reduce the chances of many types of bugs during code writing.
- **Type annotations**: Although Dart is type-safe, meaning that types are mandatory, many type annotations can be inferred by the Dart analyzer, allowing for improved code brevity.

- **Portability**: Dart can run on many different types of hardware and within many different environments. This is not only used for the web where Dart is converted or transpiled into JavaScript to run in the browser environment but also allows it to be natively compiled to **Advanced RISC Machines** (**ARM**) and **x86** code.
- **Asynchronous programming**: This allows your app to continue to be responsive even if it is doing many different tasks at the same time. An example of this would be when your app makes a call to a database to receive or write some data. This operation can take a long time but you still want your user interface to be responsive to any user actions during this database interaction. Although Dart is single-threaded, it still has a simple and intuitive asynchronous model, unlike some languages, such as Java, which have extensive but also very complex asynchronous solutions.

All Flutter development involves having intimate knowledge of the Dart language; your application code, plugin code, and management of dependencies all use the Dart language and its features. Having a strong base understanding of Dart will allow you to be more productive with Flutter and will enable you to enjoy Flutter development more. Let's continue to explore the Dart language, starting with where Dart came from.

The evolution of Dart

Unveiled in 2011, Dart has been evolving and adapting to changing needs ever since. Dart saw its stable release in 2013 and has seen some major changes since then, as outlined here:

- Dart was initially created as a replacement for JavaScript, the language used for web development. JavaScript doesn't provide the robustness that many languages do, which can lead to serious issues, especially at runtime due to the lack of type-safety in the language. Dart wanted to bring a mature successor to JavaScript, but many were worried it would fragment web development. Google was not the only company to want to replace JavaScript and Microsoft released TypeScript at a similar time, which has had much more success in this space.
- Initially, Dart did not have a type system, much like JavaScript, meaning that types were checked at runtime. The main issue with dynamically typed languages is that bugs are mainly discovered at runtime rather than compile time. This means that there is a much longer gap between code writing and bug identification and that bugs are generally found by end users rather than developers. Therefore, in 2018, Dart 2.0 was released, which introduced a full type system. Many of the subsequent changes to the language have been to improve the way the language works with the type system.
- Flutter 1.0 was released to the world at the Flutter Live event, soon after the release of Dart 2.0. As we already know, Flutter has a fundamental reliance on the Dart programming language, and, given the failure of Dart to replace JavaScript, this relationship with Flutter saved Dart from being simply an interesting footnote in the history of programming languages.

- Null safety, which involves extending the type system to define whether a type includes null, was added in Dart 2.12. This involved a huge coordinated effort from Google, plugin developers, and app developers to get everything ready for the switchover. You will still see older plugins that are not yet null-safe, and there are likely to be many older apps that have not completed work to add null-safety. However, using null-safety moves even more bug types to compile time rather than runtime issues.
- Dart 3, released in 2023, added many new features to the language. This included improvements to the null safety of the language and an exciting feature known as records, which allows a method to return multiple values to the calling method. Previously, if your method returned multiple values, you would need to create a class to hold the data. Records allow you to avoid that boilerplate code. Additionally, patterns were released, which allow more complex variable comparisons and assignments, and more refined class modifiers were added to the language.

Dart is a great modern, cross-platform, general-purpose language that continually improves its features, making it more mature and flexible. However, apart from the move to 2.0, Dart has also managed to maintain backward compatibility, meaning that much older code can run on the latest Dart version, gaining benefits such as performance improvements, if not for syntax changes.

Even with all of these changes, some fundamental features of Dart have stayed consistent, one of which is the different ways you can run or execute Dart code. This is probably one of the core reasons why the Flutter framework team chose the Dart language to work with.

How to run Dart

Running Dart code can be done in two different ways:

- Dart **virtual machines** (**VMs**)
- JavaScript compilations

These options are shown in the following diagram:

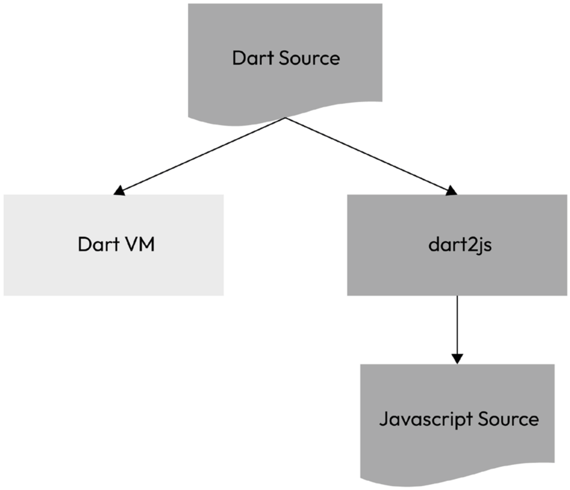


Figure 2.1 – Alternative ways to run Dart applications

As you can see, at the root of the diagram is always your Dart code. Your code and dependency choices are agnostic to the way you run your application; no changes need to be made to your code to make different options available to you.

Dart VM and JavaScript compilation

Dart code can be run in a Dart-capable environment. A Dart-capable environment provides essential features to an application, such as the following:

- Runtime systems
- Dart core libraries
- Garbage collectors

The execution of Dart code operates in two modes – **Just-In-Time** (**JIT**) compilation and **Ahead-Of-Time** (**AOT**) compilation:

- A JIT compilation is where the source code is compiled as it is needed – just in time. The Dart VM loads and compiles the source code to native machine code on the fly. This approach is used to run code on the command line or during mobile application development to allow the use of features such as debugging and hot reload.

- An AOT compilation is where the Dart VM and your code are precompiled and the VM works more like a Dart runtime system, providing a garbage collector and various native methods from the Dart **software development kit** (**SDK**) to the application. This approach has huge performance benefits over JIT compilations, but other features such as debugging and hot reload are not available.

> **Hot reload**
>
> Dart contributes to Flutter's most famous feature, hot reload, which is based on the Dart JIT compiler. This allows developers to get very fast feedback on code changes, allowing them to iterate much quicker, leading to faster and higher-quality software development.

Before we start playing with Dart, we need to explore a few fundamental aspects of the language.

Introducing the structure of the Dart language

The Dart language builds on common features and structures of many existing languages. This means that developers can find it relatively easy to move to Dart from another language.

In this section, we will explore the fundamentals of the Dart language that will allow someone already experienced in basic programming to apply that knowledge to Dart.

If you feel you need a deeper introduction to the basics of programming, then the perfect complementary book is *Learning Dart*, by Dzenan Ridjanovic.

If you have already experienced programming languages inspired by the old C language, or have some experience with JavaScript, much of the Dart syntax will be easy for you to understand. Dart provides most of the standard operators for manipulating variables; the built-in types are the most common ones found in high-level programming languages, and the control flows and functions are very similar to what you will have experienced elsewhere.

Object orientation

As with most modern languages, Dart is designed to be **object-oriented** (**OO**). Briefly, OOP languages are based on the concept of **objects** that hold both data (called **fields**) and code (called **methods**). These objects are created from blueprints called **classes** that define the fields and methods an object will have.

Following OO principles ensures that Dart has the benefits of encapsulation, inheritance, composition, abstraction, and polymorphism. We will explore Dart classes in much more detail in *Chapter 4*, *Dart Classes and Constructs*, but suffice it to say that if you have seen OO in other languages such as Java, then much of the Dart OO design will be very similar.

Type safety

Again, as with most modern languages, Dart has a type system at the heart of it that not only allows developers to identify bugs during compile time but also gives great benefits such as high-quality code completion suggestions and aids discoverability. The IDE can suggest methods it knows are valid based on the type of the variable, parameter, or return type of a method, and a developer can explore new libraries or plugins through IDE assistance.

Unlike some languages, Dart also has sound null safety. **Null** is a common concept in programming languages – it simply identifies the absence of a value. Unlike JavaScript, Dart does not have the concept of **undefined**. Sound null safety allows developers to specify and identify which variables or parameters can have a null value, or which methods can return null. Given that knowledge, the developer can tailor their code to cope with possible null values when required.

The Dart analyzer can also better identify potential null pointer exceptions (situations where a null value will cause the code to fail) and force the developer to prepare for the scenario either through extra checking or by tightening the type so that it excludes null.

Libraries

For a language to have utility, it generally needs to have a set of core libraries so that developers are freed from writing low-level functionality. Dart is no different here, containing core libraries for functionality such as input/output, date/time, collections, mathematics, internationalization, XML, and HTML. These libraries are pre-packaged directly into the Dart SDK and are very easy to add to your code through import statements.

Many of the libraries are multi-platform, meaning that they can be used in any situation, whether the code is running on a mobile device, web browser, laptop, or PC. However, there are some platform-specific libraries, especially for web browsers, with functionality such as HTML interaction and usage of scalable vector graphics.

As you can see, Dart follows lots of conventional wisdom in the way it is designed. Now, let's at how you can see Dart in action.

Hands-on with Dart

Let's look at some basic Dart code to give you a taste of the syntax and the available tools for Dart development. Don't worry – we will go through Dart in detail later in this chapter; this is simply to give you a feel for the Dart syntax and something to refer back to as you learn the Dart language.

DartPad

The easiest way to start coding is to use the DartPad tool, which you can access at the following link: `https://dartpad.dartlang.org/`.

This is a great online tool for learning about and experimenting with Dart's language features. It also supports the core libraries mentioned earlier, except for libraries such as `dart:io`, the input/output library.

This is what the tool looks like:

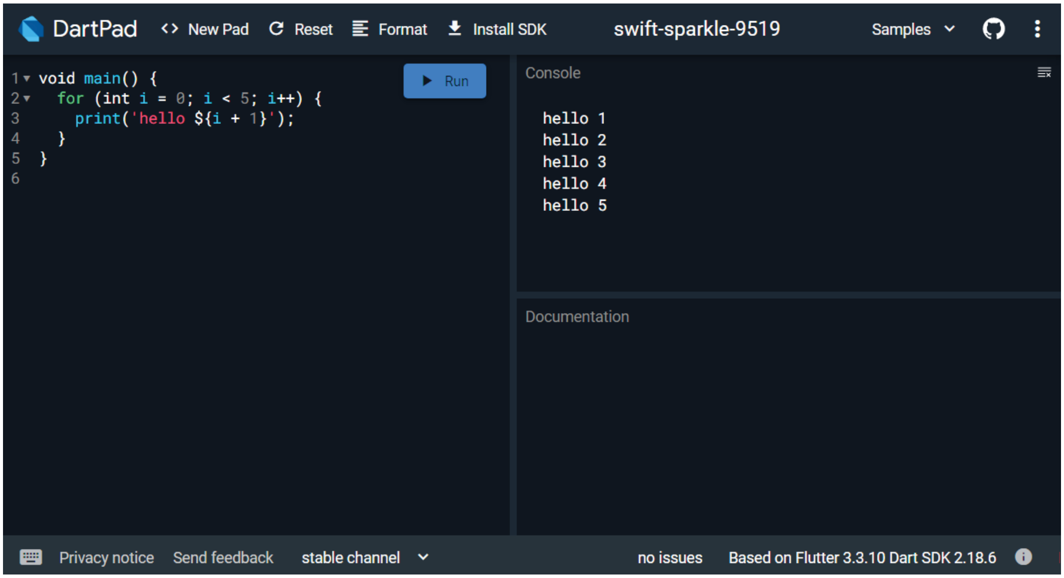


Figure 2.2 – Initial view of the DartPad tool

When you open DartPad, you will be presented with an initial piece of code. Try running it – you should see a console output similar to this:

```
hello 1
hello 2
hello 3
hello 4
hello 5
```

> **Running locally**
> If you choose to run this code locally on your machine, then save the contents to a Dart file and run it with a Dart tool in a Terminal – for example, save it to a file named `hello_world.dart` and then run the `dart hello_world.dart` command. This will execute the `main` function of the Dart script.

Let's look at the code you have in DartPad in more detail.

Hello World, Dart style

The code you will be presented with in DartPad looks similar to this:

```
void main() {
  for (int i = 0; i < 5; i++) {
    print('hello ${i + 1}');
  }
}
```

This code contains some basic language features that need highlighting.

The main function

As with most modern languages, Dart uses functions and methods as a way to break up code. A function or a method is a chunk of code that (optionally) receives some data, runs the code, and then (optionally) returns some data.

The function from the Hello World example looks like this:

```
void main() {
  …
}
```

This first line contains several important pieces of information, outlined as follows:

- The data type that is returned from the method is defined first. In this case, `void` denotes that the method does not return any data when it has completed execution. `void` is a keyword in the Dart language that can only be used in specific circumstances to denote the absence of data. We will look at data types in the next section.
- The name of the function comes next – in this case, `main`. The name is used by other pieces of code to reference this method, and, in this specific case, `main` is the function name that the Dart VM searches for when it first starts running code. Every Dart application must have an entry point, top-level function so that the Dart VM knows where to start code execution. The `main` function serves this purpose.
- The empty parentheses are where a function defines the data it expects to receive. This `main` function does not receive any data, hence the empty parentheses. We will look at the way a function can define the expected data later in this chapter.
- Finally, a curly bracket, `{`, at the end of the first line specifies where the function code starts, and the closing curly bracket, `}`, several lines later specifies where the function code ends. Unlike with some languages such as Python, the indentation or layout of the code is irrelevant to how the code is executed.

Function versus method

Functions and methods have identical syntax, and often the terms **function** and **method** are used interchangeably. So, what is the difference? Specifically, a **function** exists outside of a class (we will look at classes in *Chapter 4*, *Dart Classes and Constructs*). The `main` function is an example of this. Conversely, a **method** is tied to an instance of a class and has an implicit reference to the class instance via the `this` keyword.

So, you now know that the code is executed because the Dart VM searches for a `main` function, finds the one written previously, and then calls that function. We've also learned about the `void` data type. Before we look at the other parts of the code, let's take a look at the other data types available in Dart.

Variables and data types

Variables are key to any programming language, holding application state so that the correct execution flow can be followed, displaying the correct information to the user, and interacting with other systems through defined data structures.

Unstructured data can be dangerous, though, and may lead to bugs and difficult-to-maintain code. Therefore, a rich set of data types is required in a modern programming language. Let's explore this area of the Dart language, starting with the basics of declaring a variable.

Variable declaration

Variables store references to data and are key to decision-making within your application. Variables have to be declared before they can be used.

A variable declaration follows many of the rules of similar programming languages, but due to type inference, Dart's variable declaration can be looser.

The structure of a variable declaration is shown here:

```
type identifier = value;
```

`type` defines the data type that the variable can hold, such as a number or piece of text. If the variable can hold any type of data, then it can be declared with the `dynamic` type. The type can simply be set to `var` if the Dart analyzer can infer the variable's type from the assigned value or later code. If the Dart analyzer is unable to infer the type, then the variable becomes the `dynamic` type.

`identifier` is a name you give to the variable that describes the data it is holding. Some rules define what an identifier must be; these are outlined here:

- Cannot be a keyword, such as `new` or `class`
- Must contain alphabetical characters and numbers

- Cannot contain spaces and special characters except the underscore (_) and dollar ($) characters
- Cannot begin with a number

`value` is an initial value that the variable holds from a declaration. `value` is optional; a variable can be initialized with no value, which will set the variable to `null`.

Variables can receive new values at any point. The type will have been declared previously, so a change in variable value can simply be achieved with the following code:

```
identifier = value;
```

Let's look at some examples of variable declarations:

```
var inferredString = "Hello"; // Type inferred as String
String explicitString = "World"; // Type is explicit
```

In these variable declarations, we show the following:

- An inferred declaration of `inferredString`, where the type is inferred from the assigned value, the `"hello"` string
- A variable declaration where we use the explicit type of `String` for the `explicitString` variable

Both declaration approaches are acceptable because both variables are unambiguous. However, it is still ambiguous as to whether the variables can contain `null`, so let's learn how to remove that ambiguity.

Null safety

Dart has support for a variable to have no value, called `null`. The use of the `null` value was added as part of the type system in Dart 2.12; previously, you could assign any variable a `null` value at declaration or any later point. Now, you need to declare that a variable can accept the `null` value by specifying this on the variable's type when the variable is declared.

You may see older code that allows `null` without the explicit type declaration, simply because the change is relatively recent. In previous releases, the following code would have been acceptable:

```
int newNumber; // newNumber is initialized to null
print(newNumber); // Prints null
newNumber = 42; // Update the value of newNumber
print(newNumber); // Prints 42
```

In Dart 2.12 and later, this code is no longer allowed, showing errors within your IDE. There are two options available to declare the nullability of a variable. Let's look at both options.

? declaration

To specify that a variable can be set to the `null` value, you can add a `?` character to the type of the variable. Therefore, to fix the preceding code example, we only need to add one character and the errors will be removed, as illustrated in the following code snippet:

```
int? newNumber; // newNumber type allows nullability
print(newNumber); // Prints null
newNumber = 42; // Update the value of newNumber
print(newNumber); // Prints 42
```

If you didn't spot it, we added a `?` character after the `int` type. Now, the `newNumber` variable can either take an `int` or `null` value.

Late variables

There are times when you know a variable will have a value set before that value is accessed, but the variable's value cannot be initialized immediately at variable declaration. An example of this in Flutter is where a variable is declared with no value, but immediately at widget initialization, it is given a value. If we were forced to do null checks every time we accessed the variable, our code would be harder to read and maintain.

To solve this problem, Dart has the `late` type modifier. This tells Dart that you are completely confident that at the point the variable's value is accessed, the variable will have already been set to a value.

Let's update the example to show this in action:

```
late int newNumber; // newNumber type allows nullability
// Do some initialisation stuff
newNumber = 42; // Update the value of newNumber
print(newNumber); // Prints 42
```

In the updated example, we declare `newNumber` with no value, but this is allowed because we have said, using the `late` modifier, that the value will be set before it is accessed. Later, we do set the value as we promised, and then the value access (within the `print` method) happens after the value is set.

Accessing nullable variables

As you would expect, if a variable can have a `null` value, then you will need to check if it is `null` before you use it. For example, suppose we have a variable that stores how many goals a team has scored, but before the match starts, it is set to `null`. The following code would show errors:

```
int? goals;
// Other code
print(goals + 2);
```

The `goals` variable is still potentially `null` at the point of the `print` statement, so adding `2` to `null` is not a valid operation – hence the errors from the Dart compiler.

To solve this problem, you can explicitly check whether the variable is `null` and only access the value if it is not `null`. If it is not `null`, then Dart remembers this and will treat the variable as if it is no longer nullable. For example, the following code is allowed:

```
int? goals;
// Other code
if (goals != null) {
  print(goals + 2);
}
```

During the `if` statement, we checked that the `goals` variable is not `null`. Dart then remembers that this check has taken place and allows for the `print` statement to show `goals` with `2` added to it.

When Dart moved to null safety, it was interesting that the team behind Dart decided to change the language's default behavior. Instead of allowing existing code to work without changes (backward compatibility), they decided that forcing all code developers to re-evaluate their code concerning null safety was important enough that it should be forced upon them. Although this was a relatively painful process at the time, many bugs and code improvements have been made throughout the Flutter ecosystem (applications, plugins, and tooling), meaning Flutter is in an even better position after the switch to null safety.

Built-in types

Dart is a type-safe programming language, which means that when the code is written and compiled, each variable must have a defined type.

Although types are mandatory, type annotations are optional, which means that you don't need to specify the type of a variable when you declare it, so long as Dart can infer the type.

Here are the built-in data types in Dart:

- Numbers (such as `num`, `int`, and `double`)
- Booleans (such as `bool`)
- Collections (such as lists, arrays, and maps)
- Strings and runes (for expressing Unicode characters in a string)

Let's explore each built-in data type in detail, starting with numbers.

Numbers

Dart represents numbers in two ways, outlined as follows:

- `int`: 64-bit signed non-fractional integer values between -2^{63} to $2^{63}-1$. Examples include 27, -1, and 534.
- `double`: Dart represents fractional numeric values with a 64-bit double-precision floating-point number. Examples include 1.0, -57.00001, and 0.2.

Both of them extend the `num` type. Additionally, we have many handy functions in the `dart:math` library to help with calculations, such as the following:

- `Random` to generate a random bool or number
- `Min` or `Max` to find the larger or lesser of two numbers
- Trigonometric functions (sine, cosine, and tangent)

Note that there are some platform-specific behaviors. When running on the web, both `int` and `double` number types are compiled to JavaScript numbers and only allow values between -2^{53} to $2^{53}-1$.

> **BigInt**
>
> Dart also has the `BigInt` type for representing arbitrary precision integers, which means that the size is only limited by your computer's **random-access memory** (**RAM**). This type can be very useful, depending on the context; however, it does not have the same performance as `num` types, so you should carefully consider when to use it.

Booleans

Dart provides two well-known literal values for the `bool` type: `true` and `false`.

Boolean types are simple truth values that can be useful for any logic. Unlike in JavaScript, where everything with a value (except false) is equivalent to true and everything without a value is equivalent to false, Dart is strict about Boolean types and does not follow the same *truthy* and *falsy* approach.

Lists

In Dart, lists cover the functionality of `array` and `List` types present in other programming languages. `List`, as its name suggests, holds a list of values where the ordering of the values is important. For example, a prioritized list of activities or a time-based list of events could be held in a Dart `List`. Each value in the list has a position within the list known as its index.

There are some handy methods to manipulate lists and their values:

- The `[index]` operator allows convenient access to the value at a given index
- The + operator can be used to concatenate two lists by returning a new list with the left operand followed by the right one
- The `add` method can be used to add a value to the end of `List`
- The `length` property can be used to find out how many values are in `List`
- The `remove` method can be used to remove a value from `List`

Note that Dart lists are not naturally length-constrained, as arrays in some languages can be. Lists grow and shrink as needed through the use of the `add` and `remove` methods.

Note that a list should be created using the square brackets literal. Creating a list using the `List` type name is now deprecated. Here are some examples of how to create a `List` type:

```
List dynamicList = []; // Create an empty List
print(dynamicList.length); // Prints 0
dynamicList.add("Hello");
print(dynamicList[0]); // Prints "World"
print(dynamicList.length); // Prints 1
List preFilledDynamicList = [1, 2, 3];
print(preFilledDynamicList[0]); // Prints 1
print(preFilledDynamicList.length); // Prints 3
```

> **Semicolon**
> In the preceding example, each line of code ends with a semicolon. This is required in Dart to show the end of a statement. Statements can be written across multiple lines but must terminate with a semicolon.

During list creation, a length can be set to enforce a fixed size. Lists with a fixed size cannot be expanded, so you need to ensure it is clear that a `List` type has been created with a fixed size. The code to accomplish this is illustrated in the following snippet:

```
List fixedList = List.filled(3, "World");
fixedList.add("Hello"); // Error
fixedList[0] = "Hello";
print(fixedList[0]); // Prints "Hello";
print(fixedList[1]); // Prints "World";
```

The new keyword

In many OO languages, instances of classes such as `List` are created using the `new` keyword. This was also true in the Dart language but is now no longer used. However, note that it is still a reserved keyword, so you cannot name variables `new`.

Maps

Dart maps are dynamic collections for storing key-value pairs, where the retrieval and modification of a value are always performed through its associated key. This is very similar to a `List` except that, instead of a value being found at a specific index, it is found through the key. Both the key and value can be any type. Note that, unlike `List`, generally, `Map` has no concept of value ordering, although some types of Map can be ordered.

There are some handy methods to manipulate elements in maps:

- The `[key]` operator allows for access or to set the value for a given key
- The `length` property can be used to find out how many values are in `Map`
- The `remove` method can be used to remove a key-value pair from `Map`

`Map` should be created using the curly brackets literal. You can see examples of this here:

```
Map nameAgeMap = {}; // Create an empty Map
nameAgeMap["Alice"] = 23;
print(nameAgeMap["Alice"]); // Prints 23
Map preFilledMap = {"Sarah": 1, "Alex": 2};
print(preFilledMap["Sarah"]); // Prints 1
print(preFilledMap.length); // Prints 2
preFilledMap.remove("Alex");
print(preFilledMap.length); // Prints 1
```

Strings

In Dart, strings are a sequence of characters (**Unicode Transformation Format-16** (**UTF-16**) code) that are mainly used to represent text. Dart strings can be single or multiple lines and use matching single or double quotes to wrap the text. You can see an example here:

```
String singleQuoteString = 'Here is a single quote string';
String doubleQuoteString = "Here is a double quote string";
```

Additionally, multiline strings can be created using matching triple single quotes or triple double quotes, as illustrated in the following code snippet:

```
String multiLineString = '''Here is a multi-line single
  quote string''';
```

Note that the indentation on the second line will be included in the created string.

Strings can be concatenated (stuck together) using the plus (+) operator, as illustrated in the following code snippet. In addition, the multiplier (*) operator is used to repeat the string a specified number of times, and the `[index]` operator retrieves the character at the specified index position:

```
String str1 = 'Here is a ';
String str2 = str1 + 'concatenated string';
print(str2); // Prints Here is a concatenated string
print(str2[0]); // Prints the single character 'H'
```

String interpolation

String interpolation (or, as I prefer, variable expansion) is the action of evaluating placeholders within a string and then concatenating the results. Dart has a simple syntax for string interpolation: `${}`.

The dollar (`$`) symbol identifies the placeholders to be evaluated. If this evaluation is a single variable, then the curly brackets can be omitted (and if not omitted, then a warning is shown). For a placeholder that involves more than the evaluation of a single variable, the curly brackets denote the boundary of evaluation.

Here are some examples to explain this concept further:

```
String someString = "Happy string";
print("The string is: $someString");
// prints The string is: Happy string
// No curly brackets were required
print("The string length is: ${someString.length}");
// prints The string length is: 16
// Curly brackets were required
print("The string length is: $someString.length");
// prints The string length is: Happy string.length
// Omitting the curly brackets meant only the variable was evaluated,
not the method on the variable.
```

Dart also has the runes concept to represent UTF-32 bits. For more details, check out the Dart language tour at `https://dart.dev/guides/language/language-tour`.

Literals

A literal is a notation to represent a fixed value. You have likely already used some of these before. Here is a quick recap of literal examples for the common types:

Type	**Literal Example**
`int`	`10` , `1` , `-1` , `5`, and `0`
`double`	`10.1` , `1.2` , `3.123`, and `-1.2`
`bool`	`true` and `false`
`String`	`"Dart"`, `'Dash'`, and `"""multiline String"""`
`List`	`[1, 2, 3]` and `["one", "two", "three"]`
`Map`	`{"key1": "val1", "key2": "val2"}` and `{"Sarah": 1, "Alex": 2}`

Table 1.1 – Literal examples

Sometimes, you want your variable to hold a fixed value that cannot be changed. Let's see how we can do that.

final and const

If you create a variable that should never have the value changed, then you should use **const** or **final** to ensure the value is fixed.

To do so, simply add `final` or `const` at the start of the variable declaration, like this:

```
final String defaultLocation = "Staithes";
const int defaultStars = 3;
```

There are subtle differences between `final` and `const`, mainly around whether the value can be computed at compile time (constant) or runtime (final value). We will not explore these concepts anymore here, and we will exclude `final` and `const` from code examples in many cases to improve brevity. However, the easiest rule for `const` and `final` is that if the IDE tells you to add one of them, then do it.

dynamic and using 'as'

Sometimes you will receive data from a source where the data no type information. An example of this is taking raw Json from an API. In these situations the data will be denoted as **dynamic** and the compiler will allow you to interact with the data however you wish because it has no way of checking if the interaction is valid. As you can imagine, this can lead to runtime failures if the data type is not as expected.

For example, if you call an API using the **dio** package then you will get response data of the type `Map<String, dynamic>` where the `Map` key is the name of the `json` value, and the `Map` value is the contents of the `json` value as a `dynamic` type.

If you are confident that the `dynamic` value is of a certain type then you can tell the compiler using the **as** keyword. From that point onwards the compiler will give you type safety, but it all hinges on the assumption that you have denoted the correct type in the first place. For example, if we know the `id` property of our `json` response is going to be a `String`, then we can tell the compiler by stating the following:

```
final id = json['id'] as String;
```

The `id` variable is now a `String` type allowing compile time type checking. However, if it turns out that the `id` value is nullable and should be of type `String?` then the `as String` will fail at runtime if we have received a null value.

You have now seen how to store data in a type-safe, null-safe, and, when required, immutable way. Now, let's learn how we can manipulate and interrogate that data within our code.

Dart operators

In Dart, operators are nothing more than methods defined in classes with a special syntax. When you use operators such as the equality operator, `x == y`, it is as though you are invoking a method on the `x` variable, `x.==(y)`, to compare equality with the `y` variable. Unlike languages such as Java, which have the concept of a primitive type, `x` is an instance of a class and therefore has its own methods. This means that operators can be overridden so that you can write the logic for them within your classes.

We will look at methods later in this chapter in the *Functions and methods* section, so you may want to refer back to this section when you have a better understanding of methods. However, the concept has been introduced here so that you can appreciate why an operator may serve a different function, depending on the types it is acting on.

Arithmetic operators

Dart comes with typical operators common to many programming languages; this includes the following:

- `+` for addition.
- `-` for subtraction.
- `*` for multiplication.
- `/` for division.
- `~/` for integer division. In Dart, any simple division with `/` results in a double value. To get only the integer part, you would need to make some kind of transformation (that is, typecast) in other programming languages; however, here, the integer division operator does this task.

- `%` for modulo operations (the remainder of integer division).
- `-expression` for negation (which reverses the sign of expression).

Some operators have different behaviors depending on the left operand type; for example, the `+` operator can be used not only to sum variables of the `num` type but also to concatenate strings. This is because, as mentioned at the start of this section, the method they refer to is implemented differently in the different classes of `num` versus `string` types.

Dart also provides shortcut operators to combine an assignment to a variable after another operation. The arithmetic or assignment shortcut operators are `+=`, `-=`, `*=`, `/=`, and `~/=`. Here's an example:

```
int totalGoals = 2;
totalGoals = totalGoals + 3; // Without shortcut
totalGoals += 3; // With shortcut
print("The goal total is: $totalGoals"); // Prints 8
```

Increment and decrement operators

The increment and decrement operators are also common operators and are implemented on numbers, as follows:

- `++var` or `var++` to increment the value of the `var` variable by `1`
- `--var` or `var--` to decrement the value of the `var` variable by `1`

The Dart increment and decrement operators behave similarly to those in other languages. A good application of increment and decrement operators is for counting operations on loops.

Equality and relational operators

The equality Dart operators are as follows:

- `==` checks whether operands are equal
- `!=` checks whether operands are different

For relational tests, the following operators are used:

- `>` checks whether the left operand is greater than the right one
- `<` checks whether the left operand is less than the right one
- `>=` checks whether the left operand is greater than or equal to the right one
- `<=` checks whether the left operand is less than or equal to the right one

In Dart, unlike Java and many other languages, the `==` operator does not compare memory references but rather the content of the variable.

Also, unlike JavaScript, no === operator is required because Dart type safety ensures that the == equality operator can only be used on objects of the same type.

Logical operators

Logical operators in Dart are operators applied to `bool` operands; they can be variables, expressions, or conditions. Additionally, they can be combined with complex expressions by combining the evaluated value of the expression. The provided logical operators are described here:

- `!expression` negates the result of an expression – that is, true to false and false to true
- `||` applies a logical `OR` operation between two expressions
- `&&` applies a logical `AND` operation between two expressions

Now that we know the fundamentals of the Dart programming language, let's take a look at some real code!

Control flows and looping

Before we can finish exploring the `main` method in DartPad, we need to know how to control the flow of code execution. This is done through a series of control flow statements. These are very similar to those in other programming languages, so let's see what they look like in Dart.

if/else

Dart supports the standard `if`, `else if`, `else` decision structure. It also supports `if` statements without curly brackets, which are especially useful during Flutter widget definitions.

In these `if` statements, the next expression is evaluated if the condition is `true`. You can see an example of this in the following code snippet:

```
String winners = "Middlesbrough";
if (winners == "Everton") {
  print("Everton win");
} else if (winners == "Middlesbrough") {
  print("Middlesbrough win");
} else {
  print("Draw");
}
// Prints Middlesbrough win
if (winners == "Middlesbrough")
  print("Middlesbrough win again");
// Prints Middlesbrough win again
```

In the first example, we have initialized a variable called `winners` and assigned it a `String` value of `"Middlesbrough"`. We then use an `if/else` statement to compare the value against the `String` literal, `"Everton"`, which will fail the comparison.

The code execution then moves to the first `else` statement because the first comparison is evaluated to the `false` Boolean value and will evaluate the `if` statement defined in that `else` statement to check against the `String` literal, `"Middlesbrough"`. This combination of `else` followed by `if` is called an **else-if** statement, and you can have as many of these in an **if-else** statement as you require.

The `winners == "Middlesbrough"` condition evaluates to the `true` Boolean value, so code execution enters that branch of the code and prints `"Middlesbrough win"` and then ends execution of the `if/else` statement, moving execution below the final `else` statement.

However, if this comparison had also been evaluated as the `false` Boolean value, then we would finally have had a catch-all `else` statement that would have been executed regardless of the variable's value.

In the second `if` statement, we evaluate the `winners == "Middlesbrough"` condition again, but this time, we do not wrap the code branch in curly brackets. The line immediately after the `if` statement is run, printing `"Middlesbrough win again"`.

These `if/else` structures should be familiar to you if you have worked with other programming languages.

As mentioned previously, Dart does not deal with *truthy* and *falsy* concepts, unlike JavaScript. All conditions must evaluate to Boolean values, as illustrated in the following code snippet:

```
String test = "true";
if (test) { // Creates a compilation error
  print("Truthy");
}
```

This example will not compile because `test` is not a **Boolean**, so the condition does not evaluate to a Boolean value.

> **Equality checking and type coercion**
>
> In languages such as JavaScript, the equality of two variables can be checked either with the double equals or the triple equals operator, where the former checks whether the values match after attempting to coerce them to a similar type, and the latter checks whether both the values and their type match. For example, in JavaScript, `"7" == 7` evaluates to true, but `"7" === 7` evaluates to false. This can lead to unexpected bugs and is not an approach that many programming languages follow because of this. Dart only has the double equals operator and does not do type coercion.

while and do-while loops

`while` and `do-while` control flows loop on a specific piece of code while their condition evaluates to true; when their condition evaluates to false, the loop is exited and code execution continues after the loop.

A do-while loop differs from a while loop by having the condition evaluated at the end of the first loop, therefore ensuring at least one execution of the code contained inside.

Let's look at some examples:

```
int counter = 0;
while (counter < 2) {
  print(counter);
  counter++;
}
// Prints 0, 1
do {
  print(counter);
  counter++;
} while (counter < 2);
// Prints 2
```

The `counter` variable is initialized as an `int` type and is assigned a value of `0`. The code flow then enters the `while` loop and the condition is evaluated. At this point, the `counter` variable has a value less than `2`, so the flow enters the loop, printing the `counter` value and incrementing the `counter` variable.

After completing the loop code, the loop condition is re-evaluated – again, the `counter` variable has a value less than `2`, so the flow enters the loop again.

Finally, the value of the `counter` variable is `2`, so the loop condition evaluates to `false` and the code flow moves after the end of the loop.

The flow then enters the `do/while` loop. There is no conditional check at the start of the `do/while` loop, so the code in the loop is executed. At the end of the loop, the condition is checked and evaluates to `false`, meaning the loop is exited.

for loops

`for` loops follow this standard structure:

```
for (initialize; loop_condition; modify) {}
```

This can be broken down like so:

- `initialize`, where variables are initialized to manage the iteration
- `loop_condition`, where looping continues only if the condition evaluates to `true`
- `modify`, where variables can be modified on each loop to track progression

The following example will help make this clearer:

```
for (int index = 0; index < 2; index++) {
    print(index);
}
// Prints 0, 1
```

In the preceding example, the `index` variable is initialized to `0`, and `loop_ condition` is evaluated to `true`. On each subsequent iteration, the `index` variable is incremented by `1` and then `loop_ condition` is re-evaluated, first to `true` and then to `false` when `index` reaches `2`.

break and continue

Sometimes, it can be tricky to break out of a loop or start the next iteration of a loop without creating confusing code to manipulate the condition.

Adding a `break` statement to a loop allows you to jump out of the loop immediately, while adding a `continue` statement allows you to start the next iteration of the loop immediately.

Here is an example to help clarify this:

```
int counter = 0;
while (counter < 10) {
  counter++;
  if (counter == 4) {
    break;
  } else if (counter == 2) {
    continue;
  }
  print(counter);
}
// Prints 1, 3
```

In the preceding example, on the first iteration, the counter variable is incremented to `1`; neither of the `if` conditions evaluate to true, so the value is printed.

On the second iteration, the counter variable is incremented to `2`, so the `continue` statement is called before the `print` statement, jumping code execution to the next iteration of the loop.

On the third iteration, the counter is incremented to `3`; neither of the `if` conditions evaluate to true, so the value is printed.

On the fourth iteration, the counter variable is incremented to `4` and the `break` statement is called, breaking out of the loop and ending the code.

switch

The Dart **switch** statement allows you to branch your code based on the value of a variable. This is similar to an `if/else` construct but does have to offer some additional compile time checking if you want to branch on a specific set of values and want to ensure you have a code branch for each value. These specific sets of values are known as enums, and we will look at them in *Chapter 4*, *Dart Classes and Constructs*. A `switch` statement takes a variable and then defines a code branch for each possible value of the variable.

Here is an example to show how this looks:

```
String location = ...
switch(location) {
  case "Whitby":
    // Show Whitby information
    break;
  case "Saltburn":
    // Show Saltburn information
    break;
  default:
    // Show error message, no location information found
}
```

I've always found the syntax of the `switch` statement a little inconsistent with other constructs and it is also a constant source of bugs, so let's take a deeper look at the statement.

There are several key parts to a `switch` statement:

- On the second line, we define that we are using a `switch` statement and using the `location` variable to control our code flow.
- On the third line, we specify a **case**. This `case` takes a value to compare the `switch` variable against and if it matches, we enter the code block immediately afterwards. In this specific case, if the `location` variable has the `"Whitby"` value, then we will run the code. You can have as many `case` blocks as you wish, but the `case` comparison value cannot itself be a variable; only `switch` can take a variable.

- The most dangerous part of the `switch` statement comes on the fifth line, where we have a `break` statement (just like we saw for loops). This moves code execution out of the `switch` statement to continue after the end of the `switch` block. If you do not have a `break` statement, then code execution will continue to the next `case` block (or the `default` block), which can give complex and difficult-to-diagnose problems. Remember your `break` statements!
- Finally, on line 9, we have a `default` block. If the variable hasn't matched any of the previous `case` blocks (or you have forgotten your `break` statements), then the `default` block will run. The `default` block is optional.

In *Chapter 5*, *Building Your User Interface through Widgets*, we will see a good example of using `switch`.

Hands-on, continued

Let's look back at the DartPad `main` method. More of it should make sense to us now. You can see a representation of it here:

```
void main() {
  for (int i = 0; i < 5; i++) {
    print('hello ${i + 1}');
  }
}
```

We explored the surrounding `main` function previously, but the code inside the function should now also be familiar to you.

We have learned about `for` loops, and in this code snippet, the `for` loop initializes the `i` variable to 0 and then loops until `i` reaches a value of `5`, incrementing the value of `i` on each iteration.

Within the `for` loop, we have a `print` function. This function simply prints text to the Terminal. As a `print` statement argument, we can see some string interpolation. This evaluates the value of `i + 1` and then concatenates it on the end of `hello` to make a **string** for printing to the screen.

We briefly looked at the `main` function and how that is structured. We've now encountered the `print` function as well, so now is a good point to look at functions and their parameters.

Functions and methods

As we discussed previously, functions and methods are self-contained chunks of code that work on a specific task. Note that the syntax of methods and functions is identical, so where I refer to functions in this section, I am also referring to methods. Let's look at another example of a function:

```
String sayHello() {
  return "Hello world!";
}
```

This `sayHello` function structure is very similar to the `main` function we explored previously but also includes a return type of `String`, so the function must have a `return` statement at the end that returns a value of the expected type. In this example, the function returns a `String` literal of `"Hello world!"`. If the function could return a `String` literal or `null`, then, as we saw in the *Null safety* section, we would mark the function's return type as `String`.

Note that the function's return type can be omitted because the Dart analyzer can infer the return type from the `return` statement. If no `return` statement is provided, it assumes the function returns a **dynamic** type. If you want to tell the analyzer that the function will never return anything, you should mark it as `void`, as we saw in the `main` method earlier. Note that it is preferable to include the return type on the function signature to ensure that the code is easily understood and maintainable in the long term.

Try adding the `sayHello` function in DartPad; then, in the `main` method, replace the `for` loop with a call to the `sayHello` function so that it looks something like this:

```
void main() {
  String helloMessage = sayHello();
  print(helloMessage);
}
String sayHello() {
  return "Hello world!";
}
```

In this example, the `sayHello` function is a top-level function – in other words, it does not need a class to exist. Although Dart is an OO language, it is not necessary to write classes to encapsulate functions.

Run this in DartPad; you should see `"Hello world!"`. Congratulations – you just wrote and ran your first Dart code successfully!

It feels as though we've been saying hello to the world a lot in this chapter, but we've learned a lot about the Dart language. However, we still haven't explored what can go in those brackets that define the input data for the function. Let's take a look at that now.

Function parameters

A function can have two types of parameters: optional and required. Additionally, these parameters can be named instead of positional to make the code more readable. This is especially true in Flutter, where widgets can have lots of optional parameters, so identifying which argument is for which parameter is critical to understanding the code and diagnosing issues.

> **Parameter versus argument**
>
> The term **parameter** refers to the entries in the function signature that define the input data types and names. An argument is the data that's passed to the function when it is called from another point in the code. The argument types when calling the function must match the parameter types on the function definition, either directly or through polymorphism. This is something we will explore in *Chapter 4*, *Dart Classes and Constructs*.

A parameter's type doesn't need to be specified; in this case, the parameter assumes the **dynamic** type. Again, for long-term code readability and maintainability, adding parameter types is highly preferable.

Required positional parameters

This simple function definition can be achieved by defining positional parameters. This is the most common approach in other programming languages, so you will probably already be confident with this approach. The parameters are listed in order, and the arguments are supplied when calling the function and simply match the same ordering.

In the following function, both `name` and `age` are required positional parameters, so the caller must specify matching arguments in the same order when calling it:

```
sayHappyBirthday(String name, int age) {
  return "$name is ${age.toString()} years old";
}
```

To call this function, you need something similar to this:

```
sayHappyBirthday("Laura", 21);
```

Optional positional parameters

Sometimes, not all parameters need to be mandatory for a function, so you can specify optional parameters on the function signature as well. The optional positional parameter definition is specified using the `[ ]` syntax. Optional positional parameters must go after all of the required positional parameters, as follows:

```
sayHappyBirthday(String name, [int? age]) {
  return "$name is $age years old";
}
```

If you run the preceding code without passing a value for `age`, you will see `null` in the returned string. When an optional parameter is not specified, the default value is `null`, hence the type definition needs to include a `?` character to show it could be `null`. To help with this, you can specify default values for optional positional parameters.

To define a default value for a parameter, simply initialize the parameter value directly in the parameter definition, as illustrated in the following code snippet. This will be overwritten if the caller supplies an argument for that parameter:

```
sayHappyBirthday(String name, [int age = 21]) {
  return "Happy birthday $name! You are $age years old.";
}
```

Not specifying the parameter results in printing the default message, as follows:

```
void main() {
  var hello = sayHappyBirthday('Robert');
  print(hello);
}
// Prints Happy birthday Robert! You are 21 years old.
```

Named parameters

Named parameter definitions are specified using the { } syntax. These definitions must also go after all the required parameters. As with optional positioned parameters, named parameters can have a default value, as illustrated in the following code snippet:

```
sayHappyBirthday(String name, {int age = 7}) {
  return "Happy birthday $name! You are $age years old.";
}
```

To specify a value for `age`, the caller must include the name of the optional named parameter, as follows:

```
sayHappyBirthday("Laura", age: 21);
```

By default, named parameters are optional; the calling function does not need to include an argument to match the parameter. However, named parameters can be specified as required by marking them with `required`, as illustrated in the following code snippet:

```
sayHappyBirthday(String name, {required int age}) {
  return "Happy birthday $name! You are $age years old.";
}
```

If the caller does not include the `age` named parameter in its arguments, then the Dart analyzer will show an error against the calling code.

Records

A feature new to Dart 3 is the concept of a Record. It is a new data type that is much like a collection and allows you to group a set of objects into one object. What makes the Record type so useful is that it has full type safety on the values within it.

The syntax for defining a Record is very similar to the syntax of a function's parameters:

```
(type1, type2, {<typex> namex})
```

It can hold a mix of positional values and named values, such as the parameters of a function.

For example, if you want to define a variable of the Record type that holds a string and an integer, you would write the following:

```
(String, int) myVariable;
```

You can then assign values to your variable, similar to how you would pass arguments to a function:

```
myVariable = ("Whitby", 3);
```

Named values follow a similar format with curly brackets:

```
({String place, int distance}) myVariable;
```

They are assigned values similarly:

```
myVariable = (place: "Whitby", distance: 3);
```

The real power of Record is that using this data type allows you to define multiple return values from a function in the same way that you can define multiple parameters for a function.

For example, suppose you want to get the score for a football match broken down into the team names and scores. Before Dart had the Record type, this would have involved creating a specific class to hold the information that could be used as the return type of the function. Now, a Record can be used as the return type:

```
(String, int, String, int) getFinalScore() {
  return ("Middlesbrough", 4, "Manchester City", 0);
}
```

You can then call this method and store the values in a variable, which you can access using the index numbers:

```
var finalScore = getFinalScore();
var homeTeam = finalScore.$1;
```

For cleaner code, you can name the parts of the Record that are being returned (known as destructuring):

```
var (homeTeam, homeScore, awayTeam, awayScore) =
   getFinalScore();
print(homeTeam);
```

As you can see, the Record type is a huge benefit to the Dart language and will likely see much usage in Dart 3 code.

Function as a type

In Dart, `Function` is a type, like `String` or `num`. This means that it can also be assigned to fields or local variables or passed as parameters to other functions. Consider the following change to the `main` method:

```
void main() {
  var helloFunction = sayHello;
  String helloMessage = helloFunction();
  print(helloMessage);
}
```

The `helloFunction` variable is assigned a reference to the `sayHello` function and therefore can be invoked just like calling the `sayHello` function – that is, by calling `helloFunction()`.

Anonymous functions

An anonymous function is a function that doesn't have a name; it is also called a Lambda or closure. Using the `forEach()` function on `List` is a good example of this; we need to pass a function to it that will be executed with each of the list collection elements, as follows:

```
void main() {
  List list = [1, 2, 3, 4];
  list.forEach((number) => print('hello $number'));
}
```

In this code, we have passed in the anonymous function:

```
(number) => print('hello $number')
```

Using `=>`, which is known as the arrow operator (you can read it as "returns"), the anonymous function takes a single parameter, `number`, and runs a `print` operation that returns nothing.

Our anonymous function receives an item from the list as a parameter and prints the parameter.

Lexical scope

Dart is lexically scoped, meaning that the layout of the code determines the scope for variables. So, inner functions can access variables up to the global level, as illustrated in the following code snippet:

```
globalFunction() {
  print("Top-level globalFunction");
}
```

```
simpleFunction() {
  print("SimpleFunction");
  globalFunction() {
    print("Nested globalFunction");
  }
  globalFunction();
}
main() {
  simpleFunction();
  globalFunction();
}
```

When `main` calls `simpleFunction`, then the nested `globalFunction` function is defined, blocking access to the top-level `globalFunction` function. When `globalFunction` is called, it is the nested version that is called.

In contrast, when the `main` function calls the `globalFunction` function, the top-level `globalFunction` function is called because, in this scope, the nested `globalFunction` function from `simpleFunction` is not defined.

Hence, the output from calling the `main` method is this:

```
simpleFunction
Nested globalFunction
Top-level globalFunction
```

Summary

In this chapter, we presented some tools to help you start your Dart language studies, discovered what a basic Dart program looks like, and learned about the basic Dart code structure.

We also demonstrated how the Dart SDK works and the tools it provides that help with Flutter application development and make the Flutter framework succeed in its objectives.

Finally, we reviewed some important concepts of the Dart language, looked at the data types available, saw how null safety is a key part of variable data types, investigated functions and their range of parameter specifications such as named/positional and optional/required, and explored how to control code execution flow.

There are still large areas of the Dart language that we haven't yet explored, and these will be introduced as we progress through this book. However, you now have sufficient knowledge of Dart to get up and running and build your first Flutter application – exciting, isn't it?

In the next chapter, we will have a break from the low-level details and provide a high-level view of how Flutter compares to the other frameworks available to application developers.

Questions

There has been a lot of learning in this chapter, so use these questions as an opportunity to identify any areas that are worth revisiting. Additionally, after you have read some of the later chapters, pop back here to review your base Dart knowledge:

1. Which function is used to initialize the execution of a Dart program?
2. Explain the benefits that type safety, and the extension of null safety, bring to the Dart language.
3. Describe the structure of a variable declaration and how to subsequently change a variable's value.
4. List some of the built-in data types that are available (hint – one of the data types is mentioned in this question!).
5. What are the three main control flow loop types that Dart supports, and how would you jump out of a loop?
6. Like many other programming languages, there are required and optional parameters for functions. What is the other type of parameter that is available in Dart, and how would you use it?

Further reading

We are only halfway through our learning of the Dart programming language, so it is probably not a good idea to do wider learning of the language until we complete *Chapter 4*, *Dart Classes and Constructs*.

However, exploring the history of the language will give you a better appreciation of some of the design choices that were made.

For example, the blog article *The Fall and Rise of Dart, Google's 'JavaScript Killer'*, by David Bolton is a worthwhile read, as is *4 reasons Dart is still a language worth learning*, by Kerry Doyle.

Both of these articles can be found from a simple web search, and I recommend you do a bit of digging around on the web to get other opinions on the evolution of the language, both good and bad.

3

Flutter versus Other Frameworks

Making a technology choice is rarely simple, and generally requires an understanding of the pros and cons of the different options, and eventually a leap of faith. You may be at the point where you are deciding whether your next project is going to be Flutter-based, you may have dabbled with Flutter and want to solidify your knowledge before pushing forward with it, or you may be experienced and want a knowledge refresher. Regardless of your experience, it is always useful to understand the technology landscape and understand synergies between different frameworks.

In this chapter, you will see how Flutter compares to other frameworks: the similarities and differences, the pros and cons of the different options, and how existing knowledge of another framework can be applied to Flutter. Even if you have fully decided on using Flutter in the future, it is worth reviewing this chapter as it gives context to some of the design decisions that have been made.

The following topics will be covered in this chapter:

- Native development
- Cross-platform frameworks
- Flutter community
- Flutter strengths and weaknesses
- Live Flutter apps

Native development

Often cited as the purest solution, **native development** refers to writing apps in the language common to the platform of the device. For iOS, this is Swift (or previously, Objective-C); for Android, it is Kotlin (or previously, Java); and for the web, it is generally HTML/JavaScript:

Figure 3.1 – Swift and Kotlin logos

Native is seen as the purest solution because there is no bridge between the app and the platform – that is, there is no transpilation of code. Therefore, the code that is developed is the code that is run and talks directly to the features available from the platform, be that iOS, Android, or a web browser.

> **What is transpilation?**
>
> Transpilation of code is the idea of taking code written in one programming language and converting it into code written in another programming language. An example that you may have come across is TypeScript, which transpiles into JavaScript. This is done because web browsers are designed to run code in JavaScript, not TypeScript, so the conversion needs to be done after the TypeScript code has been written so that it can be run in web browsers.

Once you move away from native development, you introduce certain risks, such as the following:

- The software bridge has slow performance
- The software bridge or code transpilation process has deep, difficult-to-diagnose bugs
- A lack of access to key platform features
- A lack of first-class support from the platform manufacturer

The latter two are worth considering further. When Google moved Android app development from Java to Kotlin, they supplied tutorials and tooling to assist with the move. They ensured that Kotlin had similar or better access to platform features and that there was a solid migration path for developers to follow.

Google would be less invested in helping developers that perhaps used a niche development framework that transpiled to Java, so those developers would be reliant on their framework community modifying the framework and supplying a migration path.

Similarly, if phones are released with new platform features such as augmented reality, it is the native languages that are likely to get access to these features first.

Therefore, it is critically important that the quality of alternatives is assessed when you're moving away from native programming because a fundamental problem in an alternative framework or lack of support for a platform feature can block and even invalidate an app.

Learning from experience 1

A real-world example of a framework problem invalidating an app happened to me a few years ago before Flutter was created. We were using another cross-platform solution and were developing and testing on iOS. The framework effectively used a software bridge by embedding a web browser in the app, with the app running within the embedded web browser (we will see examples of this later). Once the app was nearing completion, we started testing on Android and found that the software bridge had serious performance issues that were fundamental and so serious that they could not be solved. After much heartache, the app was eventually only released on iOS, and an important lesson had been learned!

So, if native development is likely to have the best performance, the least chance of fundamental issues, initial access to new features, and is the least likely to have deep bugs, why would you ever move away from native? There are many reasons, but like I said earlier, a technology decision is rarely clear-cut. Let's explore the many factors that can contribute to deciding to move away from native programming.

Developer skillset

The technology choices for many software projects are, sadly, not decided by carefully considering the different technology options and cross-referencing them against expected development timelines, with performance benchmarks and UI studies brought to bear. Let's be honest – most technology choices are either based on the skillset available or the skillset that developers would like to learn next.

Learning a new programming language and framework will delay a project, sometimes seriously, and the code developed early in the project will be rewritten many times as developers learn to structure their code better, encounter different design methodologies, and optimize the execution flows.

This initial delay has to be taken into account when assessing technology choices; the best technology choice may not be the best project choice. If you already have a pool of developers, then the benefits of a technology change may be more than consumed by the reduction in productivity.

On the flip side, native developers tend to be more expensive and in higher demand than developers for other technologies. Additionally, learning a new skill set may initially reduce productivity, but for longer-running projects, you would expect productivity to recover.

Project management

Unless you are developing for one platform, you will need several teams of developers to develop natively. This is because a Swift developer is generally not also a Kotlin developer, or if they are, the context-switching between the two languages and development environments can seriously impact productivity.

Project-managing several development teams where the resources are not fungible (that is, you cannot move a developer from one team to another) can lead to complications in ensuring feature parity and defect resolution.

For example, suppose that there is an iOS development team and an Android development team working on the same backlog of features for an app, aiming for a shared release date.

Imagine that the iOS development team encounters a defect that is complex to diagnose and fix, while the Android development team continues development at a high velocity. As the release deadline approaches, the Android team has many more features completed than the iOS team. At this point, the project manager has to earn their money by deciding whether to do the following:

- Release the apps without feature parity. This can be a confusing experience for users who have multiple devices.
- Delay release until the iOS team catches up. What do you do with the Android team during this time? They will likely tidy up their code, fix more minor bugs, and do more extensive testing, leaving the Android code base in a much better state than the iOS code base, leading to further productivity differences going forward.
- Disable features on the Android version. This is not necessarily an easy option if, as is normally the case, the features are inter-connected, and also likely to introduce bugs going forward unless the feature that's been disabled is given time to be coded fully.

None of these options are optimal and are exacerbated if you are also developing for additional platforms such as the web.

Contrast this with a single code base where one, or many, development teams are working in the same language, development environment, and backlog of features. If there are multiple teams, then the developers are much more fungible; if one team is struggling with a feature, then a developer can more easily switch teams and assist with the development.

Defect reports

Similar to the project management considerations, having native apps will lead to disparities in defect reports. One development team may have done less testing than the other, so upon release, the app on one platform may be inundated with defect reports, while an app on another platform may be relatively defect-free.

Additionally, you now need to know which platform the user is using to know which app has the bug. In some circumstances, such as crash reporting, this isn't such an issue. However, the vaguer ways of identifying defects, such as a comment on a forum or social media, will likely not surface that information, leading to a more complex identification and resolution of the defect.

Performance

Measuring performance is notoriously difficult. Do you look at benchmarks that only exercise certain parts of the framework or programming language, or higher-level performance, which can highly depend on the app structure, how the framework has been employed, and the kinds of tasks the app is doing? Therefore, in this chapter, generalities will be used simply as a guide.

However, it is generally accepted that native apps are the fastest and it is pretty clear why. The language and framework are optimized for the platform and vice versa.

Also, and equally importantly, there are no cross-platform compromises that need to be made. To make a framework completely cross-platform means that the app code may interact with the platform in a suboptimal way so that a single piece of code can work with all platforms.

For example, to use a feature, there may only need to be a single method call, but to use the same feature on Android, several method calls might be required. Depending on how this interaction is surfaced to the developer, it may lead to suboptimal performance.

However, it is worth noting that in some situations, Flutter has been seen to be comparable with native on performance, and it doesn't appear to be an issue that is mentioned within the Flutter community.

Platform features

Native apps have access to all the features of the platform; otherwise, by definition, they can't be a feature of the platform because they would never be used.

Cross-platform solutions such as Flutter generally expose platform features through plugins. We will explore Flutter plugins later in this book, but as a quick overview, many plugins will interact directly with platform features and expose them to the app developer in a platform-agnostic way. In Flutter, there is a vibrant community creating plugins. These can be viewed in the package repository at `https://pub.dev`.

> **Plugins versus packages**
>
> In Flutter, you can add plugins and packages to your project from the package repository.
>
> A plugin in Flutter is a platform-specific implementation that provides access to native code and APIs. Plugins are typically used to integrate specific device features or third-party libraries into a Flutter application.
>
> A package in Flutter refers to a collection of Dart code files and resources that provide specific functionality or reusable components. Packages are used to encapsulate and share code that can be easily integrated into Flutter projects. Packages can contain widgets, utility classes, helper functions, networking modules, and more.
>
> You will often use a mix of plugins and packages in your Flutter projects, but the terms "plugin" and "package" are somewhat interchangeable, so don't worry about the difference.

As you can imagine, in the early days of Flutter, there were not necessarily plugins available for every platform feature, or the plugins available may not have supported the platform that you require. This is generally not an issue anymore, especially as there are often many plugins available that have similar functionality. However, given the open nature of Flutter, if you find there is no plugin available for your needs, then you are still able to write your own plugin. And, if the plugin solves a common problem, you will likely find that other developers are keen to assist in the development and maintenance of the plugin.

Another consideration is that some platforms offer features that are not available on other platforms. For example, a mobile device will have different capabilities from a browser. In this case, a plugin may have been created, but it will be unable to be platform-agnostic due to the feature inconsistencies. In this instance, you may need to include platform-specific code in your app. However, many plugin developers will design their plugin to allow you to interrogate the plugin to see if a feature is available on the current platform, allowing your code to be feature-specific and platform-agnostic.

Hot reload

One of the most awesome features of Flutter is hot reload – that is, the ability to make changes to the code and see it instantly update on the device without your state being changed. This is hugely beneficial in software development; anything that reduces the time between code and feedback allows the developer to achieve flow more easily.

Android has a feature that appears similar, called Instant Run. However, under the covers, it works in a quite different way. Instead of using the JIT approach of Flutter, Android Studio compiles the changes and then tries to update as little as possible on the device. Often, this leads to large changes and sometimes, a full rebuild of the whole app.

At the time of writing, iOS development with Swift does not have an equivalent to Flutter hot reload. There are ways to preview in XCode without running the full app, but this is much more limited than the Flutter approach.

User experience

Certain expectations of design differ between users of different platforms. For example, many apps have design differences between iOS, Android, and the web. Developing native apps allows you to design your code around these considerations, whereas in cross-platform development, you may need to have platform-specific code.

Flutter caters to this to some degree by having platform considerations embedded into the built-in widgets. For example, the back button on the **AppBar** (the top bar on the app) changes styling depending on the platform. These are known as adaptive icons, and there are quite a few icons that have direct support for the adaptive property, allowing Flutter to automatically switch to a platform-specific icon as required.

However, if you want the actual user experience to be different on different platforms (that is, the flow and interactions), then platform-specific code will need to be added. This is relatively pain-free on Flutter (we will see this in later chapters) but can lead to platform-specific bugs, so this must be a consideration.

App size

A very basic native app can often be less than 1 MB.

A minimal Flutter app has to hold the core engine (circa 3 MB), framework, and app code (circa 1 MB), as well as other files (circa 1 MB), meaning a basic Flutter app starts at 5 MB.

For larger apps, this is unlikely to be an issue because the relative size of the core engine and framework will be relatively smaller, but for very lightweight apps, it should be a consideration.

New platforms

There have been and will probably continue to be attempts to enter the mobile devices market with new platforms. An example of this is Huawei (a prolific mobile device seller), which is attempting to move from the Android platform to its own HarmonyOS platform. Additionally, they are planning to share this platform with other device makers.

Creating a development team to develop apps for a new platform can be a hugely expensive risk because the platform may not get much traction and it may be a development dead-end. However, the benefits of getting onto a platform early can be huge because there is likely to be a lack of competition.

With a cross-platform framework, if the framework is updated to support the new platform, then it can be incredibly easy to release on the new platform with very little development needed. It hugely reduces the risk of moving to the new platform while keeping the potential upside.

Unfortunately, though, if the framework is not updated to support the new platform, then you have no path to move your cross-platform app to the new platform. Note that in this situation, you are not in a worse position than having native apps; in both scenarios, you would need to create a new app natively for the new platform.

Retired platforms

On the flip side, platforms can look promising and then fail. The most notable of these was the Windows Phone by Microsoft, which struggled to get market share due to a lack of apps in its store and was eventually retired when Microsoft changed its priorities.

Being locked into a platform as it begins to fail not only impacts the success of the app on that platform but also leads to complicated political discussions:

- Should we continue to develop on that platform to keep feature parity?
- Will the platform recover? Constant analysis of the platform's sales and market share distracts from product creation.
- Should we retire the app from the platform? Will that lose us customers who will eventually move to a platform that we still support?

With a cross-platform solution, these discussion points become relatively redundant. You can continue to release new versions of your app on the failing platform for a much longer period because the features developed will be used for all platforms. There is a requirement to test on the platform, but again, this is somewhat alleviated because a lot of the testing will be carried out on other platforms anyway.

> **Learning from experience 2**
>
> When Windows Phone first arrived, I was keen to release a football (soccer) app into what I believed to be a fast-growing market. I used the native Microsoft framework **XNA** for app development and produced **SoccerTime**. As mentioned previously, there was initially a lack of competitors, so the app grew quickly. Sadly, as we all know, the platform failed, and the lock-in meant I couldn't port to iOS and Android. **SoccerTime** was no more! Interestingly, it looks like the community converted XNA into a cross-platform solution called **Monogame**, an interesting twist on the native versus cross-platform debate.

Development resources

The final aspect that we will consider is the developer resource requirements of the different options. As mentioned previously, fungibility is a key factor for resource requirements. However, if you look at overall developer needs, you can almost halve the resource requirements for a cross-platform solution such as Flutter compared to two native platform developments (and this improves further as you include more platforms). When developing on Flutter, you will generally write one set of code and then test it on the different platforms.

Your testing needs are also reduced compared to native development because on native, each code base will have its own set of bugs, whereas, on Flutter, a bug found and fixed on one platform is also fixed on other platforms. Additionally, usability issues identified on one platform only need to be improved once, fixing usability on all platforms.

This consideration is what makes cross-platform, and specifically Flutter, a very compelling decision for smaller development teams within a larger non-tech-focused company, or within a start-up with limited resources.

Overview

Let's provide a quick recap of the pros and cons of using native over cross-platform.

Pros:

- Performance
- Full platform feature access
- Closer alignment with the expected user experience

Cons:

- Multiple code bases:
  - Multiple development teams
  - Lack of fungibility
  - Disparate defect reports
- Feature parity complexities and alignment on product vision
- Expense to move to a new platform
- Complexities of moving off a failing platform
- Different platforms, different features
- Increased developer resources

Hopefully, you are sold on the idea of developing cross-platform but you also now understand the considerations and trade-offs of that decision. So, what alternatives are there to Flutter? Well, let's look at them in the next section.

Cross-platform frameworks

Let's look at a few alternative frameworks. There are quite a few options, but many are based on three core approaches: React Native, Cordova, and Xamarin.

React Native

The most common cross-platform framework before Flutter was released was React Native. Like Flutter, React Native is open source, and like Flutter, it is backed by a big software development company in the form of Facebook:

Figure 3.2 – React Native logo

It is a popular framework mainly because it reuses the technologies and methodologies of the React web framework. There is a very healthy React Native community that takes the framework forward and produces plugins for different platforms. Also, given the greater maturity of the framework, there is likely to be a greater wealth of plugin support and documentation available.

Technology-wise, React Native uses JavaScript for the app's general look and feel, and then Java or Swift to write native modules for the more complex features, such as image editing. The motto of the framework is "Learn once, write anywhere" unlike the Flutter vision of writing once and running everywhere. This is because the native modules are not reusable across the platforms, leading to different code bases.

Like Flutter, React Native has hot reloading, allowing fast development and iterations of app code.

Performance-wise, the general view seems to be that React Native is slower than Flutter. There are many reasons for this, but the fact that Flutter is compiled to native libraries whereas React Native has a JavaScript layer seems to be a key contributor. However, with such a variety of app designs, it is hard to make anything other than generalizations.

Interestingly, in the 2022 Stack Overflow survey, Flutter was noted as the 5th most loved framework, whereas React Native was noted as the 16th. Enjoying the process of coding is a huge aspect of productivity, so this is an important aspect to take into account.

Moving to Flutter from React Native

Flutter uses reactive-style views, with widgets being comparable to React components. This similarity makes it relatively easy for a React Native (or general React web) developer to understand the state, build, and `setState` aspects of Flutter.

Some key language differences between JavaScript and Dart, the programming language used by Flutter, are as follows:

- Unlike Javascript, Dart is a type-safe language, so variables must be declared with a type or the type system can infer the type. Note that React Native supports TypeScript, which does offer type-safety features.
- Dart has no concept of `undefined`. Either a variable has a value or it is null.
- Dart has no concept of truthy. Only a Boolean value of `true` is treated as a true value.

- The Javascript **Promise** is represented by the Dart **Future** object. The async and await operators act on Futures as they do on Promises in JavaScript.
- Printing to the console uses the `print()` method instead of `console.log()`.

For more details, the Flutter documentation gives a great overview of transitioning from React Native to Flutter: `https://flutter.dev/docs/get-started/flutter-for/react-native-devs`.

Xamarin

Much like React and Flutter, Xamarin is open source and backed by a big technology company – in this case, Microsoft:

Figure 3.3 – Xamarin logo

Xamarin uses .NET technologies and the C# programming language. When using Xamarin Native, you get all the performance benefits of native apps, but the user interface code is platform-specific, so roughly 75% of the code base is shared. This means knowledge of native languages is required in addition to Xamarin.

With Xamarin.Forms, a separate product that replaces the platform-specific user interface code, code sharing can be increased. However, note that Xamarin.Forms is being retired soon and replaced with the **Multi-Platform App UI** (**MAUI**).

Like React Native and Flutter, Xamarin supports hot reloading to allow faster rebuilding and testing.

Considerations for the Xamarin approach are that the licenses can be expensive, especially for an enterprise. Additionally, the Xamarin community is much smaller than the React Native and Flutter communities, which can restrict available developers and community support.

Moving to Flutter from Xamarin.Forms

The Xamarin.Forms Page concept is similar to the Route concept in Flutter. So, a Route will lead from one Page to another Page.

However, the key difference is that everything is a widget in Flutter. So, where a ContentPage will contain elements such as Entry or Button, in Flutter, the page is a widget that contains nested widgets. One of the nested widgets may draw an input field or a button.

Again, the Flutter documentation does a great job of explaining how to migrate to Flutter: `https://flutter.dev/docs/get-started/flutter-for/xamarin-forms-devs`.

Cordova

Apache Cordova takes the web technologies of HTML, CSS, and JavaScript and allows them to run on mobile apps. Formerly PhoneGap, Cordova is itself more of a platform that allows frameworks to run within it, such as Ionic:

Figure 3.4 – Apache Cordova logo

Effectively, the Cordova app runs within a WebView, which is like a built-in browser for each platform. This means that, unlike React Native and Xamarin, all the code is cross-platform. However, a major issue is that the WebView implementations for different platforms can be subtly different, leading to inconsistencies and bugs in the user interface.

Additionally, depending on WebView performance, the app can run slowly, especially on graphic-intense apps. As an added complication, the WebView can be different on different versions of the platform, so performance and the user interface can be different on different versions of the platform. This can be especially true on the Android platform.

Moving to Flutter from Cordova

One key difference you will notice immediately is that Flutter styling is embedded within the widget, rather than declared in a separate style document such as CSS.

This has many benefits, with the main one being that the mental load that is put on the developer is hugely reduced as there is one less language to contend with.

The layout of widgets does not quite match the expectations of web developers. The number of times I've caused overflows because I've reverted to the web layout way of thinking is painful.

Again, there is excellent documentation on the Flutter site to guide you through the differences: `https://flutter.dev/docs/get-started/flutter-for/web-devs`.

Framework popularity

When choosing a framework, it is important to know the popularity of that framework so that you can assess whether the framework will have long-term support.

A common way to assess popularity is to look at the Stack Overflow trends report. This shows how many Stack Overflow questions were asked about a specific framework:

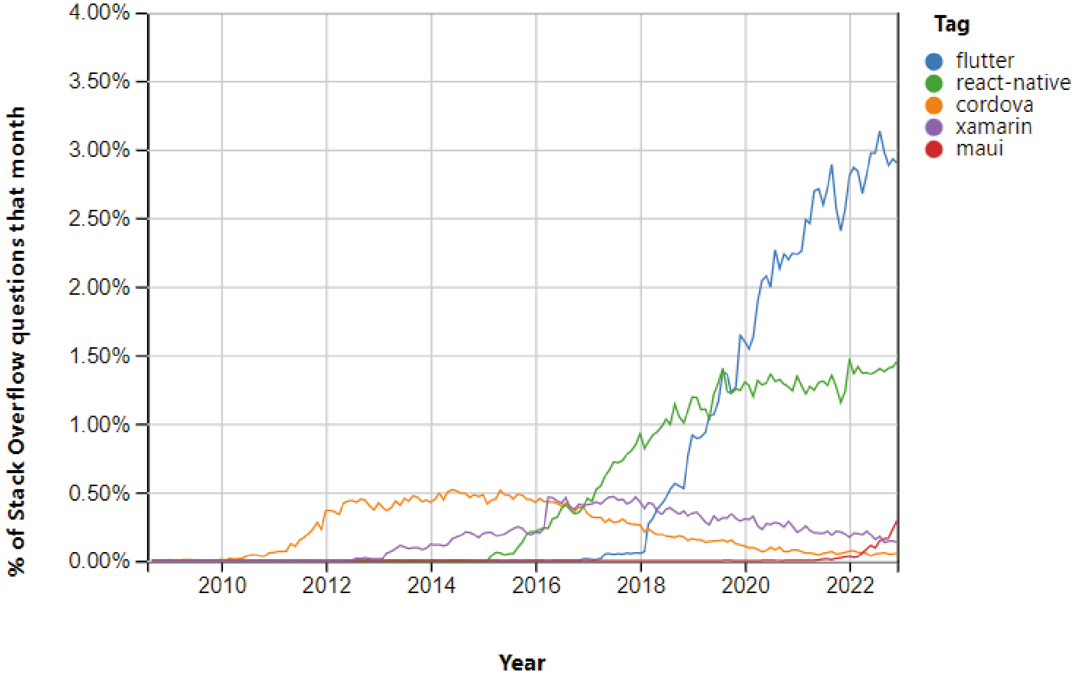


Figure 3.5 – Stack Overflow trends report

A simple comparison of the frameworks mentioned previously shows the following:

- Questions about the older frameworks of Cordova and Xamarin are reducing slowly
- Flutter, and very recently, MAUI, are seeing fast growth in questions asked
- React Native has seen a plateau in questions over the last year
- Flutter has become the most popular framework to ask about, especially since Flutter 1.0 was released in 2018

It can be argued that fewer questions need to be asked about the older frameworks because they have already been asked, so feel free to interpret the chart as you wish, but it clearly shows that there is currently a lot of interest in Flutter.

Stack Overflow is a great resource, but a framework not only needs a healthy set of Stack Overflow questions for it to grow and develop – it also needs a strong community.

The Flutter community

Flutter has a vibrant community, which is key to the long-term success of any software project that relies on community contributions. Google is very active in this, involving Flutter in conferences and organizing Flutter events.

Events

The Flutter community holds a regular marquee event dedicated to the Flutter framework. It shares best practices, new developments, feature overviews, and the chance to interact with Flutter experts.

The *Flutter Engage* event took place in 2021 and introduced a whole raft of new Flutter features, including Flutter 2.0, dual-display widgets from Microsoft, first-class Google AdMob integration, and tooling to help with Flutter migration to newer versions, among many other features and bug fixes. Flutter 2.0 also introduced full support for the web platform, which was previously a beta release. In addition, stability on all desktop platforms was announced, which led to an announcement from Canonical, publisher of Linux distribution Ubuntu, that "*Flutter is the default choice for future mobile and desktop apps created by Canonical.*"

More recently, the *Flutter Forward* event took place in 2023 and focused on four key areas that are taking the Flutter framework forward:

- Huge improvements in the performance of the graphics engine, especially for 3D
- Improved integration for web and mobile, including the ability to generate bindings to call directly into the platform code and element embedding to allow Flutter to run within a div on an existing web page
- The use of new emerging architectures, such as Web Assembly
- Continued focus on the developer experience, which included an announcement of Flutter 3 alpha

Many of these are quite advanced topics, only some of which we will explore within this book. It is worth checking out the keynote video and then exploring Flutter Forward in more detail once you feel more comfortable using Dart and Flutter: `https://flutter.dev/events/flutter-forward#on-demand`.

Google I/O, a general Google event for developers, often features Flutter talks. It is useful to attend these as not only can you learn about the new features being developed, but you can also get a feel for the strategic direction of the project. It was at Google I/O that an early preview of project Hummingbird, the move of Flutter to the web, was shown.

There are regular **meetups** around the world where groups discuss the latest Flutter technology, share their learning, and help newcomers join the Flutter bandwagon. It is worth noting that Flutter communities are not just English-speaking, with great communities such as Flutterando in Brazil (with over 8,000 members), allowing you to have Flutter meetups in your native tongue. Check out `https://meetup.com` to find a meetup near you.

News and discussion

Flutter Discord channels are a great place to raise questions and discuss issues. The channels are very active, generally with answers given within hours of questions being asked.

An alternative when you're having issues is to head to **Stack Overflow** for assistance. Many of the issues you encounter will have already been answered there, and if not, then it is very easy to ask a question.

The Flutter community page gives details of these and other online community options: `https://flutter.dev/community#community-grid`.

There is also an excellent email subscription that gives you a weekly update on all things Flutter. **Flutter Tap** gives general news and events updates, alongside tutorial videos and useful packages. Subscribe at `https://fluttertap.com/`.

Resources

All of the Flutter code is on GitHub. Here, you can view code, track defects, and follow new releases. The main repository can be found at `https://github.com/flutter/flutter`, but all the plugins will have their own repositories and issue tracking as well.

All of the plugins/packages created for Flutter and Dart are listed on the **pub.dev** site at `https://pub.dev/`. The site includes a powerful search that will list all the plugins and packages that are relevant. Importantly, the vitality of plugins and packages is reported through a series of metrics, allowing you to find the best plugin or package for your project:

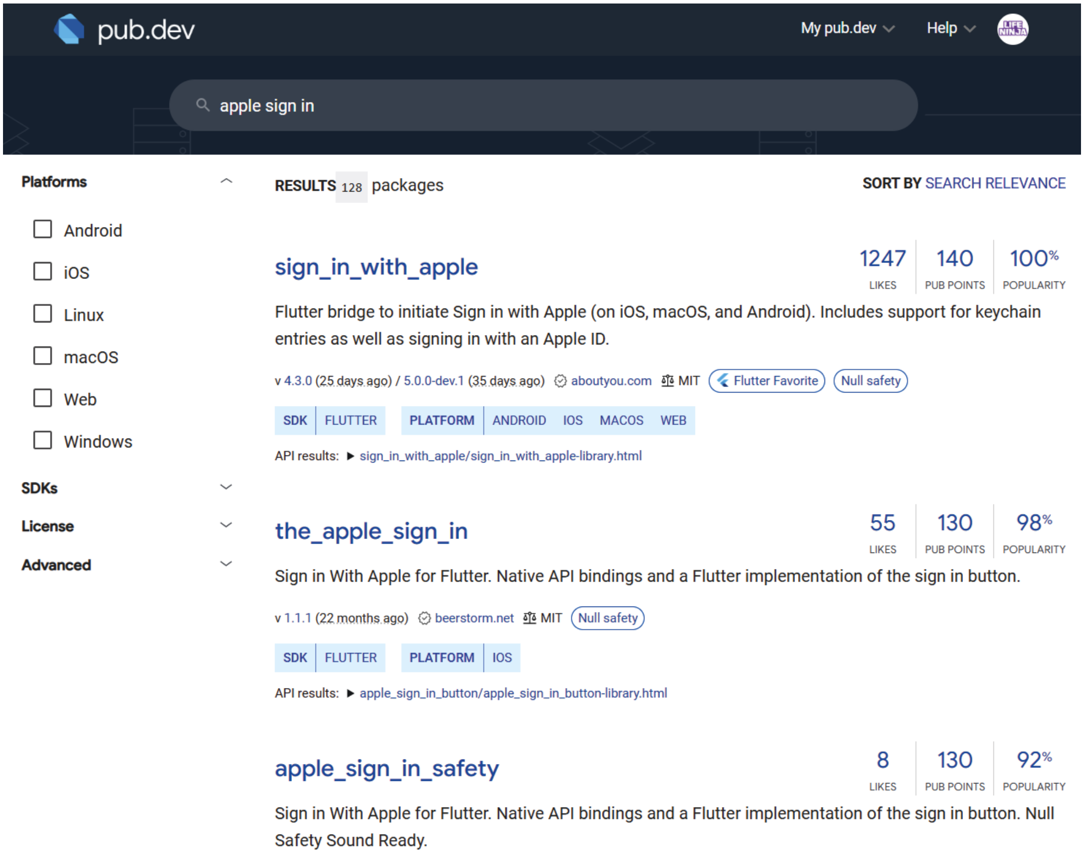


Figure 3.6 – Example pub.dev search

As you can see, a search for `apple sign in` returns at least three options. Deciding between them used to be a complicated and somewhat risky process, but now the likes, pub points (how well the project adheres to the standards, such as documentation, code style, and platform support), and popularity help you get a feel for which plugin might have the best longevity and support.

The main **Flutter website** holds huge amounts of documentation, including the latest links to the community and news of events. I strongly suggest that you take a look around the site to see what is available: `https://flutter.dev/`.

So, Flutter has a vibrant community that is helping drive the framework forward and make it even better. Let's bring together the key parts of this chapter from the point of view of Flutter itself.

Flutter strengths and weaknesses

So, we've had a look at the other options available to you for your mobile project and looked at the vitality of the Flutter community. This book is not designed to brainwash you into thinking Flutter is the best option (though it probably is), but given the context of the technology landscape, let's recap the strengths and weaknesses of Flutter so that you can make an informed decision.

Strengths

The following are some of the strengths of Flutter:

- **Hot reload**: Flutter has the best hot reload functionality (equal to React Native and Xamarin), and this is a huge productivity benefit.
- **Single code base**: Of all the options available, only a couple (Flutter and Cordova) truly have a single code base that will work across platforms. As discussed, this helps hugely with project management, defect resolution, and new platforms becoming relevant or old platforms being retired.
- **Project vitality**: Flutter has a very active community with a huge range of community plugins, easy ways to ask questions, and the most activity on Stack Overflow. If this was a concern, it should have been mitigated somewhat by our exploration of the community.
- **Performance**: Dart compiling to native and the lack of a software bridge ensure that Flutter, if not as performant as native, is more than sufficient for apps.
- **Documentation**: The documentation on Flutter is excellent. Compared to some other cross-platform frameworks, the Google team and the plugin writers have worked hard to ensure that Flutter is very well documented.

Weaknesses

The following are some of the weaknesses of Flutter:

- **New framework**: Flutter is relatively new and although that means it can learn from what has come before, it also means that there are lots of changes that can impact backward compatibility. This means developers often need to migrate their code to cope with the changes, sometimes holding up new releases.

> **Flutter migration examples**
>
> A big Flutter change was the introduction of **null safety** to the language. Null safety had to be introduced to Dart and Flutter carefully as it required migration of code, and it made sense to work on dependencies, such as plugins, before developers migrated their app code. Another example is that Flutter widgets regularly get deprecated and replaced to improve consistency in the framework; for example, `FlatButton` became `TextButton` and `RaisedButton` became `ElevatedButton`.

- **App size**: As mentioned in the native discussion, a minimal Flutter app is already 5 MB. This is comparable with other cross-platform frameworks, but significantly bigger than native apps.

Finally, let's take a look at some Flutter apps that are already in production.

Live Flutter apps

It's important to know that the platform you choose has a promising future, and that is best highlighted by seeing who else is using the platform. There are many very successful Flutter apps already in production and this should give you confidence that the platform will be capable of servicing the needs of your users.

The first one we will look at is Zap Maths, a fun game for children that teaches them mathematics as they play:

Figure 3.7 – Zap Maths Flutter app

Full confession – this is a Life Ninja app that we developed. It is very image-intensive and requires high performance for both single-player games and live online multiplayer competitions, so Flutter was the perfect choice for this app.

Probably the most famous Flutter app, especially in the early days when there were fewer Flutter apps in production, is the app for the theatre show *Hamilton*:

Figure 3.8 – Hamilton Flutter app

For many Flutter developers in those early Flutter days, especially when Flutter was in beta, it was very reassuring that something as high profile as the *Hamilton* theatre show was confident enough in Flutter to write and release their app in Flutter.

The Flutter community is very proud of the Flutter apps that have been released, and there is a whole page dedicated to the most high-profile apps out there: `https://flutter.dev/showcase`.

These include eBay, BMW, Google Classroom, Wallace and Gromit, and Toyota. Take a look at them and see what a great experience these apps give to their users.

Additionally, many apps started life using alternative technologies and then moved to Flutter as they saw the power of the platform. These include the following:

- **Justrade2.0**: A stock market trading app that was converted from Kotlin to Flutter
- **Alibaba**: The e-commerce giant converted some of its apps to Flutter to improve development efficiency and create a unified user experience across platforms
- **Google Ads**: Used to manage advertising campaigns, this app was rewritten in Flutter to leverage its cross-platform capabilities
- **Reflectly**: A popular journaling app that moved from native development to Flutter to streamline its development process and reach users on multiple platforms
- **Groupon**: The deal and coupon app transitioned parts of its app to Flutter to simplify development and deliver a cohesive experience to its users
- **eBay Motors**: A marketplace for buying and selling vehicles and automotive parts rebuilt its app using Flutter to achieve faster development cycles and feature parity across platforms
- **Abbey Road Studios**: This studio used Flutter to create “Topline,” an app designed for musicians to capture and develop their song ideas
- **Nubank**: A digital banking and financial services company based in Brazil, they used Flutter to enhance the user experience of their mobile app
- **BMW**: They utilized Flutter to create a prototype app for their new iX electric vehicle, showcasing the potential of the framework for the automotive industry
- **Grab**: A Southeast Asian ride-hailing and delivery service, they utilized Flutter to build a more responsive and feature-rich app for their users

As you can see, Flutter apps now cover many different domains and are now being developed by some very high-profile companies.

Summary

In this chapter, we looked at how Flutter compares to other mobile app development options. Initially, we explored native development options and how to use them versus general cross-platform solutions. We saw many of the advantages and disadvantages of the native approach.

We then looked at some common cross-platform frameworks and how they compare to Flutter. We saw that although they are trying to solve the same problem, they are doing so in different ways, leading to different trade-offs against the other options.

Next, we explored the Flutter community and highlighted some useful resources. This helped us understand that the Flutter community is very active, which is a huge positive for the future of Flutter.

One of the key parts of the community is the plugins that are created. We will explore these further in later chapters.

Finally, we took a quick look at some of the Flutter apps that have been released, reassuring us that the platform has a bright future.

You should now start to see why Flutter is so awesome, and why it is fast becoming one of the main development options for new app projects.

In the next chapter, you will have a proper play with Flutter, building on the Hello World! app you started in *Chapter 2*, *An Introduction to Dart*. We will particularly focus on widgets and how you can use them to create your user interface.

Questions

As before, if you are unable to answer any questions, then look back through this chapter for the relevant answers to refresh your knowledge:

1. Give three advantages of cross-platform coding over native coding.
2. Explain why project managing a cross-platform project is easier than a project with several native development teams.
3. Describe the benefit of hot-reload.
4. Name some other cross-platform frameworks.
5. What are some of the best routes to engaging with the Flutter community?
6. Where can the Flutter plugins/packages be found?

Further reading

For this chapter, I recommend that you try to start engaging with the Flutter community. As mentioned previously, there is a community page on the Flutter site that details how to access the Discord channel, Reddit community, and Stack Overflow, among others: `https://flutter.dev/community#community-grid`.

Also, watch some of the videos from the Flutter Forward event. You may not be able to follow them fully, but you will start to get a feel for some of the exciting new features coming to the framework and start to understand some of the best practices: `https://flutter.dev/events/flutter-forward`.

Sign up for the amazing Flutter Tap email subscription. These regular emails are a great way to find out about what is happening in the Flutter community, including useful tutorials and new code libraries: `https://fluttertap.com/`.

And finally, see if you can find a meetup near you where you can meet like-minded people who can share their insights and where you can bounce ideas or issues around: `https://meetup.com`.

4

Dart Classes and Constructs

In this chapter, we will look at **object-oriented programming** (**OOP**) and how this is supported by the Dart language. We will start by looking at the core principles of OOP concerning the Dart language, and then explore how to use OOP within Dart.

We will then take a deeper look at class definitions and how instances of a class are created, including an exploration of the constructor types available, which forms a key part of the way Flutter apps are coded. Additionally, we will look at how we store our code in files, and how to relate code from different files through imports.

Finally, we will look at some key Dart topics that are used throughout Flutter – generics and asynchronous programming. These are important concepts and knowledge of them will help with your understanding of the Flutter topics we will cover later in this book.

On completion of this chapter, you will have a solid foundational knowledge of Dart, which will set you in good stead as we move to a deeper exploration of Flutter.

We will cover the following topics in this chapter:

- Object orientation in Dart
- Understanding classes in Dart
- The `enum` type
- Using generics
- Asynchronous programming

Object orientation in Dart

As with most modern languages, Dart is designed to be **object-oriented** (**OO**). As initially mentioned in *Chapter 2*, *An Introduction to Dart*, OOP languages are based on the concept of **objects** that hold both data (called **fields**) and code (called **methods**). These objects are created from blueprints called **classes**, which define the fields and methods an object will have.

The terms discussed here may be new to you, but the key areas will be covered in greater depth throughout the rest of this chapter. Let's start with a brief overview of how Dart follows OOP principles.

Objects and classes

OOP arguably starts with `Class`, which is effectively a blueprint of how data will be stored, accessed, and manipulated within your software program, and a way to compartmentalize the behavior of your software.

For example, if your app refers to football teams, then you may create a `Class` definition called `FootballTeam`. This `Class` definition would define the data to be stored about the football team, how that data can be accessed, and how it can be manipulated. Additionally, it may define behaviors such as which shirt color the team should wear for a given match, or how to identify the highest-rated player for the team.

Now that you have a blueprint, you need to create instances of the blueprint. `Object` is an instance of a defined class. For example, you may create an instance of the `FootballTeam` class to hold information about Middlesbrough football club and assign this instance to a variable named `mfc`. This would be the Middlesbrough football club instance and the `mfc` variable would hold a reference to an object. You could then create subsequent instances of the `FootballTeam` class and each instance would be a unique object.

In Dart, everything is an object – that is, every value stored in a variable is an instance of a class, and all objects extend the `Object` class, directly or indirectly, through their `Class` definition. Creating an instance of a class is done using special methods called **constructors**, which have strictly defined parameters and will return an instance of the class they are defined on.

The following also applies:

- Dart classes can have both instance members (methods and fields) and class members (static methods and fields).
- Unlike languages such as Java, there are no primitive types that live outside of the object world. All types, including `int`, `float`, and others, are objects and extend the `Object` class. This means they can be extended like any other class.
- Dart classes do not support constructor overloading, but you can use the flexible function argument specifications from the language (optional, positional, and named) to provide different ways to instantiate a class. Also, you can have named constructors to define alternatives. Giving

names to your constructors allows you to have multiple constructors for a class, and also gives a clearer meaning to the reason why your class has multiple constructors.

Other OOP artifacts

Besides class definitions, other important OOP artifacts are presented in the Dart language (we will delve deeper into each of these throughout this chapter), as follows:

- **Interface**: This is a contract definition with a set of methods available on an object. From Dart 3 there is now an explicit interface type in Dart, but we can achieve the interface purpose with abstract classes.
- **Enumerated class**: This is a special kind of class that defines a set of common constant values.
- **Mixin**: This is a way of reusing a class's code in multiple class hierarchies.

Encapsulation

Dart does not have explicit access restrictions on fields and methods, unlike the famous keywords used in Java – protected, private, and public. In Dart, encapsulation occurs at the library level instead of at the class level (this will be discussed further in the following chapter). The following also applies:

- Dart creates implicit getters and setters for all fields in a class, so you can define how data is accessible to consumers and the way it changes
- In Dart, if an **identifier** (**ID**) (that is, a class, class member, top-level function, or variable) starts with an underscore, _, it's private to its library

Inheritance and composition

Inheritance allows us to extend a class definition to a more specialized type. More specifically, inheritance allows us to inherit data (fields) and behaviors (methods) from other classes, allowing them to acquire and utilize those characteristics as if they were their own.

As an example, earlier, we talked about the `FootballTeam` class definition. Suppose we wanted to create a more specialized subclass of `FootballTeam` for clubs in England called the `EnglishFootballTeam` class. This could include specific information about the history of the football team within the English football pyramid but would inherit more general traits such as shirt color and team name from the parent `FootballTeam` class definition.

In Dart, by simply declaring a class, we are implicitly extending the object type. The following also applies:

- Dart permits single direct inheritance. A class can only inherit from one other class, leading to a strict tree structure. This is similar in many other languages and can be very restrictive to class design, so Dart offers other options alongside inheritance.

- Dart supports **mixins**, which can be used to extend class functionalities without direct inheritance, simulating multiple inheritance and enabling easy reuse of code.
- Classes use the `extends` keyword to define that a child class inherits from a parent class.
- In Dart 3.0, several new class modifiers were added, including the `final` class directive, which, like other languages, restricts whether a class can be extended.

Abstraction

Following inheritance, abstraction is a process whereby we define a type and its essential characteristics. The `abstract` class is then extended by more specialized types. The following also applies:

- Abstract classes define what something does/provides, without caring about how this is implemented.
- An `abstract` method is a method signature without the implementation code.
- An `abstract` class can contain a mix of abstract and concrete methods. A concrete method is a method that has implementation code.
- Any classes that contain `abstract` methods must themselves also be declared abstract.
- Classes that extend abstract classes must either supply a concrete method for all abstract methods or be abstract themselves.
- Dart has the powerful implicit interface concept, which also makes every class an interface, allowing it to be implemented by others without the need to extend it.
- Dart 3 introduced the `interface` class modifier, which allows you to define an abstraction of a class – specifically, the method signatures that a class must implement – that can be implemented by another class.

Polymorphism

Polymorphism is achieved by inheritance and can be regarded as the ability of an object to behave like another; for example, the `int` type is also a `num` type. The following also applies:

- Dart allows you to overwrite parent methods so that you can change their original behavior.
- Dart does not allow method overloading in a way you may be familiar with in other languages. You cannot define the same method twice with different arguments. If required, you can simulate overloading by using flexible parameter definitions through optional and positional parameters, as was seen in the *Functions and methods* section of *Chapter 2*, *An Introduction to Dart*
- .

Functions as objects

Dart is called a true OO language. In Dart, even functions are objects, which means that you can do the following:

- Assign a function as a value of a variable and pass it as an argument to another function
- Return it as a result of a function as you would do with any other type, such as `String` and `int`

This is known as having first-class functions because they're treated the same way as other types, and they are used frequently within Flutter as a way to create generic widgets that can respond differently to inputs, depending on the context they are used in.

Now that we have explored some of the fundamental principles of Dart, let's dive a bit deeper and look at how these principles are manifested in the language.

Understanding classes in Dart

If you are an experienced programmer and are already familiar with Java or similar OOP languages, then you can skim through some parts of this chapter as Dart implements OOP concepts such as inheritance and encapsulation in very similar ways to those other languages. However, some areas, such as how Dart manages and defines class constructors, will probably be different from what you are used to and are incredibly important for later chapters when we explore how Flutter makes the best use of the Dart language.

In this section, we will look at what makes a Dart class, how to construct an instance of one using a constructor, and how your class can inherit from other classes. We will also explore ways to use special class constructs, such as abstract classes, interfaces, and mixins, and, finally, look at how to share class code across our code base using files and imports.

Class structure

Dart classes are declared by using the `class` keyword and the class's name. This is optionally followed by an inherited class and any implemented interfaces. Finally, the body of the class is enclosed by a pair of curly braces, where you can add class members, including the following:

- **Fields**: These are variables that are used to define the data an object can hold.
- **Accessors**: Getters and setters, as the name suggests, are used to access the fields of a class, where `get` is used to retrieve a value, and the `set` accessor is used to modify the corresponding value.
- **Constructors**: These are the creator methods of a class where an instance of the class is created. The fields of the instance are also initialized during creation.
- **Methods**: The behavior of an object is defined by the actions it can take. These are the object functions.

instance versus object

When you create an object from a `class` definition, you are said to instantiate `class`. To put it another way, you create an instance of `class`, and that instance is always an object. Therefore, the terms `instance` and `object` can be used interchangeably, so whenever you see the term `instance`, it refers to `object`.

Let's look at an example of a class definition to bring some of the concepts we've discussed to life:

```
class Person {
  String? firstName;
  String? lastName;
  String getFullName() => "$firstName $lastName";
}
```

The class structure shown in the preceding code, which should hopefully look relatively straightforward, defines a class to hold the information and behavior of a person.

The first line of the example specifies that we want to define a class using the `class` keyword, and is followed by the name of the class, which in this case is `Person`. Note that the word is capitalized, unlike a variable name, which is best practice in Dart.

The next two lines define two fields for the class that hold two pieces of data – the person's first name and last name. They will be `String` data types and can be `null`, as denoted by `?` after the data type.

The fifth line defines a method for the class. This method, named `getFullName`, takes no parameters and returns a concatenation of the first and last names. Note that this is an `arrow` function and the return value uses string interpolation on the first and last names.

Finally, on line 6, we close the curly brace to denote that the class definition is complete.

Many of the concepts discussed here, such as `null` data types, `arrow` functions, and string interpolation, were first explored in *Chapter 2*, *An Introduction to Dart*

so feel free to go back and review those sections if you need a refresher.

Now, let's look at how we could use that class definition:

```
main() {
  Person somePerson = Person();
  somePerson.firstName = "Clark";
  somePerson.lastName = "Kent";
  print(somePerson.getFullName()); // prints Clark Kent
}
```

In this `main` method, we create an instance of the `Person` class using a constructor. The constructor call looks like you are using the class name as the name of a method that you want to call:

```
Person()
```

Unsurprisingly, the return type of that constructor call is `Person`.

In the next two lines, the `Person` instance's first name and last name are set, and finally, the `print` method is called to print out the person's full name.

Given the `Person` class declared in the preceding code sample, and the code in the `main` method, we can now make some observations:

- We have not defined a constructor for the class, but we were able to create an instance. As you may have guessed, there's a default empty constructor that takes no arguments. This is already provided for us.
- To instantiate a class, we call the constructor invocation. Unlike in many OOP languages, there is no need to use the `new` keyword (although it is a reserved word and will appear in older code).
- The class does not have an ancestor class explicitly declared, but it does implicitly inherit from `Object`, as do all classes in Dart.
- The class has two fields, `firstName` and `lastName`, and a `getFullName()` method that concatenates both by using string interpolation and returning the result.
- The class does not have any `get` or `set` accessor declared, so how did we access `firstName` and `lastName` to mutate it? A default `get/set` accessor is defined for every field in a class.
- The dot `class.member` notation is used to access a class member, whatever it is – a method or a field (`get/set`).

The use of arrow notation on the `getFullName()` method is equivalent to writing the following method:

```
String getFullName() {
  return "$firstName $lastName";
}
```

However, the arrow notation is more succinct and probably easier to read. We can make this even more readable using field accessors.

Field accessors – getters and setters

As mentioned previously, getters and setters allow us to access a field on a class, and every field has these accessors, even when we do not define them. In the preceding `Person` example, when we execute `somePerson.firstName = "Clark"`, we are calling the `firstName` field's `set` accessor and sending `"Clark"` as a parameter to it. Also, in the following example, the `get` accessor is used when we call the `getFullName()` method on the person, and it concatenates both names.

For example, we can modify our `Person` class to replace the old `getFullName()` method and add it as a getter, as demonstrated in the following code block:

```
class Person {
  String? firstName;
  String? lastName;

  String get fullName => "$firstName $lastName";
}

main() {
  Person somePerson = Person();
  somePerson.firstName = "Clark";
  somePerson.lastName = "Kent";

  print(somePerson.fullName);     // prints Clark Kent
  somePerson.fullName = "peter parker";
  // we have not defined a setter fullName so it doesn't
     compile
}
```

The following important observations can be made regarding the preceding example:

- We could not have defined getter or setter methods with the same field names – that is, `firstName` and `lastName`. This would give us a compile error since the class member names cannot be repeated.
- We do not need to always define a `get` and `set` pair together. As you can see, we have only defined a `fullName` getter and not a setter, so we cannot modify `fullName`. (This results in a compilation error, as indicated in the example code.)

We could have also written a setter for `fullName` and defined the logic behind it to set `firstName` and `lastName` based on that, as illustrated in the following code snippet:

```
class Person {
  // ... class fields definition
  set fullName(String fullName) {
```

```
    var parts = fullName.split(" ");
    this.firstName = parts.first;
    this.lastName = parts.last;
  }
}
```

This way, someone could initialize a person's name by setting `fullName`, and the result would be the same. (Of course, we have not carried out any checks to establish whether the value passed as `fullName` is valid – that is, not empty, with two or more values, and so on.)

Static fields and methods

As you already know, fields are nothing more than variables that hold object values, and methods are simple functions that represent object behavior. In some cases, you may want to share a field value or method between all of the object instances of a class. For this use case, you can add the `static` modifier to them, as follows:

```
class Person {
  // ... class fields definition
  static String personLabel = "Person name:";
  String get fullName => "$personLabel $firstName $lastName";
  // modified to print the new static field "personLabel"
}
```

Hence, we can change the `static` field value directly on the class, as follows:

```
main() {
  Person somePerson = Person();
  somePerson.firstName = "Clark";
  somePerson.lastName = "Kent";
  Person anotherPerson = Person();
  anotherPerson.firstName = "Peter";
  anotherPerson.lastName = "Parker";
  print(somePerson.fullName);
  // prints Person name: Clark kent
  print(anotherPerson.fullName);
  // prints Person name: Peter Parker
  Person.personLabel = "name:";
  print(somePerson.fullName);
  // prints name: Clark Kent
  print(anotherPerson.fullName);
  // prints name: Peter Parker
}
```

The `static` fields are associated with the class, rather than any object instance. The same goes for the `static` method definitions. For example, we can add a `static` method to encapsulate the name printing, as demonstrated in the following code block:

```
class Person {
  // ... class fields definition
  static String personLabel = "Person name:";
  static void printsPerson(Person person) {
    print("$personLabel ${person.firstName} ${person.lastName}");
  }
}
```

Note that in this example, the `printsPerson` method no longer has access to any instance fields, such as `firstName`, so the instance has to be passed into the method as an argument.

As you can see, `static` fields and methods allow us to add specific behaviors to classes in general.

So, now that we've seen how to structure a class and how to use the default constructor, let's go beyond the default constructor and learn how to define and use other class constructors.

Constructors

To instantiate a class, we call the corresponding constructor with arguments, if required. Now, let's change the `Person` class and define a constructor with parameters on it, as follows:

```
class Person {
  late String firstName;
  late String lastName;
  Person(String firstName, String lastName) {
    this.firstName = firstName;
    this.lastName = lastName;
  }
  String getFullName() => "$firstName $lastName";
}

void main() {
  // Person somePerson = Person(); No longer compiles
  Person somePerson = Person("Clark", "Kent");
  print(somePerson.getFullName());
}
```

The constructor is also a method in Dart, and its role is to initialize the instance of the class properly. As a method, it can have many of the characteristics of a common Dart method, such as parameters – required or optional, and named or positional. In the preceding example, the constructor has two mandatory parameters.

If you look in our constructor body, you'll see that it uses the `this` keyword. Furthermore, the constructor parameter names are the same as the field ones, which could cause ambiguity. So, to avoid this, we must prefix the object instance fields with the `this` keyword during the value assign step. The `this` reference can be used to directly reference fields within the instance that may have been masked by local variables with the same name. In this situation, the parameters for the constructor have the same name as the instance fields, which means the instance's fields have been masked by the parameters. The only way to reference the instance's fields is to use the `this` keyword to jump up the scope.

Notice that we have to use the `late` keyword because the fields have not been declared with an initial value, but we know that the values of the fields will be set on instantiation of the class, so their values will not be accessed before they have a value set. If we were unsure when the field would be set during instance construction, then we would need to use `?` to denote that the fields can have null values.

Dart provides another way to write a constructor – using a shortcut syntax, such as the one provided in the following example:

```
Person(this.firstName, this.lastName);
```

There is no need for the constructor body since the field values are set directly in the constructor signature. It can take a little while to get used to this syntax, but it not only makes the constructor declaration more succinct – it also removes a big opportunity for code errors. Additionally, you no longer require the `late` keyword because the compiler can see that the value of the fields will be set on class instantiation.

Have a look at the following code snippet:

```
class Person {
  String firstName;
  String lastName;
  Person(this.firstName, this.lastName);
  String getFullName() => "$firstName $lastName";
}
```

As you can see, this is a much cleaner way of defining a class constructor because it is succinct, less open to code errors, and removes the need to manage the `null` type on the fields.

Named constructors

Unlike Java and many other languages, Dart does not have overload methods or constructors by redefinition, so to define alternative constructors for a class, you need to use the named constructors. For example, we could add the following constructor to the `Person` class that takes no parameters:

```
Person.anonymous();
```

The only difference compared to a simple method is that constructors do not have a `return` statement since the only thing they can do is initialize the object instance and return it.

We will see named constructors throughout this book since the framework uses these a lot to initialize widget definitions.

Factory constructors

A `factory` constructor can be used when the constructor doesn't always create a new instance of the class it is defined on. This may be used when data is being cached and we want to return an instance from the cache rather than construct a new instance.

For example, suppose we are caching `Person` instances. We could create a `factory` constructor that checks if the `Person` instance is already in a cache and returns either a value from the cache or, if there is no cache entry, constructs a new `Person` instance. For the following example, imagine we have some cache service we can ask for an instance:

```
factory Person.fromCache(String firstName, String lastName) {
  if (_cacheService.containsPerson(firstName, lastName)) {
    return _cacheService.getPerson(firstName, lastName);
  } else {
    return Person(firstName, lastName);
  }
}
```

Note that a `factory` constructor has no access to the `this` keyword because no instance of the class has been created yet, so it needs to access another constructor to create a new instance of the class.

Class inheritance

In addition to the implicit inheritance of the `Object` type, Dart allows us to extend defined classes using the `extends` keyword, where all of the members of the parent class are inherited, except the constructors.

Now, let's check out the following example, where we're creating a child class for the `Person` class:

```
class Student extends Person {
  String nickName;
  Student(
    String firstName,
    String lastName,
    this.nickName,
  ) : super(firstName, lastName);

  @override
```

```
  String toString() => "${getFullName()}, aka $nickName";
}
main() {
  Student student = Student("Clark", "Kent", "Kal-El");
  print(student);

}
```

There are some really interesting things going on here that will help us with the later chapters as we start to look at Flutter widgets.

Firstly, the `Student` class defines its own constructor. However, it passes some of the parameters in the constructor up to the parent class. This is done with the `super` keyword, which is placed at the end of the constructor, following the `:` character.

Next, you can see `@override`. This is an annotation and is metadata that gives an additional description to the method definition. There's an overridden `toString()` method on the `Student` class. This is where inheritance makes sense – we change the behavior of a parent class (`Object`, in this case) on the child class. This means that every class has the `toString` method defined on it because every class inherits either directly or indirectly from the `Object` class.

Why bother with the @override annotation?

Annotations generally contribute to the readability of the code. In this instance, the `@override` annotation has been used to mark this `toString()` method implementation as overriding the method implementation from the parent class. You may think this is obvious and that any decent **integrated development environment** (**IDE**) could show this relationship perfectly easily. However, the main value of the annotation in this situation is for code checking. If you think you have overridden a method but have misspelled it, then by explicitly saying you wish to override the method, the compiler knows your intention and can validate it. Also, if someone changes the `super` class method and removes the method you are overriding, the compiler will complain that a subclass is no longer overriding the removed method.

Finally, the `print(student)` method is called on the `main` method. As you can see in the `print(student)` statement, we are not calling any method; the `toString()` method is called for us implicitly by the `print` method.

A common example of overriding parent behavior is the `toString()` method. The objective of this method is to return a `String` representation of the object and it is defined on the top-level `Object` class.

As you can see in the preceding code example, overriding the `toString` method makes the code cleaner, and we provide a good textual representation of the object that can aid in understanding logs, text formatting, and more.

Abstract classes

In OOP, abstract classes are classes that cannot be instantiated. For example, our `Person` class could be abstract if we want to make sure that it only exists in the context of the program if it is a `Student` instance or another subtype, as illustrated in the following code snippet:

```
abstract class Person {
  // ... the body was hidden for brevity
}
```

The only thing we need to change here is the beginning of the class definition, marking it as `abstract`. We can still instantiate the subclass, as shown in the following code snippet:

```
main() {
  Person student = Student("Clark", "Kent", "Kal-El");
  // Works because we are instantiating the subtype
  // Person p = new Person();
  // abstract classes cannot be instantiated
  print(student);
}
```

As you can see, we can no longer instantiate a `Person` class itself, only concrete subclasses.

Note that this is a prime example of polymorphism. Although we are instantiating a `Student` object, we have placed it in a variable of the `People` type. This approach can be useful in certain situations, such as when your code requires a `Person` type but has no interest in the specific sub-type that it is dealing with.

As an example, perhaps you have a school open day that will be attended by students, teachers, parents, and siblings, and you want to keep a register of who attended the event. The easiest way to achieve this might be to create sub-classes for the different types – students, teachers, family – and then your register would simply take a list of people – `List<Person>` – that is agnostic to the sub-class.

An abstract class may have abstract members without an implementation, allowing it to be implemented by the child types that extend them, as illustrated in the following code snippet:

```
abstract class Person {
  String firstName;
  String lastName;
  Person(this.firstName, this.lastName);
  String get fullName;
}
```

The fullName getter from the preceding Person class is now abstract as it does not have an implementation. It is the responsibility of the child to implement this member, as follows:

```
class Student extends Person {
  //... other class members
  @override
  String get fullName => "$firstName $lastName";
}
```

The Student class implements the fullName getter because, if it did not, the Student class would itself be abstract (and would need the abstract keyword to allow the code to compile) and therefore could not be instantiated.

Interfaces

An interface is very similar to an abstract class and defines the method signatures that any class implementing the interface must possess. This is not inheritance because no behavior is included in the interface – it's just a requirement that the implementing class follows the contract defined by the interface. This has the benefit that a class can implement many interfaces, unlike single class inheritance, because there is no possibility of a clash between behaviors.

Only from Dart 3 has Dart had the interface keyword. However, before that, Dart allowed us to use interfaces in a subtly different way from what you may be used to. All class declarations are themselves interfaces, which means that when you are defining a class in Dart, you are also defining an interface that may be implemented as an alternative to being extended by other classes. This is called **implicit interfaces** in the Dart world.

On this basis, our previous Person class is also a Person interface that could be implemented, instead of extended, by the Student class, as illustrated in the following code block:

```
class Student implements Person {
  String nickName;
  @override
  String firstName;
  @override
  String lastName;
  Student(this.firstName, this.lastName, this.nickName);
  @override
  String get fullName => "$firstName $lastName";
  @override
  String toString() => "$fullName, also known as
    $nickName";
}
```

Note that, in general, the code does not change too much, but the members are now defined in the `Student` class. The `Person` class is just a contract that the `Student` class adopted and must implement. A similar interface for Person could be defined using the new `interface` keyword, as follows:

```
 abstract interface class Person {
  String get fullName;
  String toString();
}
```

As you can see, just the contract is defined in the interface; none of the class behavior or members are defined in the interface – these must be defined by the implementing class.

Note that if you create an interface without the `abstract` keyword, then you can add behavior to the interface, but that would only be used if you instantiate the interface class directly; it would not be used by any classes implementing the interface.

Mixins

In OOP, mixins are a way to include functionality in a class without there being an association between the parts, such as through inheritance.

Mixins are mainly used in places where multiple inheritance is needed as this is an easy way for classes to use common functionality. One of the main examples of this in Flutter is when you want to create a widget that is animated. Defining a widget class requires inheritance, so to add animation capabilities to your class, a mixin is required.

As an example, let's look at using mixins for our `Person` class. People have a mix of specific skills, and mixins can be ideal for reflecting this because we can add skills to a person without the need to define a common superclass for each combination or interface definition, leading to code duplication. Here, we're defining two classes to be used as mixins by specifying the mixin keyword as follows:

```
mixin class ProgrammingSkills {
  coding() {
    print("writing code...");
  }
}
mixin class ManagementSkills {
  manage() {
    print("managing project...");
  }
}
```

We have created two skills `mixin` classes, `ProgrammingSkills` and `ManagementSkills`. We can use them by adding the `with` keyword to the class definition, as illustrated in the following code example:

```
class SeniorDeveloper extends Person with ProgrammingSkills,
ManagementSkills {
  SeniorDeveloper(String firstName, String lastName) :
    super(firstName, lastName);
}
class JuniorDeveloper extends Person with ProgrammingSkills {
  JuniorDeveloper(String firstName, String lastName) :
    super(firstName, lastName);
}
```

Both classes will have the `coding()` method, without the need to implement it in each class, as it is already implemented in the `ProgrammingSkills` mixin. Additionally, the `SeniorDeveloper` class will have the `manage()` method.

Files and imports

When you look at the project structure of the `HelloWorld` project, you will notice that there is a file named `main.dart` that contains a class named `MyApp`. Unlike with some other programming languages, the class name does not need to match the filename.

Additionally, it is normal to put multiple classes, enums, and functions into one file to form a library of constructs that are closely related. This can allow nice encapsulation by making some classes private to the library through the addition of an underscore to the start of their name (as with variables). Other classes in the file can access and instantiate the private class, but it is not visible outside of the file.

When we explore widgets in the next chapter, you will see that it is quite common to have two classes within a file and they can both contribute to a single widget, one of which is private to the file.

However, you don't want all of your app's constructs in a single file as it would become harder to find the construct that you need, would hinder encapsulation, and would probably cause performance issues with your IDE. Therefore, you need a way to refer to constructs in other files. You do this using `import` statements. As with virtually any other programming language, `import` statements allow you to reference code in other classes, packages, and plugins.

If you look at the `main.dart` file in the `HelloWorld` project, you will see the following `import` statement at the very top:

```
import 'package:flutter/material.dart';
```

In this example, the `material.dart` file is being imported, with all the classes and functions within that file being made available to your class. This file holds lots of the basic constructs needed to create Flutter widgets, so most files in a Flutter project will need this import.

In this section, we looked at the structure of a Dart class, including fields and methods. Then, we explored the different ways in which constructors can be used to instantiate a class. After that, we discussed some of the special ways to use classes, such as abstract classes, interfaces, and mixins. We finished off by learning how class code can be shared across your app through files and imports. Now, let's look at a special type of construct called `enum`, which is used in very specific scenarios.

The enum type

The `enum` type is a common data type that's used by most languages to represent a set of finite constant values. In Dart, it is no different. By using the `enum` keyword, followed by the constant values, you can define an `enum` type, as illustrated in the following code snippet:

```
enum PersonType { student, employee }
```

Note that you only define the value names. `enum` types are special types with a set of finite values that have an index property representing their value. Now, let's see how it all works.

First, let's add a field to our previously defined `Person` class so that we can store its type, as follows:

```
class Person {
  ...
  PersonType type;
  Person(this.type);
  ...
}
```

Then, we can use it just like any other field, as illustrated in the following code snippet:

```
main() {
  print(PersonType.values);
  Person somePerson = (PersonType.student);
  somePerson.type = PersonType.employee;
  print(somePerson.type);
  print(somePerson.type.index);
  print(describeEnum(PersonType.employee));
}
```

The first `print` statement prints the following:

```
[PersonType.student, PersonType.employee]
```

Here, we are calling the `values` getter on the `PersonType` enum directly. This is a static member of the `enum` type that simply returns a list containing all of its values. The second `print` statement prints the following:

```
PersonType.employee
```

The next `print` statement prints `1`. Here, the `index` property is zero-based and returns a value using the declaration position of the value within `enum`. Generally, you should not rely on the `index` value because it can change if the `enum` values are reordered or a new value is added.

Additionally, Flutter supplies the `describeEnum` method, which returns just the value of the `enum` type. In the final `print` method, the printed value will be `employee`.

A common place to use enums is within a `switch` statement since a `switch` statement that doesn't include all `enum` options will trigger a warning. This is perfect if you have written code to cope with all the different `enum` values and then you later decide to add another `enum` value – the compiler will warn you that you are no longer switching on the full set of `enum` values.

As an example, let's switch on `PersonType`:

```
switch (somePerson.type) {
  case PersonType.student:
    print('Learning time!');
    break;
  case PersonType.employee:
    print('Meeting time!');
    break;
}
```

If we add another `PersonType` later, such as `PersonType.retired`, then we will get a warning that our `switch` statement doesn't cater to all of the entries in the `PersonType` enum and will remind us to come back and extend this section of code.

The more you can add type safety to your code, the safer that code will be. However, sometimes, you also want to specify the type that a class can contain. You can do this with generics.

Using generics

The `<>` syntax is used to specify the type supported by a class. If you look at the examples of lists and maps in *Chapter 2*, *An Introduction to Dart*, you will notice that we didn't specify the type that they can contain. This is because this type of information is optional, and Dart can infer the type based on elements during the collection initialization process.

When and why to use generics

The use of generics can help a developer maintain and keep collection behavior under control. When we use a collection without specifying the allowed element types, it is our responsibility to correctly insert elements of the expected type. This can lead to bugs when data of an incorrect type is placed in a collection or incorrect assumptions are made about the contents of a collection.

Consider the following code example, where we have named a `List` variable `placeNames`. We expect this to be a list of names and nothing else. Unfortunately, without generics, we can place anything into the list, including a number. This can lead to issues when retrieving values from the list:

```
main() {
  List placeNames = ["Middlesbrough", "New York"];
  placeNames.add(1);
  print("Place names: $placeNames");
}
// prints Place names: [Middlesbrough, New York, 1]
```

However, if we specify the string type for the list, then this code would not compile, thus improving the robustness of the code, as illustrated in the following code snippet:

```
main() {
  List<String> placeNames = ["Middlesbrough", "New York"];
  placeNames.add(1);
  // add() expects a String so this doesn't compile
}
```

Generics and Dart literals

In the list and map examples provided in *Chapter 2*, *An Introduction to Dart*, we used the `[]` and `{}` literals to initialize them. With generics, as an alternative to the previous approach, we can specify a type during initialization, adding an `<elementType>[]` prefix for lists and `<keyType, valueType>{}` for maps.

Take a look at the following example:

```
main() {
  var placeNames = <String>["Middlesbrough", "New York"];
  var landmarks = <String, String>{
    "Middlesbrough": "Transporter bridge",
    "New York": "Statue of Liberty",
  };
}
```

Specifying the type of list seems to be redundant in this case as the Dart analyzer will infer the string type from the literals we have provided. However, in some cases, this is important, such as when we are initializing an empty collection, as in the following example:

```
var emptyStringArray = <String>[];
```

If we have not specified the type of the empty collection, it could have any data type on it as it would infer the generic type to adopt.

Nullability in generics

Just as we saw in the *Null safety* section in *Chapter 2*, *An Introduction to Dart*, if a variable can receive a `null` value, then that must be declared on the variable's type. This is also true in generics if the type of the collection can include `null` entries.

For example, suppose in our `landmarks` map we allowed some places to have no landmarks. We would need to declare this so that when we access the map's entries, we know that `null` is a possible value. Let's update the previous example to see what that might look like:

```
main() {
  var landmarks = <String, String?>{
    "Middlesbrough": "Transporter bridge",
    "New York": "Statue of Liberty",
    "Barnmouth": null,
  };
}
```

We have specified that the value of the map entry is `String?`, meaning that it holds either a `String` or `null` value. Then, we added a new entry to the map containing a `null` value.

So far, we have learned a lot about how to add type safety to our code, and we will finish the chapter with a slight change of focus. Sometimes, we want to call some code that will take a long time to complete, so how do we do this while maintaining a great **user experience** (**UX**) for our app? Let's look at asynchronous programming.

Asynchronous programming

Dart is a single-threaded programming language, meaning that all of the application code runs in the same thread. Put simply, this means that any code may block thread execution by performing long-running operations such as **input/output** (**I/O**) or **HyperText Transfer Protocol** (**HTTP**) requests. This can be an issue if your app is stuck waiting for something slow such as an HTTP request while the user is trying to interact with it. The app would effectively freeze and not respond to the user's input.

However, although Dart is single-threaded, it can perform asynchronous operations through the use of **Futures**. This allows your code to trigger an operation, continue doing other work, and then come back when the operation has been completed. To represent the result of these asynchronous operations, Dart uses the `Future` object combined with the `async` and `await` keywords. Let's look at these concepts now so that we can learn how to write a responsive application.

Dart Futures

When our code calls a method that is a long-running task but we don't want to block execution of other parts of the app, such as the **user interface** (**UI**), we can mark the method as asynchronous using the `async` keyword. This tells all code that calls that method that it may be long-running, so it shouldn't block thread execution while waiting for the result. We can then call the method and continue the execution of other code.

However, we may want to get a result from the long-running method, so we need to come back to the method call after the long-running method has returned. To do this, we must specify that we want to return when there is a response, using the `await` keyword. A key distinction between `async` and `await` is that the method itself declares its asynchronicity using `async`, but it is the code calling the method that specifies it will return when there is a response through the use of `await`. We will see both of these keywords in use later in this section.

So, we've declared that the method should be called asynchronously using `async`, and we may have specified that we want to come back to the method call when there is a result using `await`, but what does the method return? The `Future<ResultType>` object in Dart represents a value that will be provided sometime in the future. It can be used to mark a method with a future result; that is, a method returning a `Future<ResultType>` object will not have the proper result value immediately but, instead, after some computation at a later point in time.

It is easiest to understand this when you look at code examples that are not asynchronous initially but are long-running. Consider the following code:

```
import 'dart:io';
void longRunningOperation() {
  for (int i = 0; i < 5; i++) {
    sleep(Duration(seconds: 1));
    print("Index: $i");
  }
}
main() {
  print("Start of long running operation");
  longRunningOperation();
  print("Continuing main body");
  for (int i = 10; i < 15; i++) {
    sleep(Duration(seconds: 1));
    print("Index from main: $i");
  }
  print("End of main");
}
```

Here, we have the `main` function, which calls a long-running operation. We have used the `sleep()` function, which pauses code execution. This function is available in the `dart:io` package, so we have added an `import` statement to give us access to the function.

If you execute the preceding code, the output will look like this:

```
Start of long running operation
Index: 0
Index: 1
Index: 2
Index: 3
Index: 4
Continuing main body
Index from main: 10
Index from main: 11
Index from main: 12
Index from main: 13
Index from main: 14
End of main
```

You will notice that it stops the `main` function execution while the `longRunningOperation()` function is running, printing out the `Index:` statements before continuing the `main()` execution and printing out the `Index from main` statements. This is synchronous execution of all of the code and it will likely not fit well in all use cases. If this were an app, then the UI would become unresponsive, leading to a bad UX, because the thread is stuck waiting for the `longRunningOperation()` function to complete, rather than looking after all the many other activities needed to keep an app responsive.

Now, let's say we change this example so that the `longRunningOperation()` function is an asynchronous function and `main()` can continue executing without waiting for it to complete, as follows:

```
import 'dart:io';
import 'dart:async';
Future<void> longRunningOperation() async {
  for (int i = 0; i < 5; i++) {
    sleep(Duration(seconds: 1));
    print("Index: $i");
  }
}
main() { ... } // main function is the same
```

We have made one key difference to our code – the `longRunningOperation()` function now has the `async` modifier to indicate that this is an asynchronous function and will return `Future`. Notice that we have marked that the `return` type of the function is `Future<void>`, denoting that when the `asynchronous` method has completed, `Future` will resolve to void, implying that there is no `return` object.

To access these modifiers, we have also added a new `import` statement for `dart:async`.

Now, if you execute the preceding code, you may notice something strange; the output is shown here:

```
Start of long running operation
Index: 0
Index: 1
Index: 2
Index: 3
Index: 4
Continuing main body
Index from main: 10
Index from main: 11
Index from main: 12
Index from main: 13
Index from main: 14
End of main
```

What has happened here? Nothing has changed and we are still waiting for the `longRunningOperation()` function to complete. The reason for this is the `sleep()` function. The `sleep()` function is synchronous yet it is also long-running, so the thread is getting stuck there and not being released to perform other duties. Thankfully, there is an alternative to the synchronous `sleep()` function, called `Future.delayed()`. This method is asynchronous and will allow us to release the thread.

Let's update our example so that it becomes properly asynchronous, as follows:

```
import 'dart:io';
import 'dart:async';
Future<void> longRunningOperation() async {
  for (int i = 0; i < 5; i++) {
    await Future.delayed(Duration(seconds: 1));
    print("Index: $i");
  }
}
void main() { ... } // main function is the same
```

We are now calling the `Future.delayed()` function, which is asynchronous. We want our code execution to continue from that point when the function completes, so we have specified this by adding the `await` keyword. Now, the thread will be released to do what it needs to, but when the function completes, our code execution will continue from the `await` point.

Let's run the code and see whether this works:

```
Start of long running operation
Continuing main body
Index from main: 10
```

```
Index from main: 11
Index from main: 12
Index from main: 13
Index from main: 14
End of main
Index: 0
Index: 1
Index: 2
Index: 3
Index: 4
```

We no longer have purely synchronous code where one piece of code strictly executes after another, as we did previously; here, what changes is the order. In the preceding example, the change occurs when the `longRunningOperation()` function calls `await` on another `async` function – the `Future.delayed()` function. The `longRunningOperation()` function is suspended at that point and will be resumed only after the function returns after a delay of 1 second.

After the delay, however, the `main()` function is already running again; it did not wait for the `longRunningOperation()` function to complete because we didn't specify `await`, so the `longRunningOperation()` code will be executed only after the `main()` function has finished.

If we make the `main()` function an `async` function and await the execution of `longRunningOperation()`, then the `main()` function will be suspended right when we call `await longRunningOperation()` and will only be resumed after its execution. This would behave just like the first output we saw:

```
main() async {
  print("Start of long running operation");
  await longRunningOperation();
  print("Continuing main body");
  // ... removed for brevity
}
```

One other experiment to try is to stop thread blocking in the `main()` method by replacing the `sleep()` function with `Future.delayed()`. This will then release the thread so that it can move back to the `longRunningOperation()` function and create an interlaced pattern. To do this, change the code as follows:

```
main() async {
  print("Start of long running operation");
  longRunningOperation();
  print("Continuing main body");
  for (int i = 10; i < 15; i++) {
    await Future.delayed(Duration(seconds: 1));
    print("Index from main: $i");
```

```
  }
  print("End of main");
}
```

If you run the preceding code, you will get the following output:

```
Start of long running operation
Continuing main body
Index: 0
Index from main: 10
Index: 1
Index from main: 11
Index: 2
Index from main: 12
Index: 3
Index from main: 13
Index: 4
Index from main: 14
End of main
```

To understand this pattern of output produced, you need to appreciate that Dart executes both asynchronous methods in the same thread. Both functions run asynchronously in this case, but this does not mean that they are executed in parallel. Dart executes one operation at a time; so long as one operation is executing, it cannot be interrupted by any other Dart code. This execution is controlled by the Dart event loop, which acts as a manager for Dart Futures and asynchronous code.

So, in our example, the `longRunningOperation()` function is executed, and when it reaches the `Future.delayed()` call, it relinquishes control of the thread. The thread can then continue execution of the `main()` function until it reaches its `Future.delayed()` call when it relinquishes control of the thread. After 1 second, thread execution continues from the `await` point in the `longRunningOperation()` function, printing the index and looping until it relinquishes control of the thread again, ready for the thread to continue execution from the `main()` function's `await` point. This continues until both loops complete.

Although this gives the impression of parallel code execution, there is a way to truly execute Dart code in parallel (that is, multiple code executions at the same time). To do this, we can use Dart Isolates.

Dart Isolates

So, you may have been wondering how you can execute truly parallel code and improve the performance and responsiveness of your app. Dart **Isolates** are designed exactly for this purpose. Every Dart application is composed at least of one **Isolate** instance – the main **Isolate** instance where all of the application code runs. So, to create parallel execution code, we must create a new **Isolate** instance that can run in parallel with the main **Isolate** instance, as illustrated in the following diagram:

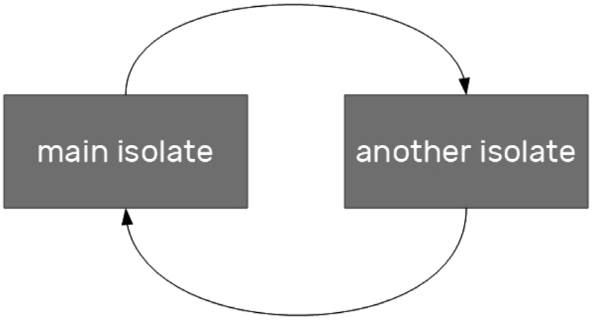


Figure 4.1 – Two Isolates in parallel

Isolates can be considered to be a sort of thread, but they do not share anything with each other, as the name suggests. This means that they do not share memory, so we do not need to use locks and other thread synchronization techniques here.

To communicate between Isolates – that is, to send and receive data between them – we need to exchange messages. Dart provides a way of accomplishing this.

Let's change the previous implementation so that it uses an `Isolate` instance instead:

```
import 'dart:isolate';
Future<void> longRunningOperation(String message) async {
  for (int i = 0; i < 5; i++) {
    await Future.delayed(Duration(seconds: 1));
    print("$message: $i");
  }
}
void main() async {
  print("start of long running operation");
  Isolate.spawn(longRunningOperation, "Hello");
  print("Continuing main body");
  for (int i = 10; i < 15; i++) {
    await Future.delayed(Duration(seconds: 1));
    print("Index from main: $i");
  }
  print("End of main");
}
```

As you can see, there are some minor changes to the code, as outlined here:

- The `longRunningOperation()` function is almost identical, but we've added a `message` parameter to show how arguments can be passed on `Isolate` creation.

- To initiate the Isolate process to be executed, we use the `spawn()` method from the `Isolate` class. This takes two arguments – the function to be spawned and a parameter to be passed to the function.
- We have added the `dart:isolate` **import** statement to gain access to the `Isolate` class.

Running the preceding code, you will note a very similar output to before, as illustrated here:

```
Start of long running operation
Continuing main body
Index from main: 10
Hello: 0
Index from main: 11
Hello: 1
Index from main: 12
Hello: 2
Index from main: 13
Hello: 3
Index from main: 14
End of main
Hello: 4
```

Again, both functions run interleaved, but this time, the `main` function runs ahead of the `longRunningOperation()` function. This is because, unlike the previous example, where the thread did not relinquish control until it reached `await Future.delayed()`, the `spawn` operation creates an Isolate asynchronously, allowing the `main()` function thread to immediately move to its `await Future.delayed()` function. Also, note that there is no dance we had in the previous example where each function relinquished thread control to the other at the `await` point. These are effectively two separate threads running independently.

Summary

In this chapter, we looked at how Dart fits with the OOP basics, which led to an exploration of Dart classes, including inheritance, abstraction, and mixins.

We took a deeper look at class constructors and the different types of constructors available in Flutter, including named and factor constructors.

We then explored enums and examples of how and when they should be used.

Finally, we looked at some more advanced Dart topics that are relevant to Flutter development. The first topic was generics, which allows you to specify the type of information for a class, such as a collection or a Future. The second topic covered asynchronous programming, the use of `Futures`, `async`, and `await`, and then Isolates and how they can be used to allow parallel processing.

This chapter will have given you a strong foundational knowledge of Dart and the programming concepts that will be used throughout Flutter development. You may want to refer back to this chapter as we start to look at more advanced Flutter concepts that are built on these foundational principles.

In the next chapter, we will look at Flutter widgets, which will immediately make use of your new Dart knowledge!

Questions

We gained a lot of knowledge in this chapter, so don't be hard on yourself if you can't answer all of these questions on your first attempt:

1. How many superclasses can a class inherit from in its class definition?
2. If you want to create a new class that inherits from many parent classes, how could you achieve this?
3. Describe polymorphism and give an example of how it could be useful.
4. Explain the difference between `instance` fields/methods and `static` fields/methods.
5. What is the purpose of starting your class name, field name, or method name with an underscore?
6. Can you remember how to initiate class fields from a constructor without the need for a constructor body?
7. Give some examples of where you would use generics and why that would benefit your code's type safety.
8. What happens to your code execution if you call an `async` method with or without `await`?

Further reading

If you have previously worked on OOP languages but need a refresher, then I suggest looking at the many videos available for free on YouTube. As an example, `freecodecamp.org` have a good video at `https://www.youtube.com/watch?v=SiBw7os-_zI`.

For a deeper exploration of the fundamentals of OOP, it is worth reading an excellent book named *Learning Object-Oriented Programming*, by Gaston C. Hillar.

Dart's official documentation on event loops will give you a further understanding of how Isolates work: `https://dart.dev/articles/archive/event-loop`. Note that this is an advanced topic and rarely used in Flutter, so only read further if the topic interests you.

Part 2: Building a Basic Flutter App

Now that you have a strong foundational knowledge of Flutter and Dart, this part will build on that knowledge with the introduction of Flutter concepts, such as widgets, and user input, such as gestures (for example, tapping and scrolling).

We will then look at how we can make these widgets look pretty through colors, images, styling, and decorations.

Finally, we will introduce the idea of screens within an app and look at how a user can navigate between these screens to explore the functionality of your app.

This part contains the following chapters:

- *Chapter 5, Building Your User Interface through Widgets*
- *Chapter 6, Handling User Input and Gestures*
- *Chapter 7, Let's Get Graphical!*
- *Chapter 8, Routing – Navigating between Screens*

5
Building Your User Interface through Widgets

In this chapter, we will move beyond the world of pure Dart and into Flutter. One of the key aspects of Flutter is a special type of class called a **widget**. We will explore what a widget is and the three different types of widgets: stateless, stateful, and inherited. We will explore some of the most common widgets in Flutter, view them in action, and learn how to add them to the *Hello World!* application you created in *Chapter 1*, *What Is Flutter and Why Should I Use It?* Additionally, you will gain an understanding of how layout widgets can help you structure your **user interface** (**UI**).

Widgets are classes and objects within the Dart language. Therefore, this chapter will use a lot of the knowledge that you gained in *Chapter 4*, *Dart Classes and Constructs*, regarding Dart classes and enums. Armed with this knowledge, we will explore **stateful** and **stateless** widgets, which are classes that inherit from specific superclasses and are key to how you manage the UI of your app.

Next, we will take a closer look at the built-in widgets that come as part of the Flutter framework and cover most of your UI needs. It is useful to be aware of what is already available, including the layout widgets that control the positioning of their nested child widgets, which, in turn, gives you greater control of how your app looks to the user.

We will also start to look at how you can use widgets to interact with your user, a topic that we will continue to explore in *Chapter 6*, *Handling User Input and Gestures*.

The following topics will be covered in this chapter:

- Stateful/stateless widgets
- Built-in widgets
- Understanding built-in layout widgets
- Widgets for user interaction

By the end of this chapter, you should have a good idea of how Flutter apps are put together and why widgets are such an important part of the Flutter framework.

Technical requirements

You will need your development environment again for this chapter. Take a look back at *Chapter 1*, *What Is Flutter and Why Should I Use It?*, if you require further information on how to set up your IDE or to refresh your knowledge regarding the development environment requirements.

You can find the source code for this chapter on GitHub at `https://github.com/PacktPublishing/Flutter-for-Beginners-Third-Edition`.

Stateful/stateless widgets

In *Chapter 1*, *What Is Flutter and Why Should I Use It?*, we learned that widgets play an important role in Flutter application development. They are the pieces that form the UI; they are the code representation of what is visible to the user.

UIs are rarely static; they change frequently, as you will have experienced when you have used a web page or an application. Although immutable by definition, widgets are not meant to be final – after all, we are dealing with a UI, and a UI will certainly change during the life cycle of any application. That's why Flutter provides two types of widgets: stateless and stateful.

As you might expect, a stateless widget has no state, whereas a stateful widget holds state and adapts based on that state. This difference impacts the life cycle of the widget, how it is constructed, and how the code is structured. It's the developer's responsibility to choose what kind of widget to use in each situation. Generally speaking, a developer should look at stateless as the default option unless the widget needs to hold state. A stateful widget could be used for every scenario, but this will impact performance and code maintainability.

> **Immutability**
>
> Most programming languages refer to the term "immutable." An immutable object is an object that never changes – that is, it cannot change itself, and it cannot be changed externally. Instead, if a change is needed, then the object is simply replaced. A stateless widget is immutable because it cannot change its properties or state, nor can something external change its properties or state. If the widget needs to change, then it is effectively replaced by a new widget that has different properties or states.

Additionally, Flutter uses the concept of inherited widgets (the `InheritedWidget` type), which is also a kind of widget, but it is slightly different from the other two types that we've mentioned.

Stateless widgets

A typical UI will be composed of many widgets, and some of them will never change their properties after being instantiated. They do not have a state; that is, they do not change by themselves through an internal action or behavior. Instead, they are changed by external events on parent widgets in the widgets tree. So, it's safe to say that stateless widgets give control regarding how they are built to a parent widget in the tree. The following diagram shows a representation of a stateless widget:

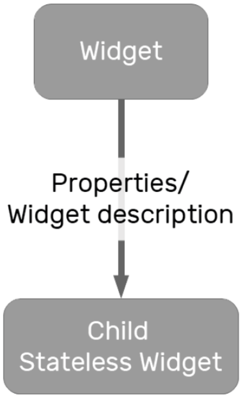


Figure 5.1 – A stateless widget

In the preceding diagram, the parent widget instantiates the child stateless widget and passes a set of properties during the instantiation. The child widget can only receive these properties from the parent widget and will not change them by itself. In terms of code, this means that stateless widgets only have final properties defined during construction, and these properties can only be changed by updating a parent widget with the changes and then rippling it down to the child widgets.

Let's take a look at an example of a stateless widget from the *Hello World!* app that we explored in previous chapters.

Code example

The very first stateless widget inside the application is the application class itself:

```
class MyApp extends StatelessWidget {
  @override
  Widget build(BuildContext context) {
    return MaterialApp(
      title: 'Flutter Demo',
      theme: ThemeData(
        primarySwatch: Colors.blue,
      ),
```

```
      home: MyHomePage(title: 'Flutter Demo Home Page'),
    );
  }
}
```

As you can see, the MyApp class extends StatelessWidget and overrides the build (BuildContext) method. The **build** method is critical to all widgets and describes how the widget should appear on the screen. It does this by building a widget subtree below it. MyApp is the root of the widget tree; it is the top-level widget that is instantiated within the **runApp** method in the Dart **main** method. Therefore, it builds all the widgets down the tree. In this example, the direct child is **MaterialApp**. According to the documentation, MaterialApp can be defined as follows:

> *"A convenience widget that wraps several widgets that are commonly required for material design applications."*

> **Material Design**
>
> Material Design is a standard set of designs and digital experiences that were created by Google to help teams build high-quality UIs. Apple has an equivalent named Cupertino, and we will look at examples of both throughout the remainder of this book.

In this example, the stateless widget does not receive any properties from its parent because it doesn't have a parent. We will view examples of properties being passed later.

BuildContext is an argument that's provided to the build method as a useful way to interact with the widget tree. It allows you to access important ancestral information that helps describe the widget that is being built. For example, the theme data defined in this widget can be accessed by all child widgets to ensure there is a consistent look and feel to your application.

In addition to other properties, MaterialApp contains the home property. This is the first widget that is displayed within your application. Here, home refers to the MyHomePage widget, which is not a built-in widget but rather a stateful widget defined within the Hello World! application.

Let's try creating a new StatelessWidget to get a better understanding of how they are constructed. We will create a DestinationWidget widget that will display information about an interesting location that could be the destination of a holiday.

Create a new file in your Hello World lib folder and call it destination_widget.dart. This will open a blank file and, depending on your IDE, you may be able to generate a stateless widget simply by starting to type stateless – code assist should kick in. If this does happen, then name your stateless widget DestinationWidget. If code assist doesn't snap into action, then simply copy the following example code to get started:

```
class DestinationWidget extends StatelessWidget {
```

```
  const DestinationWidget({Key? key}) : super(key: key);

  @override
  Widget build(BuildContext context) {
    return Container();
  }
}
```

This is the standard structure of a stateless widget and is very similar to the `MyApp` stateless widget we saw previously.

The class will require an `import` statement so that it can link in the definitions of `StatelessWidget`, `BuildContext`, and `Container`, the latter of which is itself a widget. There are three places you could import these from:

- `package:flutter/widgets.dart`
- `package:flutter/cupertino.dart`
- `package:flutter/material.dart`

The first `import` option, `widgets.dart`, holds all the useful definitions for widgets, and is included in the two other import options, `material.dart` and `cupertino.dart`, which add extra definitions to the base widget definitions. Therefore, generally, you will use one of `material.dart` or `cupertino.dart`. In this scenario, we will use `material.dart`, the most common option. Add the following `import` statement to the top of your file:

```
import 'package:flutter/material.dart';
```

We will now simplify this example so that you can appreciate the core capabilities of a stateless widget. First of all, let's change the constructor so that it receives a single `String` argument from whatever parent widget instantiates it. We will also remove the `Key` and `super` sections from the constructor for clarity, an area that we will explore later in the *The widget key property* section. It is worth noting the use of the nullability operator on the key parameter; the key property is optional for both this stateless widget and for the superclass widget:

```
class DestinationWidget extends StatelessWidget {
  DestinationWidget({required this.destinationName});

  final String destinationName;

  @override
  Widget build(BuildContext context) {
    return Container();
  }
}
```

We've made quite a few changes here. We have now specified that to instantiate this widget, it requires a single argument named `destinationName`. This needs to be stored somewhere, so we have created a final variable of the `String` type with the same name so that we can use the shortcut constructor syntax of `this.variableName` to directly set the variable.

Now, let's take a look at the `build` method. At the moment, the method simply returns a child widget of the `Container` type. This is the simplest widget and effectively does nothing unless it is customized in some way. We want to display information about our destination, so the easiest starting point is to use the `Text` widget, a widget that, as its name suggests, displays text on the screen. The content of the file now looks like this:

```
import 'package:flutter/material.dart';

class DestinationWidget extends StatelessWidget {
  DestinationWidget({required this.destinationName});
  final String destinationName;
  @override
  Widget build(BuildContext context) {
    return Text(destinationName);
  }
}
```

Our widget now takes a single required argument and when the `build` method is called, it instantiates a child widget to display the text on the screen.

You should now be starting to understand how Flutter composes widgets to create a display. Let's take a look at the partner of stateless widgets – that is, the stateful widget.

Stateful widgets

Unlike stateless widgets, which receive properties from their parents that are constant throughout the widgets' lifetime, stateful widgets are meant to change their properties dynamically during their lifetimes. By definition, stateful widgets are also immutable, but they have a companion **State** class that represents the current state of the widget. This is shown in the following diagram:

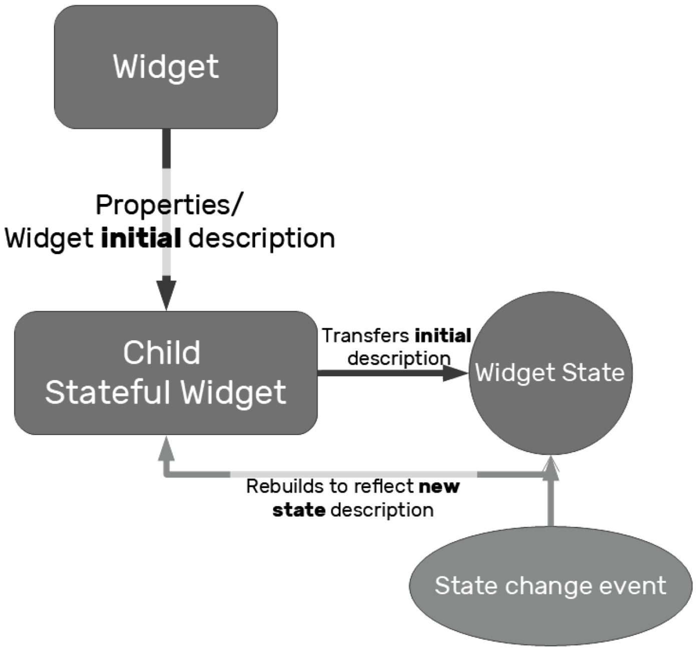


Figure 5.2 – A stateful widget

In the preceding diagram, a widget instantiates a child widget and, similarly to the stateless widget example, passes properties to the child. These properties are, once again, final and cannot be changed within the widget. However, unlike the stateless widget example, a companion **State** object also has access to the widget properties and, additionally, can hold other properties that are not final.

By holding the state of the widget in a separate **State** object, the framework can rebuild the widget whenever necessary without losing its current associated state. The **State** object will notify the framework when the widget needs to be rebuilt and the framework will redraw the widget using the updated state.

Code example

`MyHomePage` is a stateful widget, so it is defined with a `State` object named `_MyHomePageState`, which contains properties that affect how the widget looks and behaves. First, let's take a look at the widget:

```
class MyHomePage extends StatefulWidget {
  MyHomePage({Key key, required this.title}) :
    super(key: key);
  final String title;
  @override
  _MyHomePageState createState() => _MyHomePageState();
}
```

The first thing that you should pay attention to is that this extends `StatefulWidget`, identifying that this will have a `State` companion object. Stateful widgets must override the `createState()` method and return an instance of the companion object. In this example, it returns an instance of `_MyHomePageState` through the use of an arrow function. Note that the `@override` annotation has been used to signify that this is overriding the inherited class' function.

Additionally, in this example, properties have been passed from a parent widget and these are surfaced in the widget constructor. Note that the `title` property has been passed in and is stored in the widget in the final field, which is named `title`. As discussed in the *Stateless widget* section, Dart has some clever shortcuts in the way it structures constructors, and by using `this.title` in this constructor body, we can automatically assign the value of the `title` property to the `title` field.

Normally, stateful widgets define their corresponding `State` classes in the same file. Additionally, `State` is typically private to the widget library since external clients do not need to interact with it directly, hence the use of the underscore in the class name to mark it as private.

The following `_MyHomePageState` class represents the `State` object of the `MyHomePage` widget:

```
class _MyHomePageState extends State<MyHomePage> {
  int _counter = 0;
  void _incrementCounter() {
    setState(() {
      _counter++;
    });
  }

  @override
  Widget build(BuildContext context) {
    return Scaffold(
      appBar: AppBar(
        title: Text(widget.title),
      ),
      body: Center(
        child: Column(
          mainAxisAlignment: MainAxisAlignment.center,
          children: <Widget>[
            Text(
             'You have pushed the button this many times:',
            ),
            Text(
              '$_counter',
              style: Theme.of(context).textTheme.headline4,
            ),
          ],
```

```
        ),
      ),
      floatingActionButton: FloatingActionButton(
        onPressed: _incrementCounter,
        tooltip: 'Increment',
        child: Icon(Icons.add),
      ), // This trailing comma makes auto-formatting
          nicer for build methods.
    );
  }
}
```

There is a lot in this class definition, so let's go through the code section by section.

First, there is only one class field, which is named `_counter`, so you can infer that the state of the `MyHomePage` widget is defined by that single property. The `_counter` property records the number of presses of the button in the lower-right corner of the screen. How this `_counter` property changes will be defined in your business logic.

What is business logic?

Business logic is the part of the code where you specify the business rules for your app. Unlike much of your app code, which is concerned with lower-level details, such as how to display widgets or connect to the database, the business logic determines how a user interacts with your app, and how that interaction impacts state data.

For example, where a widget is placed on the screen, what color it is, and how it reacts when pressed is not business logic. However, if by pressing it the user can modify information about themselves such as their gender, home address, or how many cakes they want to buy, then that is business logic.

The first method we encounter is `_incrementCounter`. This takes no arguments and has a **void** return code, specifying that it returns no value. However, it does do something crucial that we should explore in further detail:

```
    setState(() {
      _counter++;
    });
```

A stateful widget is meant to change its appearance during its lifetime – that is, it defines what will change – and so it needs to be rebuilt to reflect such changes. In the `StatefulWidget` diagram (*Figure 5.2*), we saw that the framework rebuilds `StatefulWidget` to reflect a new state. However, how does the framework know when something in the widget changes and that a rebuild is required?

The answer is the `setState` method. This method receives a function as a parameter that updates the widget's corresponding **state**. In this case, we have created an anonymous function, and in the function body, we have specified that the `_counter` variable should be incremented. By calling `setState`, the framework is notified that it needs to rebuild the widget. Once called, the widget will be redrawn with the new `_counter` value already set.

This is a fundamental part of Flutter and is worth fully understanding. If our code simply updated the `_counter` variable without calling `setState`, then the Flutter framework is very unlikely to redraw the widget and therefore react to the change in state. A lot of issues you may find in your apps, especially when we look at input fields, can be attributed to not notifying the framework that a state change has occurred. The `setState` method is your way to say that the state has changed in a meaningful way and the widget needs to be built again.

When `setState` has been called, then the framework, among other activities, will call the `build` method again on the widget's `State`. The method signature and intended function are identical to the build method of `StatelessWidget`, which we discussed earlier. However, unlike `StatelessWidget`, we now have a state that will affect how we draw the widget, which could lead to far more complex code involving even more conditional statements.

The `build` method can look intimidating, and we will look at the individual widgets in more detail later in this chapter. However, at this point, try to get a feel for the structure shown and how widgets are composed of other widgets. The method returns a `Scaffold` widget at the top level that is composed of three child widgets via three constructor arguments:

- `appBar`: This holds a widget of the `AppBar` type, which itself has one constructor argument named `title`. As you can guess, this describes the widget that will appear at the top of the screen as an app bar.
- `body`: This can hold any widget and appears in the main body of the application (that is, between the top app bar and any bottom menu bar). In this case, it holds a `Center` widget (which centers the child content). This, in turn, holds a `Column` widget (which creates a vertical column of widgets). Finally, this holds two `Text` widgets (which display a string of text).
- `floatingActionButton`: This holds a widget of the `FloatingActionButton` type, which is a button that floats above the app's body in the lower-right corner (as the default configuration) and acts as a button.

Note that one of the arguments for the `FloatingActionButton` constructor is `onPressed` and that its value is the `_incrementCounter` method:

```
floatingActionButton: FloatingActionButton(
  onPressed: _incrementCounter,
  tooltip: 'Increment',
  child: Icon(Icons.add),
 )
```

This ties the whole flow together:

1. The `MyHomePage` widget calls the `build` method on the widget's companion `State` instance to display the app bar, body, and action button.
2. The user presses the action button.
3. The `onPressed` argument value is triggered, which calls the `_incrementCounter` method.
4. The `_incrementCounter` method calls the `setState` method with the anonymous function as an argument, specifying that the `_counter` variable should be incremented.
5. The framework calls the anonymous function that was passed as an argument, thereby incrementing the `_counter` variable.
6. The framework redraws the widget by calling the `build` method on the widget's companion `State` instance again to display the updated app bar, body, and action button:

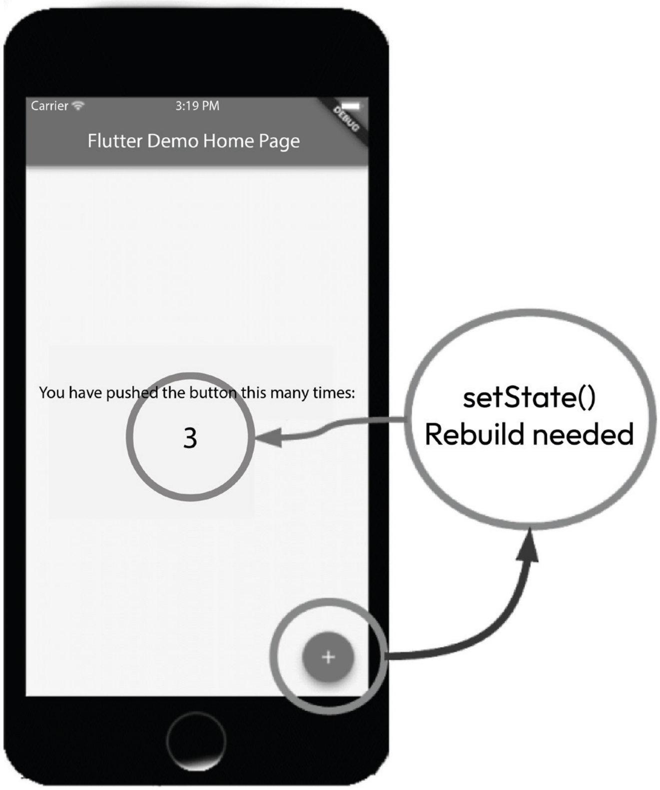


Figure 5.3 – The home page

As the preceding diagram shows, the `setState` method is crucial to this whole flow, and understanding this redraw flow is central to how the Flutter framework works.

Most of the time, those are the two widget types that you will need to know about, but let's complete this section by looking at a less well-known widget type: **InheritedWidget**.

Inherited widgets

Besides `StatelessWidget` and `StatefulWidget`, there is one more type of widget in the Flutter framework: `InheritedWidget`. Sometimes, one widget might require access to data further up the widget tree. In such scenarios, one solution is to replicate the information down to the interested widget by passing it through all of the intermediate widget constructors. Let's view an example widget composition structure so that we can examine this in more detail:

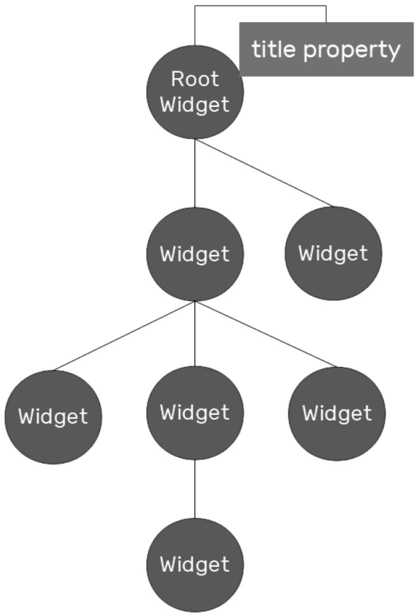


Figure 5.4 – A widget tree with a title property

In this scenario, let's suppose that one of the widgets down the tree requires access to the title property from the root widget. For this to happen in a world where there are only stateful and stateless widgets, we would need to pass the `title` property to every child widget via their constructors so that the child widget could, in turn, pass the `title` property to its child widgets. This can lead to lots of boilerplate code, can be error-prone if one of the widgets isn't coded quite right, and can be painful if it is decided that the child widget needs another property, which means that all of the intermediate widgets need to be updated.

To address this problem, Flutter provides the `InheritedWidget` class. This is an auxiliary kind of widget that helps propagate information down the tree, as shown in the following diagram:

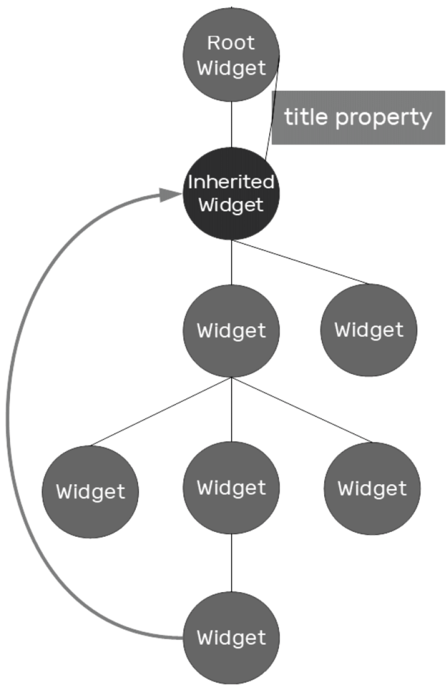


Figure 5.5 – A widget tree with the title property inherited

By adding `InheritedWidget` to the tree, any widget below it can access the data it exposes by using the `of(InheritedWidget)` method of the `BuildContext` class that receives an `InheritedWidget` type as a parameter and use the tree to find the first ancestral widget of the requested type.

There are some very common uses of `InheritedWidget` in Flutter. One of the most common uses is from the `Theme` class, which helps describe colors for a whole application and therefore needs to be available to all of the widgets so that they can get theme information for the design. We will explore `Theme` in *Chapter 6*, *Handling User Input and Gestures*, so we will leave further exploration of `InheritedWidget` until then.

Now, let's investigate something that you might have spotted in some of the previous code examples – that is, a constructor property called **key**.

The widget key property

If you take a look at the constructors of the `StatelessWidget` and `StatefulWidget` classes, you will notice a parameter named `key`. This is an important property for widgets in Flutter because of the way that the framework renders widgets.

The widget tree does not work alone in the framework. It has the help of the element tree; a tree that relates to the widget tree by representing the built widget on the screen, so every widget will have a corresponding element in the element tree after it is built.

The element tree has an important task in Flutter: it helps map onscreen elements to the widget tree. Also, it determines how widget rebuilding is done in update scenarios. When a widget changes state and needs to be rebuilt, this will cause an update on the widget's corresponding element in the element tree.

The element stores the type of the corresponding widget and a reference to its children element types. This loose coupling has many benefits for performance but means that in certain situations, the element tree may fail to reflect changes to the widget tree.

The element tree is a very simple representation of the widget tree that only holds the widget's type and the references to its children widgets. When a change or rebuild occurs, the framework uses the widget's type and children references to determine whether a redraw is needed.

In situations where there are many widgets with the same type as other children of the same widget (for example, `Text` widgets held in a row or column), there can be situations where the ordering of the widgets changes but doesn't invalidate the element tree. In this situation, the behavior of Flutter can be unexpected.

The `key` property allows you to preserve the state of a specific widget between rebuilds. Without keys, the element tree would not know which state corresponds to which widget, as they would all have the same type. When a widget has a state, it needs the corresponding state to be moved around with it. Put simply, that is what `key` helps the framework do. By holding the `key` value, the element in question will know the corresponding widget state that needs to be linked to it.

In most situations, a key is not needed (and should not be used); however, if you see some strange behavior where you are sure your widget is changing state but this is not being correctly reflected on the UI, then it is worth checking whether the framework is misunderstanding the element tree and whether a key might be a suitable remedy for the situation. If you need more information regarding how a key affects the widget and the available types of keys, please check out the official documentation's introduction to keys: `https://flutter.dev/docs/development/ui/widgets-intro#keys`.

We have now explored the fundamental building blocks of Flutter: widgets. Specifically, we have looked at three types of widgets – stateless, stateful, and inherited – along with the situations that you would use them in, and how to link those widgets to the element tree using keys. Next, we'll look at some widgets you get for free when you start your UI.

Built-in widgets

Flutter has a big focus on the UI, and, because of this, it contains a large catalog of widgets that allow you to get started with a high-quality UI relatively easily.

The available widgets of Flutter range from simple ones, such as the `Text` widget in the Flutter counter application example, to complex widgets that enable you to design a dynamic UI with animations and multiple gesture handling.

In this section, we will go through some of the most common built-in widgets in more detail. We will start with the basic widgets for displaying text and images, move on to more advanced widgets involving user interaction, such as buttons, and finish with a look at layout widgets, which control how other widgets are positioned on the UI.

Display widgets

The display widgets in Flutter are a good starting point, not simply because of their ease of use, but because they also demonstrate the power and flexibility of the framework, even in simple scenarios.

In this section, we will explore the most common widgets that you are likely to use as you get started with Flutter. However, there are many more widgets available that you can explore in the *Widget catalog* at `https://flutter.dev/docs/development/ui/widgets`.

The Text widget

The `Text` widget displays a string of text that can be styled as follows:

```
Text(
  "Some exciting text",
  style: TextStyle(color: Colors.red, fontSize: 14),
  textAlign: TextAlign.center
)
```

Pay attention to the structure of the `Text` constructor. The first parameter, the string of text, is positional. It is then followed by a series of named parameters. Flutter leans heavily on the named parameter approach to keep widget trees readable, but where a parameter is fundamental to the widget, such as the text for a `Text` widget, this is often the first positional parameter.

The most common properties of the `Text` widget are as follows:

- `style`: This holds a `TextStyle` instance that controls how the text should be styled. The `TextStyle` constructor has properties that allow you to set the text color, background, font family (including the use of a custom font from the assets section of the `pubspec.yaml` file, as mentioned in *Chapter 1*, *What Is Flutter and Why Should I Use It?*), line height, font size, and more.
- `textAlign`: This holds a value from the `TextAlign` enum describing how the text should be aligned. Options include center alignment and justified alignment.
- `maxLines`: This holds an integer specifying the maximum number of lines that the text can be wrapped over before it is truncated.

- `overflow`: This holds a value from the `TextOverflow` enum describing how the text should be shown that exceeds the available space. Options include fading, ellipsis, or clipping.

To view all of the available `Text` widget properties, please refer to the official `Text` widget documentation page at `https://docs.flutter.dev/development/ui/widgets/text`.

The Image widget

The `Image` widget displays an image from different sources and formats. At the time of writing, the supported image formats are JPEG, PNG, GIF, animated GIF, WebP, animated WebP, BMP, and WBMP:

```
Image(
  image: AssetImage(
    "assets/dart_logo.jpg"
  ),
)
```

The `Image` widget is not quite as simple to construct as the `Text` widget because it needs to know the source of the image file. This could be from the internet, from a file on the device, or from within the app, as defined in the assets. To manage this, the widget has an `image` constructor property that specifies an `ImageProvider` type.

In this example, the image comes from an asset within the app. This is denoted by using an `AssetImage` provider that takes the location of the asset as a positional constructor parameter. To retrieve an image from the internet, instead of `AssetImage`, you should use the `NetworkImage` provider, which works similarly. To retrieve an image from a file on the device, you should use the `FileImage` provider.

The `Image` class contains convenience constructors to help you load images, such as the following:

- `Image.asset`: This creates an `AssetImage` provider, which is used to obtain an image from your assets using the `asset` key. For example, take a look at the following:

  ```
  Image.asset(
    'assets/dart_logo.jpg',
  )
  ```

- `Image.network`: This creates a `NetworkImage` provider to obtain an image from a URL:

  ```
  Image.network(
    'https://picsum.photos/250?image=9',
  )
  ```

- `Image.file`: This creates a `FileImage` provider to obtain an image from a file:

  ```
  Image.file(
    File(file_path)
  ```

  Note that this uses a `File` object to refer to the location of the file.

Material Design and iOS Cupertino widgets

Many of the widgets in Flutter are descended, in some way, from a platform-specific guideline: Material Design or iOS Cupertino. This enables the developer to follow platform-specific guidelines in the easiest possible way.

For example, Flutter does not have a `Button` widget; instead, it provides alternative button implementations for Google Material Design and iOS Cupertino guidelines. However, you can easily choose one set of implementations to use in the development of your app and use that for all releases (such as the Play Store, the App Store, or the web). There is no need to switch between Material and Cupertino, depending on whether the app is running on Android or iOS.

Dialogs

A dialog pops over the top of the currently displayed UI as a modal window, and the display behind it is masked with a translucent gray mask. They are useful for popping short snippets of information, warnings, or errors.

Both Material Design and Cupertino dialogs are implemented by Flutter. On the Material Design side, they are `SimpleDialog` and `AlertDialog`; on the Cupertino side, there is `CupertinoAlertDialog`. Let's look at some of the built-in widgets that will allow a user to interact with your app.

User interaction widgets

User interaction widgets are crucial to the functioning of any app because they allow you to invite the user to interact with your app so that the information your app presents, or the actions that your app takes, are based on the needs of the user. There are many ways that a user can interact with an app, and we will explore user interaction in much more detail in *Chapter 6*, *Handling User Input and Gestures*, so in this section, I will give you the base options to help you get started.

Buttons

Buttons are widgets that automatically accept a user interaction (such as a tap or a click) and call the relevant code or method supplied to them in their constructor.

On the Material Design side, Flutter implements the following button widgets:

- `FloatingActionButton`: As we mentioned earlier, a floating action button is circular, shows an icon, and hovers over the page, generally in the lower-right corner, although its position can be configured. It is used to enact a primary action for the page it is shown on. For example, on a page showing email messages, the action button could have a plus icon on it, denoting the ability to create a new email when it is pressed.
- `TextButton`: A text button is a string of text printed on a Material widget that will react to touch by showing the standard Material splash or ripple.

- `ElevatedButton`: The `ElevatedButton` widget is a button that is very similar to `TextButton` but appears to hover slightly above the page.
- `OutlinedButton`: This is a button that is very similar to `TextButton` but has an outlined border around the text, denoting the edge of the button.
- `IconButton`: An icon button is a picture printed on a Material widget that, like the `TextButton` widget, will react to touch by showing a splash or ripple effect.
- `DropDownButton`: The `DropDownButton` widget is very similar to the drop-down buttons that you view on web pages. It shows a currently selected item alongside an arrow. Pressing this button will drop down a menu that allows the user to select another item.
- `PopUpMenuButton`: The `PopUpMenuButton` widget will pop up a menu of options to the user, allowing the user to take action on the app.

For the iOS Cupertino style, Flutter provides the `CupertinoButton` class.

Text fields

Text fields allow a user of your app to enter text using their device's keyboard.

Text fields are implemented in both guidelines by the `TextField` widget in Material Design and by the `CupertinoTextField` widget in iOS Cupertino. Both of them display the keyboard for user input. Some of their common properties are as follows:

- `autofocus`: This indicates whether `TextField` should be focused automatically when it is shown (if nothing else is already focused on).
- `enabled`: This sets the field as editable or not.
- `keyboardType`: This changes the type of keyboard that is displayed to the user when editing. For example, if you only want the user to enter numbers, then the number pad is shown, or if you want the user to enter a password, then autocorrect is disabled.

We will look at `TextField` widgets in much more detail in *Chapter 6*, *Handling User Input and Gestures*, especially their use within an input format.

Selection widgets

Selection widgets allow a user to select one or more answers to a question.

The available control widgets for selection in Material Design are as follows:

- `Checkbox` allows you to select multiple options in a list
- `Radio` allows a single selection in a list of options

- `Switch` allows you to toggle (on/off) a single option
- `Slider` allows you to select a value in a range by moving the slider thumb

On the iOS Cupertino side, some of these widget functionalities do not exist. However, there are some alternatives available, as follows:

- `CupertinoActionSheet`: This is an iOS-style modal bottom action sheet that enables you to choose one option among many
- `CupertinoPicker`: This is a picker control that is used to select an item in a short list
- `CupertinoSegmentedControl`: This behaves like a radio button, where the selection is a single item from an options list
- `CupertinoSlider`: This is similar to `Slider` in Material Design
- `CupertinoSwitch`: This is also similar to Material Design's `Switch`

It is worth noting that there is no issue with mixing and matching widgets. If you decide that a Cupertino widget looks better than a Material widget, then feel free to use it within your app.

Date and time pickers

For Material Design, Flutter provides date and time pickers through the `showDatePicker` and `showTimePicker` functions, which build and display the Material Design dialogue for the corresponding actions via a dialogue.

On the iOS Cupertino side, the `CupertinoDatePicker` and `CupertinoTimerPicker` widgets are provided, following the previous `CupertinoPicker` style.

Now that you have an idea of the vast number of built-in widgets available in Flutter, the next natural question to ask is how you should control where they appear on the screen.

Layouts

From the widgets we have looked at so far, it may not seem obvious how to place these widgets at specific positions on the screen, and how that layout might change based on different screen sizes or ratios.

For example, to position a button in the bottom corner of the screen, we might assume we can specify a positioning that is relative to the screen. However, as you might have noticed, buttons and other widgets do not have a position property.

So, you might be asking yourself, "How are widgets organized on the screen?" Well, the answer is more widgets! Flutter provides widgets that allow you to compose the layout itself, with positioning, sizing, styling, and more.

Displaying a single widget on the screen is not a good way to organize a UI. Usually, we lay out a list of widgets that are organized in a specific way; to do so, we use container widgets.

Let's take a look at the most common built-in layout types.

Container

The simplest way to manage the layout of a widget is to instantiate it as the child of a `Container` widget. Take a look at the following example:

```
Container(
  padding: EdgeInsets.all(14),  decoration: BoxDecoration(
    border: Border.all(),
  ),
  child: Text(
    'Beautiful Teesside',
  ),
)
```

In this example, the `Container` widget will put 14 pixels of padding around itself, then place a border on all four sides, and then, finally, place the `Text` widgets containing the text `'Beautiful Teesside'` within the border.

The `Container` widget holds useful attributes, such as the following:

- `padding`: This indicates how much space should be placed around the container when placing it within the widget tree.
- `color`: The background color of `Container`.
- `margin`: This indicates the amount of space to place around the child widget within `Container`.
- `decoration`: This allows you to choose whether the `Container` widget should have a background image or color, whether it should have borders around it, whether the borders should have sharp or curved corners, and much more.

  Note that you cannot define both the `color` parameter and `decoration` parameter within the same `Container` declaration. If you use the `decoration` parameter, then the `color` parameter moves inside the `decoration` object.
- `height/width`: This allows you to decide how much space the `Container` widget should take up on the screen.

Specialized containers

There are more specialized widgets that build on the generality of the `Container` widget. This includes animated `Container` widgets, which we will explore in *Chapter 11*, *Using Widget Manipulations and Animations*, and also many more basic widgets.

Centering a widget inside a parent widget can be achieved by wrapping the child inside a `Center` widget:

```
Center(
  Child: Text('Saltburn pier'),
}
```

Aligning a child widget relative to a parent can be done with the `Align` widget, where you specify the desired position through its `alignment` property:

```
Align(
  alignment: Alignment.topRight,
  child: Text('Whitby Abbey'),
)
```

Another useful widget is `Padding`, which allows you to specify the amount of space around the given child:

```
Padding(
  padding: EdgeInsets.all(16.0),
  child: Text("Robin Hood's Bay"),
)
```

As you can see, when specifying padding, we use the `EdgeInsets` class. There are several factory constructors to assist with the instantiation of `EdgeInsets`. The one shown here sets a size for all of the sides of the widget.

The `fromLTRB` constructor allows you to set the size for each of the four sides in turn:

```
EdgeInsets.fromLTRB(left, top, right, bottom);
```

The only constructor takes named parameters to allow you to specify the sizes for individual sides:

```
EdgeInsets.only(right: 5)
```

And finally, the quite elegant symmetric constructor allows you to specify a size for the horizontal or vertical sides of the widget:

```
EdgeInsets.symmetric(vertical: 5)
```

You will find that you use `EdgeInsets` often within your widget layouts. Both the padding and margin parameters take the `EdgeInsets` type, so take a moment to familiarize yourself with the different options.

The functionalities of all of these widgets are available in the more generic `Container` widget, which includes these common positioning and styling controls so that you can apply them to a child directly. However, using specialized widgets such as `Center` makes the code much cleaner, shorter, readable, and maintainable.

Row and Column

The most common containers in Flutter are the Row and Column widgets. They have a children property that expects a list of widgets to display in some kind of direction (that is, a horizontal list for Row or a vertical list for Column). You viewed a Column widget in the Hello World! app, so let's take a look at a Row example first:

```
Row(
  mainAxisAlignment: MainAxisAlignment.spaceBetween,
  children: [
    Text("Staithes"),
    Text("Saltburn"),
    Text("Whitby"),
  ],
)
```

In this example, a row of three pieces of text will be placed on the screen.

The mainAxisAlignment parameter specifies how to space out the children within the parent on the main axis, which for Row is horizontal. The value of MainAxisAlignment.spaceBetween denotes that the children must have an equal amount of space between them.

Note that Row isn't great at managing overruns of space, so on a smaller device, you would need to add additional widgets or properties to ensure that the text is displayed correctly.

Now, let's create Column but use the stateless widget that we created at the start of this chapter. The syntax for a Column widget is very similar to that for a Row widget, but the children are displayed vertically:

```
Column(
  crossAxisAlignment: CrossAxisAlignment.start,
  mainAxisSize: MainAxisSize.min,
  children: [
    DestinationWidget(destinationName: 'Staithes'),
    DestinationWidget(destinationName: 'Saltburn'),
    DestinationWidget(destinationName: 'Whitby'),
  ],
)
```

The crossAxisAlignment parameter specifies how to space the children within the parent on the axis that crosses the main axis. The main axis of Column is vertical, so the cross axis is horizontal. CrossAxisAlignment.start aligns all the children to the left of Column, the start of the axis.

The mainAxisSize parameter denotes how much space Column should occupy. MainAxisSize.min specifies that Column should take up the minimum space after allocating space for its children.

What is with that trailing comma?

You might have noticed that when declaring lists, or passing arguments to constructors, we often have a trailing comma. Dart doesn't care whether your list has a trailing comma: `[item1, item2]` versus `[item1, item2,]`. However, there are a few reasons why you might choose to include a trailing comma. Firstly, adding items to a list is easier if there is already a comma present. Secondly, copying and pasting become much easier because every entry in the list has the same syntax. Thirdly, the Dart formatter automatically places each list entry onto its own line if there is a trailing comma at the end of the list.

Stack

Another widely used widget is the `Stack` widget, which organizes children widgets in layers, where one child can overlap another child either partially or totally.

This appears similar to a `Row` or `Column` widget in that it takes a list of children widgets and layers them in the order they are defined. So, the first widget is effectively at the bottom of the stack, and the last widget is at the top, potentially covering the lower widgets.

Scaffold

Scaffold implements the basic structure of a Material Design or iOS Cupertino visual layout. Generally, you would use this as the root widget of your page because it allows you to lay out your whole page in a somewhat standard format.

For Material Design, the `Scaffold` widget can contain multiple Material Design components, such as the following:

- `AppBar`: This sits at the top of the device screen. Generally, it will hold a child widget containing text (the title of the page), which appears on the left, and then some action widgets, generally buttons, which appear on the right.
- `TabBar`: Generally, `TabBar` is just below `AppBar` and allows the user to switch horizontally between several sub-pages of your page. For example, you might have a chat client and want the user to be able to switch between live messages and pinned messages. `TabBar` will allow this to happen with a horizontal swipe.
- `TabBarView`: To work with `TabBar`, you will need to define the views that appear as the user moves between the tabs. `TabBarView` fits that need and will need to match.
- `body`: This is the main chunk of the page. It will appear below `AppBar` or `TabBar` (if you have either) and cover the whole screen.
- `BottomNavigationBar`: This sits at the base of the device screen, allowing the user to switch between the top-level app views via a single tap.

- `Drawer`: This is a panel that slides in from the side of the screen, allowing the user to quickly navigate the app. Generally, you would use a bottom navigation bar for the main context changes (for example, to switch from an email view to a calendar view), and then possibly use `Drawer` to navigate within that context (for example, to choose the inbox or spam folder within the email view). However, Flutter is not opinionated in terms of how you should design your app, so you are free to choose how you use these widgets.

In iOS Cupertino, the structure is different with some specific transitions and behaviors.

The available iOS Cupertino classes are `CupertinoPageScaffold` and `CupertinoTabScaffold`, which are typically composed of the following:

- `CupertinoNavigationBar`: A top navigation bar, which is typically used with `CupertinoPageScaffold`
- `CupertinoTabBar`: A bottom tab bar, which is typically used with `CupertinoTabScaffold`

As you can see, Cupertino's `Scaffold` is far more limited in terms of its structure and features than Material's `Scaffold`. Generally, a good starting point to get a page of your app up and running is to use Material's `Scaffold` because it covers most of the needs of a page right from the start.

Let's modify the `Scaffold` widget we found in the *Hello World!* code so that we can include our `Column` from earlier. The `body` section of `Scaffold` already holds a `Center` widget that has a child of `Column`. We can replace the existing `Column` with our new `Column` of destinations, and remove `floatingActionButton` to get something like this:

```
@override
Widget build(BuildContext context) {
  return Scaffold(
    appBar: AppBar(
      title: Text(widget.title),
    ),
    body: Center(
        child: Column(
      crossAxisAlignment: CrossAxisAlignment.start,
      mainAxisSize: MainAxisSize.min,
      children: [
        DestinationWidget(destinationName: 'Staithes'),
        DestinationWidget(destinationName: 'Saltburn'),
        DestinationWidget(destinationName: 'Whitby'),
      ],
    )),
  );
}
```

We still have `AppBar` in place. Now, `body` contains our `Column` of `DestinationWidget` wrapped in a `Center` widget. You can run the code to see your updates in action:

Figure 5.6 – Destinations in the Column widget

`DestinationWidget`, which contains a `Text` widget, is listed vertically in `Column`, which has been centered within the body space of `Scaffold` through the use of the `Center` widget. This is the first bit of the layout completed.

ListView and GridView

If you have developed an application before, then you might have already used lists and grids. Flutter provides classes for both of them, namely, the `ListView` and `GridView` widgets.

`ListView` is very similar to a `Column` widget; however, it is designed to be scrollable and also draw widgets on-demand. For example, if our destination list had more than 20 destinations, then the destinations may not all fit onto the screen, requiring the ability to scroll the list, and, when we are using more complicated widgets, performance reasons may mean we might not want to draw all of the widgets to the screen immediately, only when they scroll into view.

`ListView` allows you to scroll a list and draw these widgets as they arrive on the screen through scrolling or orientation changes, using the `ListView.builder` constructor. We will look at this in more detail in later chapters, but in the meantime, let's see a basic `ListView` in action by first trying to extend our `Column` from the previous section so that it has 20 `DestinationWidget` with some padding around each one.

Each `Column` entry will look like this:

```
Padding(
  padding: const EdgeInsets.all(16),
  child: DestinationWidget(destinationName: 'Staithes'),
)
```

Run the preceding code, or simply make an update to your code while the app is running and let hot reload do its thing, to see what happens:

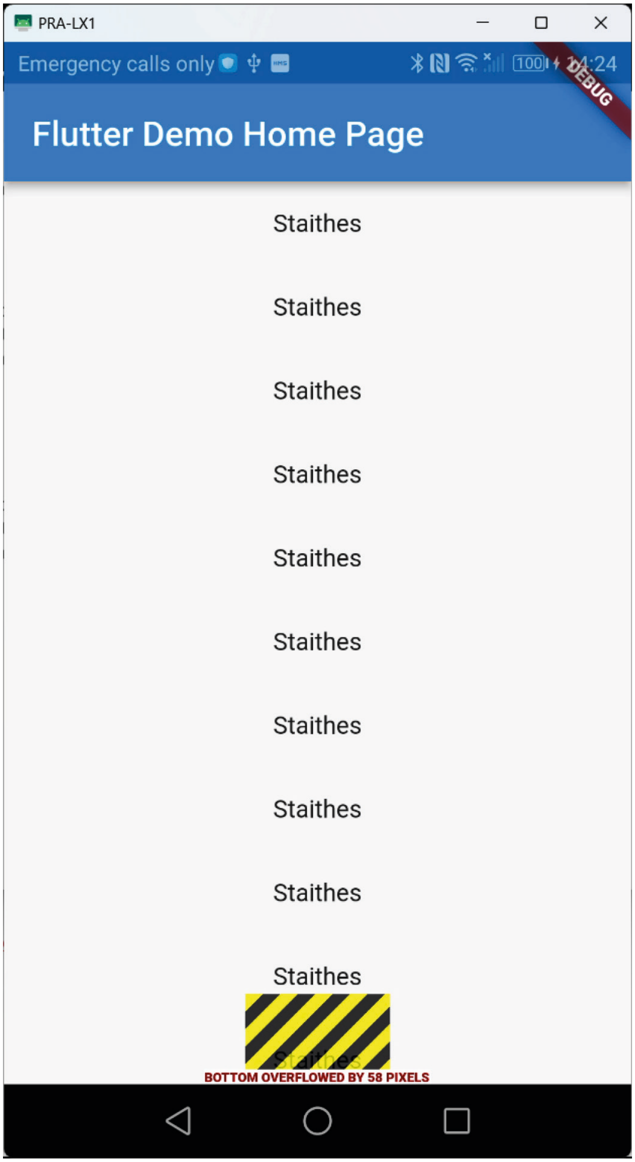


Figure 5.7 – Column is too long

The scary yellow and black warning show that `Column` is too long for the screen, so some of it has overflowed outside of its visible area. If you try to scroll the screen, you'll notice that nothing moves. `Column` by itself is not scrollable.

Let's replace `Column` with `ListView` and see what happens then:

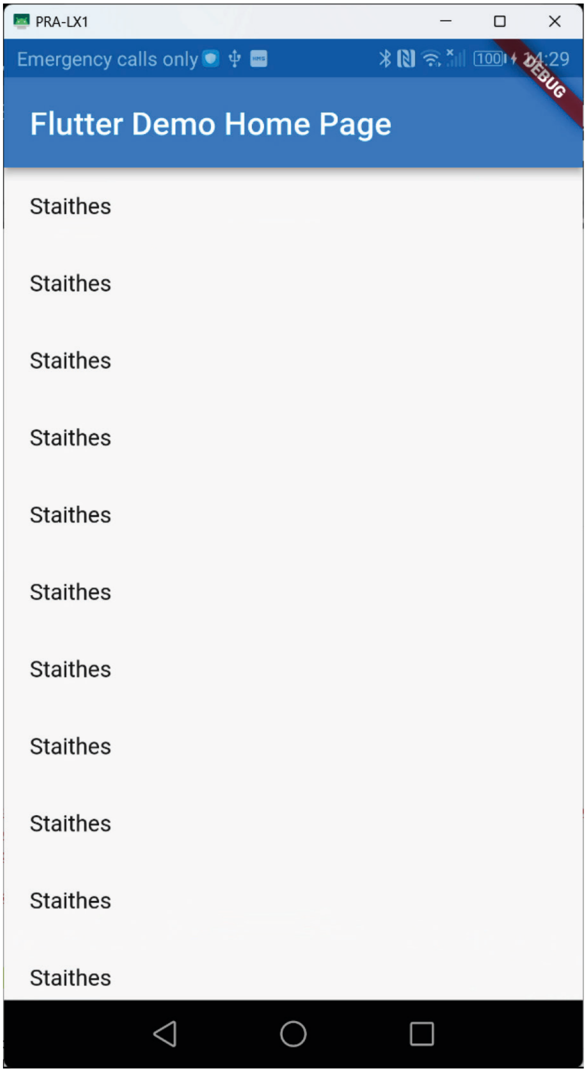


Figure 5.8: ListView of destinations

The scary yellow and black lines have gone and now we have a list that responds to scroll so that you can see all of the entries in the list. This is a simple demonstration of `ListView`, but hopefully, this gives you an idea of the need to consider the widget that will fit the needs of different situations.

`GridView` is also very similar but creates grids of widgets rather than simple lists. It also has the on-demand ability of `ListView`.

In addition to this, other less typical, but important, container widgets are available, such as `Table`, which organizes children in a tabular layout.

Other layouts

There are also design-specific widgets that are unique to each platform. Material Design, for example, has the concept of cards, which are defined in the documentation as follows:

> *"A sheet of Material used to represent some related information."*

On the other side of things, Cupertino-specific widgets could have unique transitions present in the iOS world.

It is worth exploring this further and then deciding on a design standard for your app. Consistency is important so that the user feels comfortable and confident interacting with your app, so take the time to decide on your approach.

Advanced widgets (gestures, animations, and transformations)

Flutter provides widgets for anything related to the UI. For example, gestures such as scroll or touch will all be related to a widget that manages gestures. Animations and transformations, such as scaling and rotation, are also all managed by specific widgets. We will be examining some of them in more detail in the following chapters.

Summary

In this chapter, you looked at the different types of widgets, such as stateless, stateful, and inherited, which are classes that inherit from the built-in widget type of classes. You examined the differences between the types, when to use each type, and how to make use of the features of each type.

Next, you explored the built-in widgets that are available as part of the Flutter framework, including the base display widgets and user interaction widgets that allow you to show information and react to user interactions.

Finally, we looked at the layout widgets, all the way from the basic `Container` widget up to the much more feature-rich layouts of `ListView` and `GridView`. Learning how to combine these layout widgets will be fundamental to how you design your apps.

You should now have a better understanding of how Flutter apps are put together; however, as you can imagine, there's still a lot to explore. In the next chapter, we will take a further look at how users interact with Flutter apps.

Questions

You've had your first taste of widgets, so let's see how much you remember about them. If you find any gaps in your knowledge, then a revisit is worth it at this stage because we will be using widgets throughout the rest of this book:

1. Explain the difference between a stateful and a stateless widget.
2. How would you trigger a rebuild of a stateful widget?
3. What is the purpose of an inherited widget?
4. Why do you sometimes need to use the `Key` parameter when constructing a widget?
5. What are the three places where you can retrieve images for the `Image` widget?
6. Name three types of buttons that are available as built-in widgets.
7. What widgets could you use to create a vertical list of widgets within the center of the screen?
8. Can you remember some of the key parameters for constructing a `Scaffold` widget?
9. What extra functionality does `ListView` have over `Column`?

Further reading

The best thing you can do now is mess around with some of the built-in widgets. Take the example code and just swap in other widgets or manipulate the arguments to the parameters.

Take a look at the widget catalog to see what other widgets are available: `https://docs.flutter.dev/development/ui/widgets`.

There are many widgets that we couldn't explore within this chapter, so take a look at what other widgets are available. Hopefully, you will start to be able to visualize how you could build an app from this catalog of widgets.

Additionally, start to look at some examples of apps and try to work out which widgets are being used. More advanced apps will have transitions, animations, and complex interactions, but at their core, they will be using the widgets we have already explored: `https://flutter.github.io/samples/#`.

6
Handling User Input and Gestures

With the use of widgets, it is possible to create an interface that is rich in visual resources while also allowing user interaction through gestures and data entry. In this chapter, you will learn about the widgets that are designed to handle user gestures and receive and validate user input, along with how to create your own custom inputs.

The following topics will be covered in this chapter:

- Handling user gestures
- A deeper look at the stateful widget life cycle
- Input widgets and forms
- Creating custom inputs

Technical requirements

You will need your development environment again for this chapter. Look back at *Chapter 1*, *What Is Flutter and Why Should I Use it?*, if you need to set up your IDE or refresh your knowledge of the development environment's requirements.

You can find the source code for this chapter on GitHub at `https://github.com/PacktPublishing/Flutter-for-Beginners-Third-Edition`.

Handling user gestures

A mobile application would be very limited without some kind of interactivity. The Flutter framework allows you to handle user gestures in every possible way, from simple taps to drag and pan gestures. The screen events in Flutter's gesture system are separated into two layers, as follows:

- **Pointers layer**: This layer holds the raw information about how a pointer (for example, a touch, mouse, or stylus) is interacting with the screen. This raw data will include the location and movement of the pointer.
- **Gestures layer**: This layer takes multiple pointer actions and tries to assign them some meaning as a user action. These semantic actions (for example, a tap, drag, or scale) are often more useful to the application, and they are the most typical way of implementing user input handling.

Let's go over these two layers in more detail.

Pointers

Flutter starts screen input handling in the low-level pointer layer. Generally, there is no need to use events from this layer in your application, but, if you need to do some bespoke input handling, then you can use this layer to receive events on every pointer update and decide how to control it. For example, if you are coding a game, then you may need precise details on every pointer update rather than relying on the higher-level gesture events.

The Flutter framework informs the widget tree of pointer events through the following sequence:

- `PointerDownEvent` is where the interaction begins, with a pointer coming into contact with a certain location of the device's screen. Here, the framework searches the widget tree for the widget that exists in the location of the pointer on the screen. This action is called a hit test.
- Every event, including the initial `PointerDownEvent` event, is dispatched to the innermost widget that matches the location and then propagates to all parent widgets up the tree from the parent widget to the root. This propagation of event actions cannot be interrupted.
- Subsequent events could be `PointerMoveEvent`, where the location of the pointer is changed, `PointerUpEvent`, indicating that the pointer is no longer in contact with the screen, or `PointerCancelEvent`, where the pointer is still active on the device but is no longer interacting with your app.
- The interaction will finish with one of the `PointerUpEvent` or `PointerCancelEvent` events.

Flutter provides the `Listener` widget, which can be used to detect the pointer interaction events listed previously. You can wrap a widget tree with the `Listener` widget to handle pointer events on its widget subtree.

Gestures

Although possible, it is not always practical to handle pointer events by ourselves using the `Listener` widget. Instead, the events can be handled on the second layer of the gesture system. The gestures are recognized from multiple pointer events, and even multiple individual pointers (multitouch). Many kinds of gestures can be handled:

- **Tap**: A single tap/touch on the device screen
- **Double-tap**: A quick double-tap in the same location on the device's screen
- **Press and long-press**: A press on the device screen, similar to a tap, but having contact with the screen for a longer period before release
- **Drag**: A press that starts with a pointer having contact with the screen in some location, which is then moved either horizontally or vertically, and stops having contact at another location on the device screen
- **Pan**: Similar to drag events but can vary in direction; pan gestures cover both horizontal and vertical drag
- **Scale**: Two-pointers are used for a drag move to employ a scale gesture. This is also similar to a zoom gesture

Like the `Listener` widget for pointer events, Flutter provides the `GestureDetector` widget, which contains callbacks for all of the preceding events. You would use them according to the interaction you want to allow. Let's take a look at some examples of `GestureDetector`.

GestureDetector

Let's create a stateless widget called `DestinationLike` to have a look at `GestureDetector` detecting a gesture event:

```
class DestinationLike extends StatefulWidget {
  DestinationLike ({Key? key}) : super(key: key);

  @override
  State<DestinationLike> createState()
    =>_DestinationLikeState ();
}

class _DestinationLikeState extends State<
  DestinationLike > {
  int _likeCounter = 0;
  @override
  Widget build(BuildContext context) {
```

```
    return GestureDetector(
      onTap: () {
        setState(() {
          _likeCounter++;
        });
      },
      child: Container(
        color: Colors.grey,
        child: Text(
          "Like count: $_likeCounter",
        ),
      ),
    );
  }
}
```

In this example, we have a stateful widget named `DestinationLike` and its companion state class, `_DestinationLikeState`. The widget will allow us to track the number of "likes" a destination has received.

The widget follows the stateful widget structure we saw in the previous chapter. We need to have a state because we want the widget to react to user input, and this will involve changing the value of a variable and then redrawing the widget.

In the state object, we have a single `_likeCounter` variable to show how many likes a destination has received, which in this example equates to how many taps have been performed on the widget. The state object also has the obligatory `build` method, which holds the details of how the widget should be drawn to the screen. As mentioned previously, this is done by returning a child widget tree.

The top widget that is returned is `GestureDetector`, which, in turn, has a child constructor parameter into which we have passed a `Container` widget holding a `Text` widget. `GestureDetector` wraps the child widgets and reports on gestures that happen within the child widget tree. Let's look at how we listen to the different gestures.

Tap

A tap gesture involves a pointer contacting the screen at a location and then ending contact at the same, or a very close, location, without moving away from the location during the contact.

In the preceding example, we have specifically used the `GestureDetector` widget's `onTap` constructor parameter. Let's look closer at the key section of the code:

```
GestureDetector(
  onTap: () {
    setState(() {
```

```
        _likeCounter++;
      });
    },
    ...
```

The `onTap` parameter on the `GestureDetector` constructor is a function type, and we have passed an inline function as the argument that increments the `_likeCounter` variable within the `setState` method.

If you wish to listen to more fine-grained gestures around taps, other constructor parameters can be used on `GestureDetector`:

- `onTapDown`: A pointer, that may be about to tap, has come into contact with the screen
- `onTapUp`: A pointer, that has tapped the screen, has finished touching the screen
- `onTapCancel`: A pointer, that triggered `onTapDown` (so the gesture layer thought there was a chance the full gesture was going to be a tap), did not do a tap

Using `GestureDetector` to receive gestures is really that simple, so let's look at the other gestures available to us.

Double-tap

A double tap has very similar constraints to a tap but adds the stipulation that there must be two taps in quick succession.

The code will look very similar to the tap example:

```
GestureDetector(
  onDoubleTap: () {
    setState(() {
      _likeCounter++;
    });
    },
  …
```

The only difference from the previous example is that the `onDoubleTap` constructor parameter is used. We have passed in the same inline function as the argument and the function will be called every time double-taps are performed at the same location on the screen.

If you wish to listen to more fine-grained gestures around double-taps, other constructor parameters can be used on `GestureDetector`:

- `onDoubleTapDown`: A pointer, that may be about to double-tap, has come into contact with the screen
- `onDoubleTapUp`: A pointer, that has double-tapped the screen, has finished touching the screen

- `onDoubleTapCancel`: A pointer, that triggered `onDoubleTapDown` (so the gesture layer thought there was a chance the full gesture was going to be a double-tap), did not do a double-tap

Note that some of the more fine-grained, or partial, gestures may be triggered before the full gesture has been resolved, and therefore not align with the correct gesture. For example, `onTapDown` would be triggered on the first tap of a double-tap, but ultimately, the tap gesture would not complete because the user did a double-tap rather than a single tap. So, be careful when you use these partial gestures.

Press and hold

Pressing on the device's screen is similar to a tap but has contact with the screen for a longer period before release and with no movement away from the location during the contact.

The code will look very similar to the previous examples:

```
GestureDetector(
  onLongPress: () {
    setState(() {
      _likeCounter++;
    });
  },
  ...
```

The only difference from the previous item is that this time, the parameter is `onLongPress`, which will be called every time a tap is performed and held for some time before being released from the screen.

If you wish to listen to more fine-grained gestures around long-press, other constructor parameters can be used on `GestureDetector`:

- `onLongPressStart`: A pointer that's in contact with the screen has been recognized as enacting a long press
- `onLongPressEnd`/`onLongPressUp`: A pointer, that has long-pressed the screen, has finished touching the screen
- `onLongPressMoveUpdate`: A pointer, that triggered `onLongPressStart`, has now been drag-moved

It is possible to use many of the different gestures in the same `GestureDetector`. `GestureDetector` will decide which gesture, if any, applies to the touch and call the function supplied for that gesture.

Drag, pan, and scale

Drag, pan, and scale gestures are similar to each other, and we have to decide which one to use in each situation as they cannot all be used together in the same `GestureDetector` widget.

Drag gestures are separated into vertical and horizontal gestures. Even the callbacks are separated.

Horizontal drag

A horizontal drag, as its name suggests, is where the pointer has been placed on the screen, dragged in a mainly horizontal direction, and then released. Unlike taps or presses, the main purpose for listening on a drag is to react to the drag as it happens, such as to move a widget. Therefore, the gestures for horizontal drags are naturally more fine-grained.

Let's see how the detection of a horizontal drag looks in code:

```
GestureDetector(
  onHorizontalDragStart: (DragStartDetails details) {
    setState(() {
      _move = Offset.zero;
      _dragging = true;
    });
  },
  onHorizontalDragUpdate: (DragUpdateDetails details) {
    setState(() {
      _move += details.delta;
    });
  },
  onHorizontalDragEnd: (DragEndDetails details) {
    setState(() {
      _dragging = false;
    });
  },
  …
```

As you can see, this time, we need a bit to do more work than for tap or press events.

Three parameters are needed for horizontal drags:

- `onHorizontalDragStart`: A pointer in contact with the screen has been recognized as possibly enacting a horizontal drag. The callback receives a `DragStartDetails` argument that contains information about the global and local position of the pointer.
- `OnHorizontalDragUpdate`: A pointer, that triggered `onHorizontalDragStart`, has now been drag-moved horizontally. The callback receives a `DragUpdateDetails` argument that contains information about the movement of the pointer, known as the delta, and its global and local positions again.
- `onHorizontalDragEnd`: A pointer, that has been dragged horizontally, has finished touching the screen. The callback receives a `DragEndDetails` argument that contains the velocity of the pointer when it stopped contacting the screen. As you can imagine, this information would be useful for a flick-type gesture.

We used these parameters to manage two properties present in the widget's state:

- `_dragging`: This is set to `true` when a drag starts, and set to `false` on completion of a drag. You might use a similar property in your code to highlight the widget that is being dragged.
- `_move`: This accumulates the offset of the dragging that is applied to the widget. You might use a similar property to move widgets relative to the movement of the drag. Note that, because this is a horizontal drag, the delta will only have changes in the horizontal direction.

Vertical drag

A vertical drag, as its name suggests, is where the pointer has been placed on the screen, dragged in a mainly vertical direction, and then released.

The vertical version of drag is almost the same as the horizontal version. The significant differences are in the callback properties, which are `onVerticalDragStart`, `onVerticalDragUpdate`, and `onVerticalDragEnd`.

What changes for vertical and horizontal callbacks in terms of code is the delta property value of the `DragUpdateDetails` class. For horizontal, it will only have the horizontal part of the offset changed, and for vertical, the opposite is the case.

Pan

A pan is similar to a horizontal or vertical drag where the movement of the pointer, when in contact with the screen, is not predominantly in only the horizontal or vertical direction but is instead a mix of both.

The main difference to the previous examples is the callback properties, which are now `onPanStart`, `onPanUpdate`, and `onPanEnd`. For pan drags, both axes' offsets are evaluated; that is, both delta values in `DragUpdateDetails` are present, so the dragging has no limitation on the direction.

Scale

The scale version is nothing more than panning on more than one pointer.

Let's see what the scale version of panning looks like:

```
GestureDetector(
  onScaleStart: (ScaleStartDetails details) {
    setState(() {
      _scale = 1.0;
      _resizing = true;
    });
  },
  onScaleUpdate: (ScaleUpdateDetails details) {
    setState(() {
```

```
        _scale = details.scale;
      });
    },
    onScaleEnd: (ScaleEndDetails details) {
      setState(() {
        _resizing = false;
      });
    },
    ...
```

We used the following callbacks to manage two properties in the state:

- `_resizing`: This is set to `true` when a scale starts, and set to `false` on completion of a scale. This could be used to give feedback to the user that they are scaling a widget.
- `_scale`: This stores the scale value from the `ScaleUpdateDetails` parameter, and could be used to change the size of a widget.

As you can see, scale callbacks look very similar to drag callbacks in that they also receive parameters related to each event: `ScaleStartDetails`, `ScaleUpdateDetails`, and `ScaleEndDetails`. These contain values that may help at each stage of the scale event.

Gestures in Material widgets

While `GestureDetector` is a very useful widget, most of the time, you will not need to use it because built-in widgets will already have gesture management built into them. It is probably only in advanced user interfaces that you will need `GestureDetector`, such as in a game, but it is useful to understand the underlying functionality that Flutter provides.

Material Design and iOS Cupertino widgets have many gestures abstracted to a constructor parameter by using the `GestureDetector` widget internally in their code.

For example, Material widgets such as `ElevatedButton` embed a special widget named `InkWell` that, in addition to giving access to the tap gesture event, will also create a splash effect on the target widget. The `onPressed` property of `ElevatedButton` exposes the tap functionality that can be used to implement the action of the button.

Consider the following example:

```
ElevatedButton(
  onPressed: () {
    print("Destination liked ");
    setState(() {
      _likeCounter++;
    });
```

```
      ...
    },
    child: Text("Like destination"),
  )
```

A child `Text` widget is displayed in `ElevatedButton` and a tap on the button is handled by the function passed as the argument to the `onPressed` constructor parameter.

The other buttons we learned about in the previous chapter, such as `TextButton` and `IconButton`, work similarly with a parameter to set a `callback` function.

Now would be a good time to modify our `DestinationWidget` so that it includes a counter of likes, but to do that, we first need to learn a little more about stateful widgets.

A deeper look at the stateful widget life cycle

In the previous chapter, we looked at how stateful widgets differ from stateless widgets and how the `build()` method can be called multiple times, triggered by the `setState()` method.

However, there are some additional parts of the life cycle of a stateful widget that we must explore at this point because they are important to how we manage input data. They will also become increasingly important throughout the rest of this book as we look at more advanced widget interactions.

Key life cycle states

There are several life cycle states that a stateful widget can pass through. In this section, we will look at the states that you will need in most situations. Later in this book, we will introduce additional life cycle states for specific scenarios and corner cases.

Creation of the state

The creation of a state happens at the very start of the stateful widget's life cycle, just after the constructor is called. The stateful widget creates a companion `State` object to hold the mutable state by calling the `createState()` method and passing an instance of the companion `State` object. This is a required step in the life cycle; otherwise, the stateful widget will not have a state.

We saw an example of the `createState()` method in the previous chapter:

```
class MyHomePage extends StatefulWidget {
  MyHomePage({Key key, this.title}) : super(key: key);
  final String title;
  @override
  _MyHomePageState createState() => _MyHomePageState();
}
```

Let's convert our `DestinationWidget` into a stateful widget by following a similar pattern:

```
class Destination extends StatefulWidget {
  DestinationWidget({required this.destinationName});

  final String destinationName;

  @override
  _DestinationWidgetState createState() =>
    _DestinationWidgetState();
}
```

This shows our stateless widget, `DestinationWidget`, creating the `State` object, but what does our `State` class look like?

```
class _DestinationWidgetState extends State
  <DestinationWidget> {
  @override
  Widget build(BuildContext context) {
    return Text(widget.destinationName);
  }
}
```

This `build` method in `_DestinationWidgetState` matches the stateless widget's `build` method from *Chapter 5, Building Your User Interface through Widgets*. The only difference is that it is now in the `State` class rather than the widget class. However, this does mean that to get the `destinationName` parameter, we now have to prefix it with a reference to the widget, giving the variable identifier as follows:

```
widget.destinationName
```

This is because the `destinationName` parameter is on the widget, not on the `State` object, so it has to be retrieved from the widget using the `widget` reference that is available to `State`.

Initializing the state

The instance of `State` can initialize its state variables or other infrastructure requirements (such as database connections) in the `initState()` method. This method is only called once when the widget is added to the widget tree for the first time (that is, it becomes visible to the user) and is optional.

We will see some examples of this later in this chapter, but a basic example of the `initState()` method looks as follows:

```
@override
void initState() {
  super.initState();
```

```
    // Custom initialization logic here
  }
```

In this example, we can see that the first line of the method must be a call to initialize the state of the `super` class. This is followed by any custom logic that is required to initialize the widget.

For our `DestinationWidget`, we could initialize a like counter from a database. For simplicity, let's simply use a local variable to hold the counter:

```
class _DestinationWidgetState extends State
  <DestinationWidget> {
  late int _likeCounter;

  @override
  void initState() {
    super.initState();
    // Could be initialised from a database call
    _likeCounter = 0;
  }
  @override
  Widget build(BuildContext context) {
    return Text(widget.destinationName);
  }
}
```

Note that we have had to make `_likeCounter` a *late* variable because it is initialized after the class is constructed. However, it will be set before we use it in our code, so there is no need to make it nullable. We have also prefixed it with an underscore because the variable can be private.

Build

As you saw in the previous chapter, the `build` method is called when the widget is to be drawn to the screen. It is called after `initState()` and then called every time `setState()` is triggered.

Let's add a button to our `DestinationWidget` to allow someone to like a destination:

```
  @override
  Widget build(BuildContext context) {
    return Row(
      children: [
        Text(widget.destinationName),
        Column(
          children: [
            IconButton(
              onPressed: () {
                setState(() {
```

```
                  _likeCounter++;
                });
              },
              icon: const Icon(Icons.thumb_up),
            ),
            Text(_likeCounter.toString()),
          ],
        ),
      ],
    );
  }
```

This may seem like a big piece of code, but if you look at it widget by widget, you'll see that it contains all the things you already know about.

Firstly, we now have `Row`, which has two children; the `Text` widget, which shows the destination's name, and `Column`. These will be laid out horizontally.

`Column`, in turn, has two children; `IconButton`, which uses a `thumb_up` icon, and another `Text` widget showing how many likes the destination has had. These will be laid out vertically.

Finally, `IconButton` has an `onPressed` parameter that we have set as an anonymous function that calls `setState`, which itself has a parameter that we have set as an anonymous function that increments `_likeCounter`.

> **What is this Icon you speak of?**
>
> Flutter allows you to display an icon using the `Icon` widget, which takes `IconData` as a constructor parameter. You don't need to know about `IconData` because the Flutter framework conveniently has a set of prepared `IconData` values available as static variables in the `Icons` class. In our example, we are getting the `thumb_up` icon's `IconData` from the `Icons` class and passing it as an argument to the `Icon` widget to display a `thumb_up` icon.

Disposing of the state

When a widget is removed from the widget tree, the `dispose()` method is called. Any infrastructure clean-up needed, generally for activities that happened during `initState()`, such as setting up database listeners or internet connections, will be done in the `dispose()` method.

Again, we will see an example of this later in this chapter, but here is the skeleton structure of the method:

```
@override
void dispose() {
  // Custom clean-up code here
  super.dispose();
}
```

In this example, we can see that the last line of the method must be a call to dispose of the state of the `super` class. However, before this, any custom logic that is required to dispose of the widget can be placed.

> **Not disposing of connections**
>
> A common source of errors in an application is failing to close connections to databases or other internet resources within the `dispose` method. If you do not close your connections, then they will remain active and continue to try to interact with your widget, thus using up valuable resources such as device memory and processing power. You will see errors in your logs if you have a connection that is trying to call `setState()` on a widget that is no longer mounted on the widget tree, and this is a big hint that you are not cleaning up connections.

Mounted

In addition to the life cycle states, there is an important method available to you called `mounted()`. This will tell you whether the widget is still mounted onto the widget tree. Specifically, when `initState` is called, `mounted` is marked as `true`, and when `dispose` is called, `mounted` is marked as `false`.

You would use this in situations such as listening on a database or internet connection. If a change in database or internet connection state was coded to trigger an update of the widget (perhaps through `setState()`), then it is prudent to add a `mounted` check before calling `setState()` as the widget may have been removed from the widget tree between the time you set up the listener and the time it received an update.

Let's look at a simple example:

```
if (mounted) {
  setState(() {
    // Change state here
  });
}
```

In this example, we have wrapped a `setState()` call within a `mounted` check to ensure the widget is still on the widget tree and able to be redrawn.

So, now that you know a lot more about the stateful widget life cycle and have the knowledge of user input via gestures, let's look at another common way to receive user input – that is, via input widgets and forms.

Input widgets and forms

The ability of your app to manage gestures is a good starting point for interaction with the user, but for many apps, you also need a way to get other types of input from a user. Getting user data is what allows for custom content and customization in your app.

Flutter provides many input data widgets to help developers get different kinds of information from the user. We saw some of them in *Chapter 5*, *Building Your User Interface through Widgets*, including `TextField`, and different kinds of `Selector` and `Picker` widgets.

Getting input through the onChanged callback

A `TextField` widget lets the user enter text with a keyboard. The `TextField` widget exposes the `onChanged` parameter, which takes a function and can be used to listen for changes in its current value. This is the simplest way to track the text within `TextField` and behaves much like the `onPressed` example we saw earlier in this chapter:

```
TextField(
  onChanged: (text) {
    print('New destination name: $text');
  },
)
```

In this example, an anonymous function has been passed to the `onChanged` parameter. Whenever the text entered by the user is changed, it will print out the value of the text.

However, another way to listen for changes is by using a controller.

Getting input through a controller

When using a standard `TextField` widget, we can use the `controller` parameter to access the current value of `TextField` – that is, the text that has been entered into `TextField` by the user.

This can be done with the `TextEditingController` class. You can instantiate a controller using the standard constructor:

```
final _controller = TextEditingController();
```

Alternatively, you can use a factory constructor to set an initial value on `TextEditingController`:

```
final _controller = TextEditingController.fromValue(
  TextEditingValue(text: "Initial value"),
);
```

As you can see, the factory constructor takes a parameter of the `TextEditingValue` type. By constructing `TextEditingValue` and setting the `text` property on it, we can specify the initial value of the `TextField` widget it will be used to control.

After instantiating `TextEditingController`, we set it on the `controller` property of the `TextField` widget so that it "controls" the widget:

```
TextField(
  controller: _controller,
);
```

`TextEditingController` is notified whenever the `TextField` widget has a new value. To listen for changes, we need to add a listener to our `_controller`:

```
_controller.addListener(() {
  print('New destination name: ${_controller.text}');
});
```

We have to specify a callback function that will be called every time the `TextField` widget changes. In this case, we have made a simple inline function that, once again, prints out the value of the text in `TextField`, as retrieved via the `text` property on the controller.

This listener needs to be set up before the widget is drawn via the `build` method so that we can ensure we listen to all events. We now know of a method in the widget life cycle that would fit this need perfectly – the `initState` method:

```
@override
void initState() {
  super.initState();
  _controller.addListener(() {
    print('New destination name: ${_controller.text}');
  });
}
```

After we've called `initState` on the superclass, we set up the listener on the controller.

We have now constructed a controller, initialized its listener, and added it to `TextField`. The one thing we haven't done yet is dispose of the listener when the widget is removed from the widget tree. With any controller, you need to make sure you dispose of them when their widget is disposed of so that their resources are freed up, they are no longer listening to any events, and they are not trying to make changes to the disposed state. Again, we know of a method in the widget life cycle that will fit this need perfectly – the `dispose` method:

```
@override
void dispose() {
  _controller.dispose();
```

```
    super.dispose();
  }
```

In our `dispose` method, we dispose of the controller and then call the `dispose` method on the superclass.

A similar approach using controllers or `onChanged` callbacks can be used for other input widgets. Often, though, you will want to construct a form that holds a group of input data widgets and have validation and feedback for users that works across the whole form.

Form and FormField

Flutter provides two widgets to help organize how input data is stored, validate it, and provide feedback promptly to the user. These are the `Form` and `FormField` widgets.

The `Form` widget holds the state of the fields within it. This wraps around the `FormField` widgets to allow the fields to be managed as a single group or form.

The `FormField` widget works as a base class that can be extended to create specialist input fields within a form. Its functions are as follows:

- To help with the process of setting and retrieving the current input value
- To validate the current input value
- To provide feedback from validation

Many of the built-in input widgets in Flutter have a corresponding `FormField` widget implementation. One example of this is the `TextField` widget, which has a corresponding form-specific `TextFormField` widget. The `TextFormField` widget helps us with accessing the `TextField` value and also adds form-related behaviors to it, such as validation.

Although `FormField` widgets often have a `Form` widget as an ancestor, in some cases, this is not needed. For example, when we have a single `FormField` to take input, there is probably no need for a `Form` widget to manage the form updates.

Let's look at how we can use a `FormField` widget in isolation. Later, in the *Form* section, we will look at adding the `Form` widget as a wrapper.

Accessing FormField's state

If we are using the `TextFormField` widget, then there is a specific `FormField` approach to accessing the input data using the state of `FormField`:

```
final _key = GlobalKey<FormFieldState<String>>();
  ...
TextFormField(
```

```
  key: _key,
);
```

We can add a key to `TextFormField` that can later be used to access the widget's current state through the `key.currentState` value, which will contain the updated value of the field. We saw the use of `Key` in *Chapter 5*, *Building Your User Interface through Widgets*, where we needed it to differentiate between similar widgets. As we saw then, `Key` is used to uniquely identify a single widget and the same is true here. It gives us a way to interrogate the state of a specific field.

The specialized type of key refers to the kind of data the input field works with. In the preceding example, this is `FormFieldState` of the `String` type, because it is a `TextFormField` widget, so the key type depends on the particular widget used.

The `FormFieldState<String>` class also provides other useful methods and properties to deal with `FormField`:

- `validate()` will call the widget's validator callback, which should check its current value and return an error message, or null if it's valid.
- `hasError` and `errorText` result from previous validations using the preceding function. In `material` widgets, for example, this adds some small text near the field, providing proper feedback to the user about the error.
- `save()` will call the widget's `onSaved` callback.
- `reset()` will put the field in its initial state, along with the initial value (if any) and clear validation errors.

Form

Having a `FormField` widget helps us access and validate its information individually. But when we have a set of input widgets in a form structure, we can use the `Form` widget. The `Form` widget groups the `FormFieldWidget` instances logically, allowing us to perform operations, including accessing field information and validating the whole set of fields in a more structured way.

The `Form` widget allows us to run the following methods on all descendant fields easily:

- `save()`: This will call the `save` method of all `FormField` instances, saving all the form data in the fields at once
- `validate()`: This will call the `validate` method of all `FormField` instances, causing all the errors to appear at once
- `reset()`: This will call the `reset` method of all `FormField` instances, resetting the whole form to its initial state

Accessing Form's state

Your app will need to be able to access the state of `Form`, much like we accessed the state of `FormField`, so that you can run validation, data saves, and resets from other parts of the user interface, not just within the form widget tree. For example, you may have a floating action button that allows you to save the form, or an app bar button to reset the form.

Let's look at two ways to access the form state.

Using a key

The `Form` widget must be used with a key of the `FormState` type. `FormState` contains helpers to manage all of the children of `FormField`:

```
final _key = GlobalKey<FormState>();
  ...
  Form(
    key: _key,
    child: Column(
    children: <Widget>[
      TextFormField(),
      TextFormField(),
    ],
  ),
);
```

In this example, we have `Form` with a global key and, indirectly, two `TextFormField` as children.

We can then use the key to retrieve the associated state of `Form` and call its validation with `_key.currentState.validate()`.

Most of the time, this is the best way to access the form's state, but if you have a complex widget tree, then there is another option. Let's have a look at this alternative option.

Using InheritedWidget

The `Form` widget comes with a helpful class to dispense with the need to add a key to it and still get its benefits.

Each `Form` widget in the tree has an associated `InheritedWidget` with it. `Form` and many other widgets expose this in a static method called `of()`, where we pass `BuildContext`, and it looks up the tree to find the corresponding state we are looking for. Knowing this, if we need to access the

`Form` widget somewhere below it in the tree, we can use `Form.of()`, and we gain access to the same functions as we would have if we were using the `key` property:

```
Widget build(BuildContext topContext) {
  return Form(
    child: Column(children: <Widget>[
        TextFormField(),
        TextFormField(),
        Builder(
          builder: (BuildContext subContext) => TextButton(
            onPressed: () {
              final valid = Form.of(subContext).validate();
              print("valid: $valid");
            },
            child: Text("validate"),
          ),
        )
      ],
    ),
  );
}
```

For this example, we have added a `Builder` widget to render `TextButton`.

The `Builder` widget simply gives you an easy way to get `BuildContext` at a specific part of the widget tree. As we have seen before, the inherited widget can be used to look up the widget tree. When we use `Form.of(subContext)`, it uses `BuildContext` from `Builder`, which is lower down the widget tree than the `Form` widget. Therefore, `Form.of(subContext)` will search up the widget tree and find `Form`.

If the builder wasn't present and we used the context from the `build` method, then `Form.of(topContext)` would start the search on the widget tree above the `Form` widget and would not find the `Form` widget during that search.

Validating user input

Validating user input is one of the main functions of the `Form` widget. To ensure the data entered by the user is valid, it is fundamental to run validation checks as the user probably doesn't know all the allowed values for the field, or may have made a mistake in their data entry.

The `Form` widget, combined with `FormField` instances, helps you show an appropriate error message if an input value needs to be corrected, before saving the form data through its `save()` function.

Let's look at the validation flow for a form:

1. Create a `Form` widget with `FormField` as a child on it.
2. Define the validation logic on each `FormField` validator constructor property by passing a validation function as the argument. Here is an example of an inline function:

```
TextFormField(
  validator: (String value) {
    return value.isEmpty ? "Cannot be empty" : null;
  },
)
```

3. When a user chooses to submit the form, call `validate()` on `FormState` by using its key, or use the `Form.of` method discussed previously.
4. Each `FormField` that is a child of the form will have the `validate()` method called:
   - Where the validation is unsuccessful, some error text is returned as a string. This error text is then displayed on `FormField` to the user so that they can correct the issue and submit the form again.
   - Where the validation is successful, a null value is returned.
5. If the validation is successful, the `save()` method can be called on `FormState` to persist all of the data from the input fields.

Now that you have an understanding of forms, let's dive deeper into customizing our form inputs.

Custom input and FormField

So far, we have seen how the `Form` and `FormField` widgets help with input manipulation and validation. We also know that Flutter comes with a series of input widgets that are `FormField` variants containing helper functions such as `save` and `validate`.

The extensibility and flexibility of Flutter are everywhere in the framework, so creating custom input fields is entirely possible.

Creating custom inputs

Creating a custom input in Flutter is as simple as creating a normal widget and including the methods described earlier. We normally do this by extending the `FormField<inputType>` widget, where `inputType` is the value type of the input widget.

So, the typical process is as follows:

1. Create a custom widget that extends `StatefulWidget` (to keep track of the value) and accepts input from the user by encapsulating another input widget, or by customizing the whole process, such as by using gestures.
2. Create a widget that extends `FormField` that basically displays the input widget created in the previous step and also exposes its fields.

Custom input widget example

Later, in *Chapter 10*, *Popular Third-Party Plugins*, we will learn how to use a plugin to add authentication to our app. For now, we will be creating a custom widget that will be similar to the one used in that step.

In this example, we will ask the user for a phone number and then pretend they have been sent a six-digit verification code. We will then ask them to enter the verification code, which must match the server value so that they can successfully log in.

For now, that's all the information we need to know to create the custom input widget. This is what it's going to look like:

Figure 6.1 – Example of a custom input widget

The widget will start a simple six-digit input widget, which will later become a `FormField` widget and expose the `save()`, `reset()`, and `validate()` methods.

Creating an input widget

We will start by creating a normal custom widget. Here, we'll expose some properties. Bear in mind that in a real application, we would probably expose more than the properties exposed here, but it's enough for this example:

```
class VerificationCodeInput extends StatefulWidget {
  VerificationCodeInput({required this.borderSide, required this.
onChanged, required this.controller});
  final BorderSide borderSide;
  final Function(String) onChanged;
  final TextEditingController controller;
  @override
  State<VerificationCodeInput> createState() => _
VerificationCodeInputState();
}
```

The only important property exposed here is `controller`. We will see the reason in a few moments. Let's check the associated `State` class:

```
class _VerificationCodeInputState extends State
  <VerificationCodeInput> {
  @override
  Widget build(BuildContext context) {
    return TextField(
      controller: widget.controller,
      inputFormatters: [
        FilteringTextInputFormatter.allow(RegExp("[0-9]")),
        LengthLimitingTextInputFormatter(6),
      ],
      textAlign: TextAlign.center,
      decoration: InputDecoration(
        border: OutlineInputBorder(
          borderSide: widget.borderSide,
        ),
      ),
      keyboardType: TextInputType.number,
      onChanged: widget.onChanged,
    );
  }
}
```

As you can see, the widget simply returns `TextField` in the `build` method with some predefined customization:

- `FilteringTextInputFormatter` allows you to specify a regex with either the allowed or denied characters for the input. The `.allow` and `.deny` constructors can be used to create the relevant filter check. In this example, we have used the `.allow` constructor to specify a regex that allows numbers.
- By setting the `keyboardType` property with `TextInputType`, you can make sure the best keyboard is popped up to the user. We only want numbers, so popping up a full keyboard would be unhelpful to the user. In this example, we have ensured that just a number pad is popped up by using `TextInputType.number`.
- `LengthLimitingTextInputFormatter` specifies a maximum character limit for the input.
- Also, to make it look a bit fancy, a border has been added through the `OutlineInputBorder` class.

Take note of the important part of this code: `controller: widget.controller`. Here, we are setting the controller of the `TextField` widget to be a controller that's passed to our custom input from a parent widget so that the parent widget can take control of our custom input's value.

Turning the widget into a FormField widget

To turn the widget into a `FormField` widget, we start by creating a widget that extends the `FormField` class, which is `StatefulWidget` with some `Form` facilities.

This time, let's start by checking out the new widget's associated `State` object. Let's do this by breaking it into parts:

```
class _VerificationCodeFormFieldState extends FormFieldState<String> {
  <VerificationCodeFormFieldInput> {
  final TextEditingController _controller =
    TextEditingController(text: "");
  @override
  void initState() {
    super.initState();
    _controller.addListener(_controllerChanged);
  }
  …
```

From the preceding code, you can see the state has a `_controller` field, which will represent the controller used by the `FormField` widget. It is initialized in the `initState()` function, where we add a listener to it so that we know when the value is changed in the `_controllerChanged` listener.

The remainder of the widget is as follows:

```
void _controllerChanged() {
  didChange(_controller.text);
}
@override
void reset() {
  super.reset();
  _controller.text = "";
}
@override
void dispose() {
  _controller?.removeListener(_controllerChanged);
  super.dispose();
}
```

There are also other important methods that we must override to make it work properly:

- With `initState()`, we now use its opposite in the `dispose()` method. Here, we stop listening to changes in the controller.
- The `reset()` method is overridden, so we can set `_controller.text` to `empty`, making the input field clear again.
- The `_controllerChanged()` listener notifies the super `FormFieldState` state via its `didChange()` method so that it can update its state via `setState()` and notify any `Form` widget that contains it about the change.

Now, let's examine the `FormField` widget's code to see how it works:

```
class VerificationCodeFormField extends FormField<String> {
  VerificationCodeFormField({
    Key? key,
    FormFieldSetter<String>? onSaved,
    FormFieldValidator<String>? validator,
  }) : super(
          key: key,
          validator: validator,
          onSaved: onSaved,
          builder: (FormFieldState<String> field) {
             VerificationCodeFormFieldState state = field as _
VerificationCodeFormFieldState;
            return VerificationCodeInput(
              controller: state._controller,
              borderSide: BorderSide.none,
              onChanged: (_) => print(_),
```

```
            );
          },
        );
    @override
    FormFieldState<String> createState() => _
  VerificationCodeFormFieldState();
  }
```

The new part here is in the constructor. The `FormField` widget contains the `builder` callback, which should build its associated input widget. It passes the current state of the object so that we can build the widget and retain the current information. As you can see, we use this to pass the controller constructed in the state, so it persists even when the field is rebuilt. That's how we keep the widget and state synchronized and also integrate with the `Form` class.

Summary

In this chapter, we learned how gesture handling works in the Flutter framework, along with the methods for handling gestures, such as tap, double-tap, pan, and zoom, for example. We looked at some widgets that use `GestureDetector` by themselves to handle gestures.

We then looked deeper at the life cycles of stateful widgets so that we could use this new knowledge to explore input widgets and access their data.

Finally, we extended this knowledge of input widgets by exploring the use of the `Form` and `FormField` widgets to properly validate and handle user data.

In the next chapter, you will put together the widget knowledge you have gained from the previous two chapters to create full app pages and navigate between them using the `Route` concept.

Questions

This chapter has drawn on a lot of knowledge and concepts from previous chapters, so take some time to review how much of this you have retained through these questions. As mentioned previously, if you struggle with any of the questions, then revisit the relevant sections of this chapter to refresh your knowledge:

1. What are the two layers in Flutter's gesture system?
2. We explored six different types of gestures. Can you name and define them?
3. There is a specific widget that allows us to be notified of user gestures. What is the name of this widget?
4. What are the three main life cycle methods of a stateful widget?
5. Name the method that allows you to identify whether a widget is still on the widget tree.

6. Describe the two ways to be notified of `TextField` state changes.
7. What additional functionality does `FormField` bring to an input field?
8. Explain how to use the two different ways you can get the state of `Form`.

Further reading

It can be a little tricky to understand forms without creating code examples. At this point, I highly recommend that you put together a form example and explore form keys, validation, saves, and error messages. You could even dabble in adding custom input, but don't worry if that feels a step too far – it's not needed for most standard apps.

Finding examples of forms online will help give you more guidance. This great page on LogRocket shows another example of creating a form and is worth a read to reinforce your learning in this chapter: `https://blog.logrocket.com/flutter-form-validation-complete-guide/`.

We also only touched on the `Builder` class, but it's worth reading about this a bit more so that you understand the purpose of the class and how it can be useful with inherited widgets: `https://api.flutter.dev/flutter/widgets/Builder-class.html`.

7
Let's Get Graphical!

In this chapter, we will build on our high-level understanding of the built-in widgets by learning how to make them look pretty. A slick and well-styled user interface not only enhances the clarity of the app's functionality but also elevates the user experience, increasing the likelihood of users wanting to continue its use.

There are many ways to add styling to existing widgets and to use new widgets that we haven't seen yet, which can give us great default styling. Our focus in this chapter will be the static graphics – how a widget looks in a resting state, and perhaps how it looks in an active state – and we will move on to animations and advanced graphics in *Chapter 11*, *Using Widget Manipulations and Animations*.

This is definitely one of the most fun aspects of Flutter because it is so easy to make a widget or a full page look beautiful. It feels like Flutter was born to be pretty and you just need to give it a gentle helping hand by telling it what pretty looks like to you.

The following topics will be covered in this chapter:

- Styling text
- Decorating a container
- Adding style to your buttons
- Using special tiles in the List and Grid views
- Advanced image types
- Exploring slivers

Technical requirements

You will need your development environment again for this chapter as we will explore animations for the `Hello World` project. Look back at *Chapter 1*, *What Is Flutter and Why Should I Use It?* if you need to set up your **integrated development environment** (**IDE**) or refresh your knowledge of the development environment requirements.

You can find the source code for this chapter on GitHub at `https://github.com/PacktPublishing/Flutter-for-Beginners-Third-Edition`.

Make me pretty

In *Chapter 5*, *Building Your User Interface through Widgets*, we had a look at the `Text`, `Image`, and `Container` widgets and how they can be used to manage the layout of child widgets. We only briefly looked at how to manage the appearance of those widgets, so now is the time to delve a little deeper. However, before we do that, let's briefly learn how to use colors in Flutter.

Using colors

Anytime you want to change the color of a widget, you will need to understand how to use the `Color` class. There are a few options available and, often, you will just choose for convenience.

The easiest option is to use the `Colors` abstract class, which holds lots of predefined colors. You have probably seen this being used in previous chapters as a way to give color to widgets. Take a look at the *Colors class* documentation to see all the predefined colors, which includes transparency: `https://api.flutter.dev/flutter/material/Colors-class.html`.

To use the `Colors` class, simply refer to one of the constants defined in the class, like this:

```
Colors.grey
```

As you would expect, this will return a gray color that you can use with your widgets. You can then refine this by specifying a shade of the color. This can be especially useful when working with background colors such as gray where you may want a slightly lighter or darker color than the default gray. To do this, you call the shade getter on the `Color` constant, like this:

```
Colors.grey.shade50
```

Shades run from 50 (lightest) to 900 (darkest), so this example will be a very light shade of gray.

If you don't want to use the pre-built color constants, or your designers have very specific requirements on color choices, then you may have received the color as a hex code or a **red-green-blue** (**RGB**) triple. Both of these can be constructed into a color, so let's look at a hex example first:

```
var color = Color(0x32a852);
```

This will construct a `Color` instance using the hex value supplied. The `0x` part at the start of the hex number denotes that the value following is a hexadecimal value. This means the number is base-16 (unlike standard base-10 integers that we generally use), so the value is represented by `0-9` for numbers 0-9 and `a-f` for numbers 10-15.

Hex 8-digit versus 6-digit notation

You may have seen hex colors written with both six characters and eight characters. These are the same color, but the last two characters in an 8-digit notation define the alpha channel of the color or the transparency. If the 8-digit hex value ends with `00`, then the color is completely transparent; if it ends with `FF`, the color is completely opaque, with values in between denoting higher or lower levels of opacity. Flutter works with both notations.

The RGB option uses a factory constructor and looks like this:

```
var color = Color.fromRGBO(50, 168, 82, 1);
```

The first three parameters accept the red, green, and blue parts of the color and take values from `0` to `255`. Note that the RGB constructor also takes an opacity value – the last parameter to the constructor. This takes a value from `0.0`, which is fully transparent, to `1.0`, which is fully opaque.

Now we have the basics of colors sorted, let's start exploring how to decorate our widgets, starting with the `Text` widget.

Text style

As a reminder, the `Text` widget can be incredibly easy to use and, in its simplest form, looks something like this:

```
Text(widget.destinationName)
```

This will generally be passed as a child to another widget and will print the text to the screen using whatever default font styling has been defined in the theme of your app.

Often, you will want to style your text in a specific way and the style constructor parameter is designed to do exactly this. `TextStyle` needs to be supplied as the parameter value, so let's look at the main properties of that class now:

- `backgroundColor` – If you want to put color behind the text, such as highlighting, then you can use the `backgroundColor` parameter. It takes any of the `Color` values we saw previously in the *Using colors* section.
- `color` – This parameter allows you to set the color of the text itself. Again, this takes a `Color` value.
- `decoration` – This allows you to add some limited decoration to your text, including underlining and line-through.
- `fontSize` – This is the size of your text. If you've ever used a word processor such as Microsoft Word, then you will have seen that font sizes are defined by **pixels** (**px**). More specifically, these are logical pixels that adapt based on screen resolution. As a rough guide, very small text would be 6-8 px, normal text would be 12-16 px, and very large text would be 30-60 px.

- `fontWeight` – This is the thickness of the font being used. Again, using a word processor, you will have seen the use of bold to increase thickness. Flutter goes further with weightings from `100` to `900` using the `FontWeight` class.
- `fontStyle` – This allows you to make your text italic using `FontStyle.italic`.
- `wordSpacing` and `letterSpacing` – These control how much whitespace appears between individual letters or at the start of a whitespace character in pixels.
- `overflow` – If your text does not fit into the space it has been given, and there is no scroll in use, then `overflow` allows you to control how the text should appear. By using the `TextOverflow` parameter, you can say whether the text is clipped, an ellipsis is added, or there is a fade.

Let's take a look at `TextStyle` with an example that uses many of these parameters:

```
Text(
  widget.destinationName,
  style: TextStyle(
    backgroundColor: Color.fromRGBO(50, 168, 82, 1),
    color: Colors.red,
    fontSize: 14,
    fontWeight: FontWeight.w300,
    fontStyle: FontStyle.italic,
    letterSpacing: 2,
    wordSpacing: 3,
    overflow: TextOverflow.fade,
    decoration: TextDecoration.underline,
  ),
),
```

To show what this looks like, `DestinationWidget` has been updated to display the destination name using this `TextStyle`, with the destination description left with the same styling as it had previously.

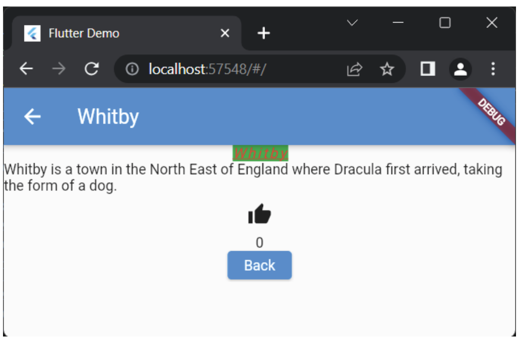


Figure 7.1: Destination name using TextStyle

The name of the destination (in this case, "Whitby") is styled completely differently from the description of the destination. Now we can style text, let's look at more general widget decoration through the `Container` widget.

Container decoration

The `Container` widget is an incredibly versatile widget, and, like some other widgets, can also receive a decoration defining how the widget should appear to the user.

The `Decoration` class (or rather, subclass, as `Decoration` is itself abstract) can be supplied as a constructor parameter to some widgets. Therefore, although we will focus on the `Container` widget in these examples, a lot of this knowledge can be applied to other widgets that use a decorator.

As our first foray into the `Decoration` class, let's make some tweaks to our `Destination` widget from *Chapter 5, Building Your User Interface through Widgets*. We will wrap the `Text` widget containing the name of our destination in `Container`:

```
Container(
  child: Text(widget.destinationName),
),
```

Nothing complicated there; we have set the `Text` widget as the child of `Container`, but the container doesn't make any difference to the appearance of the `Text` widget.

Now, let's add some decoration to the `Container`. We can start with a simple border along the bottom edge of the `Container`. This acts as a kind of underline to the text and gives us some control over the styling that we wouldn't get just from using `TextStyle` on the `Text` widget.

To do this, we need to add a decoration to the `Container` using the `decoration` constructor parameter. This takes a value of the `Decoration` type, which, in most cases, will use the `BoxDecoration` subclass. Here is an example of `BoxDecoration` in action:

```
          Container(
            decoration: BoxDecoration(
              border: Border(
                bottom: BorderSide(
                  color: Colors.red,
                  width: 3,
                ),
              ),
            ),
            child: Text(
              widget.name,
            ),
          ),
```

In this example, we have added a `BoxDecoration` subclass to the `Container` widget and, specifically, denoted that we want to add a border. The `border` parameter takes a `Border` value, which can either be the general `Border()` constructor where each side is specified using name parameters, or can use factory constructors such as the `Border.all` or `Border.symmetric` options, which define what parts of the border are being manipulated.

Within the `Border` constructor, we have specified that we want to customize the bottom border of the container by making it red, using our `Color` constants, and having a width of `3` px.

If we use this customized `Container` on our `Destination` page, the text will look like this:

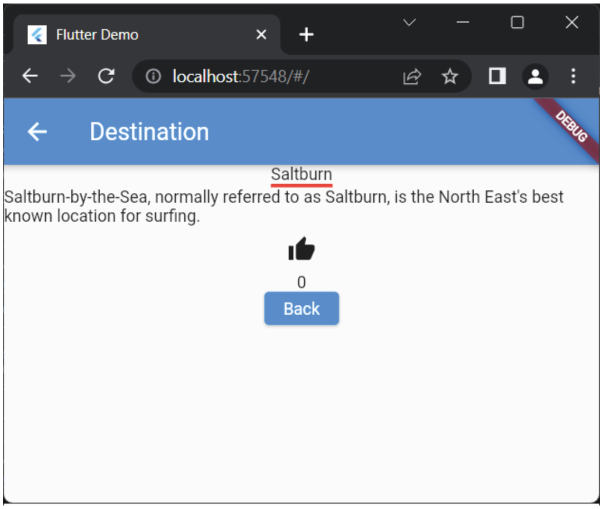


Figure 7.2: Container decoration of text

As you can see in the figure, this decoration creates an underline effect on the text much like the underline we saw on `TextStyle`.

There are many different ways to decorate a container, so you should spend some time exploring this area further. There have been many, many situations where a bit of container styling has been required to match a widget up to the designer's wishes.

An example of styling that I've used often is the `StadiumBorder` style:

```
Container(
  decoration: ShapeDecoration(
    shape: StadiumBorder(
      side: BorderSide(
        color: Colors.green,
        width: 6,
      ),
```

```
          ),
        ),
        child: Text(
          widget.name,
        ),
      ),
```

Note that this uses a `ShapeDecoration` subclass because it isn't creating a box. This will give styling like this:

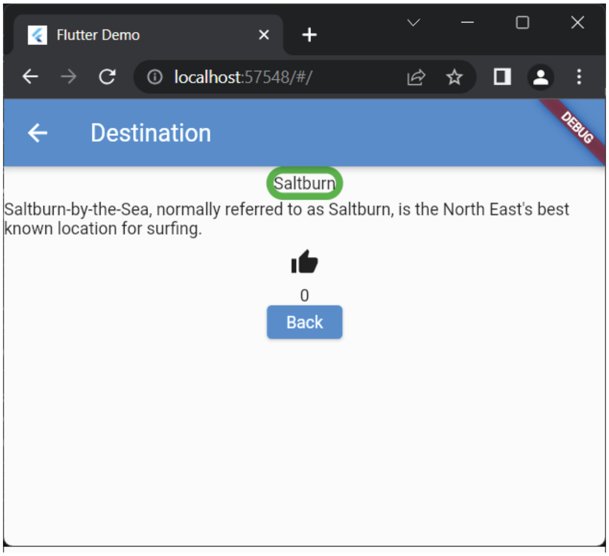


Figure 7.3: Container with stadium border

As you can see in the figure, the `StadiumBorder` shape is, as the name suggests, the shape of a sports stadium with rounded ends – a great shape for buttons.

Buttons

We explored the different types of buttons in *Chapter 5*, *Building Your User Interface through Widgets*, but you can also add styling to your buttons.

The different buttons take the `ButtonStyle` class as their `style` constructor parameter. You can choose which style properties to override by only defining those properties you want to override in the `ButtonStyle` instance. The other properties that are not defined remain as default.

For example, to modify the alignment of `ElevatedButton`, you would do the following:

```
ElevatedButton(
  style: ButtonStyle(
    alignment: Alignment.bottomCenter,
  ),
  ...
)
```

However, as a button can exist in many different states, such as active, disabled, and being pressed, your styling may need to adapt to the different states. The solution to this is `MaterialStateProperty`, or one of the subclasses such as `MaterialStateColor`, which supplies the set of states that are currently active on the button so that you can programmatically decide which styles should apply.

For example, suppose we want the background color of our button to be green except when it is being pressed, then we could create a style like this:

```
ElevatedButton(
  style: ButtonStyle(
    alignment: Alignment.bottomCenter,
    backgroundColor: MaterialStateColor.
resolveWith((Set<MaterialState> states) {
      if (states.contains(MaterialState.pressed)) {
        return Colors.red;
      }
      return Colors.green;
    }
  ),
),
  ....
)
```

This may at first glance seem a little confusing, but what we have specified is that the background color of our `ButtonStyle` changes depending on the state of the button. We do this using the `resolveWith` static method of the `MaterialStateColor` class, which supplies a set of states of the `MaterialState` type that describe the current active states of the button.

We then return `Color` from the function depending on the active states. Specifically, in this example, we return red if the `states` set contains the `pressed` state, and green in all other cases.

As mentioned previously, `MaterialStateColor` is a subclass of `MaterialStateProperty`, and is equivalent to using the following statement:

```
MaterialStateProperty.resolveWith<Color>
```

Other properties of ButtonStyle take similar MaterialStateProperty values, allowing you to take control of your button properties as it passes through the different states.

Hopefully, this has given you an idea of some of the ways we can decorate and style our widgets. Let's now look at the Scaffold widget in more detail.

The Scaffold widget

We have seen the Scaffold widget many times, but there are many hidden depths to the Scaffold widget that can really bring your app to life. In this section, we'll explore some of the most used features so that you have a starting point for your apps.

Drawer

One of my favorites is the drawer parameter, which allows you to add a sidebar to your app that can slide in and out from the side of the screen on demand. You have probably seen this on other apps and assumed it would be really complicated to achieve. However, with Flutter, it is surprisingly easy. Let's walk through an example of adding a drawer to our app.

Firstly, we need to define a global key. This allows us to refer to the scaffold directly, so we add the following line to our class:

```
final _scaffoldKey = GlobalKey<ScaffoldState>();
```

We then set the key as the parameter to Scaffold, thereby linking the key to the widget:

```
Scaffold(
  key: _scaffoldKey,
  ...
)
```

Next, we need to define what we want to have in the drawer. Here is an example that holds a close button and two destination buttons:

```
drawer: Drawer(
  child: Column(
    children: [
      IconButton(
        onPressed: () => _scaffoldKey.currentState!.closeDrawer(),
        icon: Icon(Icons.close),
      ),
      TextButton(
        child: Text("Whitby"),
        onPressed: () {...},
      ),
```

```
        TextButton(
          child: Text("Saltburn"),
          onPressed: () {...},
        ),
      ],
    ),
  ),
```

This is set as the `drawer` parameter on `Scaffold`. Our drawer uses the `Drawer` widget as the top-level widget, but this is not a requirement, it just gives you a starting point with a flat background color and drop shadow. It also contains a column and several buttons, all constructs that we have seen and explored before.

The most interesting part of the example is this line on `IconButton`:

```
onPressed: () => _scaffoldKey.currentState!.closeDrawer(),
```

When the button is pressed, the state is retrieved from the `Scaffold` using `_scaffoldKey` we defined earlier upon which we call the `closeDrawer()` method.

Finally, we just need a way to open the drawer, so we can add a button to the home page that will trigger the opening of the drawer:

```
ElevatedButton(
  onPressed: () => _scaffoldKey.currentState!.openDrawer(),
  child: Text("Open drawer"),
),
```

As you can see, this is very similar to the `closeDrawer()` method in that we get the `Scaffold` state through the use of the global key and then call `openDrawer()`. As you would expect, pressing this button causes the drawer to slide open smoothly from the side of the screen.

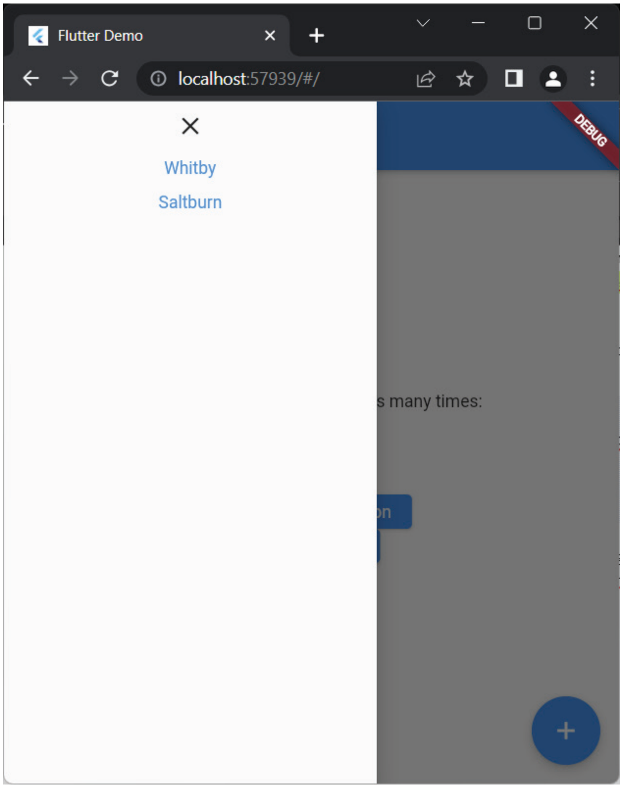


Figure 7.4: The drawer slides out from the side of the screen

This is a very easy way to make your app seem advanced and professional.

Snackbar

Similar to the drawer is the **snackbar**. This is a lightweight message that can slide up from the bottom of the screen to give feedback to the user such as the results of actions they have performed.

Surprisingly, using the snackbar is a very different process from using the drawer, even though they perform very similar activities.

Let's take a look at an example and then we can analyze the code:

```
ElevatedButton(
  onPressed: () {
    ScaffoldMessenger.of(context).showSnackBar(
      SnackBar(
        content: Text('The parmo is a famous food from Teesside.'),
      ),
```

```
        );
      },
      child: Text('Show SnackBar'),
    ),
```

Again, we have used `ElevatedButton` to activate the widget. However, we didn't need to assign a key to `Scaffold` as in the `drawer` example; we simply needed to find the inherited widget of the `ScaffoldMessenger` type, which takes care of the snackbar creation and display. Hopefully, the use of inherited widgets is somewhat familiar now:

```
ScaffoldMessenger.of(context)
```

This code uses `BuildContext` passed into the parent widget to find `ScaffoldMessenger`. We can then call the `showSnackBar()` method on the messenger and pass in a `SnackBar` widget that contains the content we want to show – in this case, a `Text` widget.

There is no need to implement a `close` action for the snackbar because it will automatically close after a configurable period of time.

And there's much more…

As mentioned at the start of the section, there are many ways you can use the `Scaffold`, including displaying the following:

- `BottomSheet`, which is similar to the drawer but slides in from the bottom of the screen
- `BottomNavigationBar`, which is a row of buttons at the bottom of the screen – generally used as top-level navigation around the app
- `FloatingActionButton`, which is included in the `Hello World!` app
- `AppBar`, which appears at the top of the page and generally displays a page title and one or two action buttons that can be used to open a menu, probably via a drawer
- `MaterialBanner`, which is similar to the snackbar but displayed at the top of the screen

I would love to give you examples of all of these in the book, but the next best thing is to include code examples on GitHub, so take a look at the repository if you want inspiration.

We've now looked at making base widgets pretty and how to add core functionality to our app in a stylish way via `Scaffold`. We now turn our attention to lists of data and how we can make those look top-notch too.

Creating elegant content lists

We briefly learned about `ListView` in *Chapter 5*, *Building Your User Interface through Widgets*. When we tested out `ListView`, we put relatively basic widgets into `ListView`, but there is a widget that is specially designed for lists, `ListTile`.

`ListTile` simply creates an elegant structure for you to put your display widgets into, be they icons, text, or images. You can emulate the structure of `ListTile` through the widgets we have seen before, but abstracting away structure and the boilerplate code required to create it allows you to focus on the core value of your app.

Let's look at an example of `ListTile`:

```
ListTile(
  title: Text("Teesside"),
  subtitle: Text("The home of the Lemon Top ice cream"),
  leading: Icon(Icons.location_on),
  onTap: () {...},
  trailing: IconButton(
    icon: Icon(Icons.thumb_up),
    onPressed: () {...},
  ),
)
```

Before we analyze the code, it is easier to evaluate if you see an example, so here is the same `ListTile`:

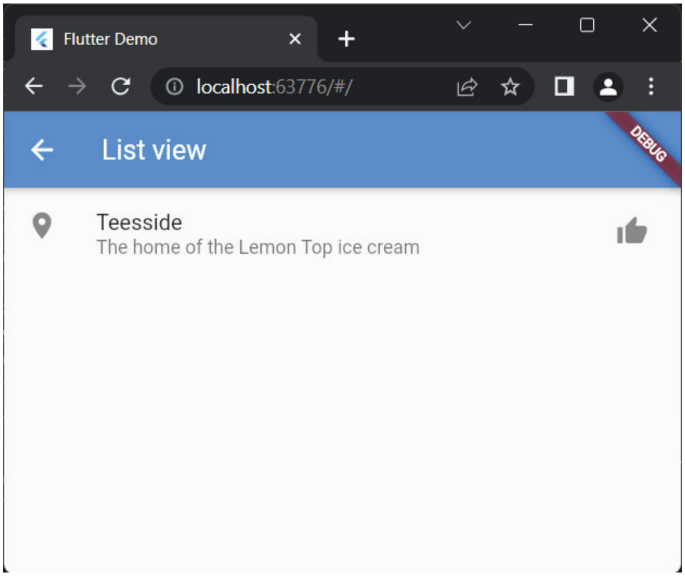


Figure 7.5: An example of ListTile

Now you can visualize `ListTile`, let's review the code and specifically the parameters for the `ListTile` constructor:

- `leading`: A widget that will be displayed on the far left of the `ListTile` widget. Generally, an icon or image is great in that spot. Imagine a film review site or a weather app – both would suit using `ListTile` to display their data with an image on the left.
- `title`: The text that appears in bold and large font at the top of the widget. For a film review site, this could be the film's title, and for a weather app, this could be a summary of the predominant weather.
- `subtitle`: The text that appears under the title in smaller font. This could be a film summary or details on the weather, such as temperature, wind speed, and chance of precipitation.
- `trailing`: Similar to `leading`, this appears on the far right of the widget and often will hold action buttons such as liking a film or sharing a weather forecast.

In addition, `ListTile` has lots of other capabilities, such as the following:

- It can be used as a button with splash, hover, focus, and colors all customizable.
- It will reverse the `leading` and `trailing` widgets if the language being used is right-to-left.
- The colors of the tile, such as the background and text colors, can be managed.
- The density of the widgets within `ListTile` can be changed if you need to show more content or only have limited space. One key feature is the ability to set `isThreeLine`, which allows the subtitle to extend onto a third line.

Overall, `ListTile` is a very handy widget and can save lots of time that would otherwise be spent on messing around with layouts, especially when you are first prototyping your app.

However, sometimes, you can make your app look great simply by adding some great images. Let's take a look at Flutter's support for the different image types and when to use the different formats.

Understanding image types in Flutter

There are many different image formats available, and knowing which format to use in which situation can be tricky. This section is by no means exhaustive, but it aims to give you an overview so that you can make a more informed decision when presented with the question of what image type you need for your app.

Out-of-the-box support

Flutter supports many image formats out of the box (i.e., there is no plugin or specific platform support required):

- **JPEG** – This stands for **Joint Photographic Experts Group**. It is a very common format predominantly used for photography. It uses lossy compression (meaning that as the image is compressed to reduce size, it loses details about the image) and is the most widely used image format because it suits photographic compression very well. However, it is really not well suited to line drawings or iconography because the compression process can create artifacts in the image.
- **PNG** – This stands for **Portable Network Graphics**. Unlike JPEG, the compression of a PNG file is lossless, meaning that a large file can often be compressed to a smaller file without information loss. PNG supports palette-based images of 24-bit RGB or 32-bit RGBA, grayscale, or full-color non-palette-based images. However, it is not designed for professional-grade print graphics. PNG was created as an open source alternative to the GIF standard, which relies on a patent for compression.
- **GIF and Animated GIF** – This stands for **Graphics Interchange Format**. Each GIF image defines its own 256-color palette, which works very well for low-resolution images but is too limited for more detailed photographic images. GIFs can be animated, as has been used by tooling such as Giphy to create amusing snippets of videos.
- **WebP and Animated WebP** – To quote from the WebP website, "*WebP is a modern image format that provides superior lossless and lossy compression for images on the web. WebP lossless images are 26% smaller in size compared to PNGs.*" This is a relatively new format that is growing at a decent rate and is worth investigating.
- **BMP and WBMP** – Bitmap images are relatively pure representations of the image that has been captured. Therefore, they are held in large files and are generally not a good solution for apps or websites. However, Flutter supports them for situations where the raw BMP is required by your app.

These are regularly well-known image formats, and choosing between them should be relatively easy given the context of any decision.

However, there are a couple of other image formats that are worth investigating.

SVG

The **Scalable Vector Graphics** (**SVG**) standard uses XML to define the image through vectors. This has the wonderful benefit that no matter how much you enlarge the image, there is no loss in quality. Additionally, standard XML compression tools will work on an SVG file in a lossless way.

However, SVG is a complicated standard and can make use of the full range of **Cascading Style Sheets** (**CSS**) functionalities as used by websites.

Flutter does not have standard support for SVG, and it can be somewhat challenging to use SVG within your Flutter app.

My explorations have led me to find two plugins that offer SVG support:

- `flutter_svg`: This plugin is very straightforward to use and works for most SVG images. Loading SVG images works similarly to other images and uses the `SvgPicture.asset(assetName)` widget constructor. However, it does not have full support for CSS, so you need to ensure that your SVG images are using presentation attributes rather than inline CSS.
- `jovial_svg`: A very powerful SVG plugin that supports CSS and, therefore, can work with most SVG images. It is slightly more complicated to use than `flutter_svg` but I haven't yet found an SVG that it can't cope with.

It is worth noting that both of these plugins have the capability to precompile the SVG files into binary equivalents for faster processing. This suggests that SVG may not be a great format for high-speed apps. Precompiling is a relatively straightforward process, and the compiled image files can be added to your code much like a standard image file.

Lottie files

I must admit, I love **Lottie** files! Take a look at the Lottie files website and then tell me you haven't fallen in love with them as well: `https://lottiefiles.com/`.

They are like a cross between animated GIFs and SVGs and there are loads of freely available animations for you to get your hands on.

The `Lottie` plugin is incredibly easy to use. Simply by adding a line like this, you will be able to show a great animation on your app:

```
Lottie.asset('assets/LottieLogo1.json')
```

Just add your Lottie files to your `assets` folder and away you go. I strongly recommend you give it a try – quality animation can really make your app look professional.

After a bit of fun with images, let's finish the chapter off with something very cool and only slightly complicated – slivers.

Slivers

I'll be honest, the first few times I tried to use slivers, I really struggled. It's a bit of a mental switch from the widgets we have learned about so far because it introduces the complexities of scrolling. We have already seen slivers in action when we briefly looked at `ListView`.

The main issue is that when you add scrolling into your app, you effectively remove constraints around the size of your widget. If a widget is in a vertically scrollable area, then it can become infinitely tall and, unsurprisingly, Flutter isn't keen on displaying infinitely large widgets.

Therefore, although we will look at this area now, I strongly suggest that if you want to use slivers, you do some serious research into the area first. Otherwise, you'll be bouncing from errors to overflows and back to errors with no hope in sight. However, if you can master this area, then you can make some seriously impressive layouts that will definitely impress your users.

Lists with navigation

To start our exploration, we will look at an example. Suppose you want to have a column in your app where the user is shown a list of information and then, at the base of the column, the user can press a button to move to the next step in their app usage.

You have two requirements:

- The **Next** button must be at the base of the screen if the content in the column does not fill the screen
- The **Next** button must be below the base of the screen if the content in the column goes beyond the base of the screen, with all the contents of the column scrollable so that the user can view all the contents and get to the **Next** button

This scenario is incredibly common, but very hard (if not impossible) to achieve without slivers. Let's start our example and then explore the code:

```
Scaffold(
  body: CustomScrollView(
    slivers: [
      SliverFixedExtentList(
        itemExtent: 100.0,
        delegate: SliverChildBuilderDelegate(
          (BuildContext context, int index) {
            return Container(
              color: index.isEven ? Colors.red : Colors.black,
            );
          },
          childCount: 3,
        ),
      ),
      SliverFillRemaining(
        child: Column(
          mainAxisAlignment: MainAxisAlignment.end,
          children: [
            TextButton(
              child: Text("Next"),
              onPressed: () {...},
            ),
```

```
            ],
          ),
        ),
      ],
    ),
  )
```

In this example, we've created a `Scaffold` that holds `CustomScrollView`. This widget moves you into the land of slivers and makes whatever is contained scrollable.

Obviously, being scrollable is important if we have too much content to fit on the screen.

`CustomScrollView` takes a list of slivers and we have used two here – `SliverFixedExtendList` (which is like a list view) and `SliverFillRemaining` (which will fill the rest of the scroll view). `SliverFillRemaining` is generally the last sliver in any list because it will consume the remaining space of the scrollable area.

The details of `SliverFixedExtentList` are a little tricky to read, but basically, it takes the equivalent of a widget builder and returns `SliverChildBuilderDelegate`. This delegate specifies how many children will be in the list via the `childCount` property, and then, using the index, returns a container of a different color depending on an even or odd index.

Finally, `SliverFillRemaining` takes all the remaining space, into which we put a column, align the children to the end of the column, and put a button there to move to the next page.

The output looks like this:

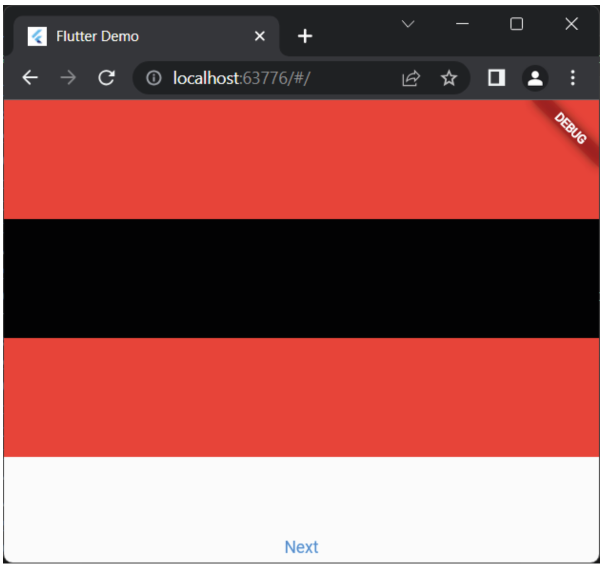


Figure 7.6: Using slivers to display containers and buttons

As we can see, the **Next** button has moved to the base of the screen as we hoped.

Now, let's add more children to the list to see what happens when the **Next** button is pushed off the screen. Will we get an overflow or a similar nasty error message, or will it work as we hope?

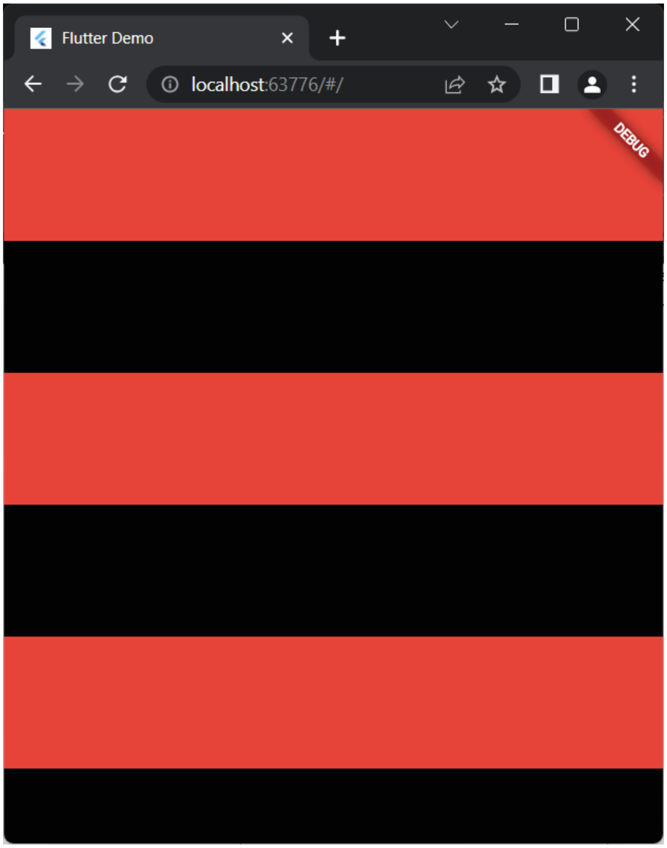


Figure 7.7: Sliver with content longer than the screen

The content of the list has now gone beyond the base of the screen. However, the content is scrollable, so if we scroll down, we see that the **Next** button is exactly where it should be:

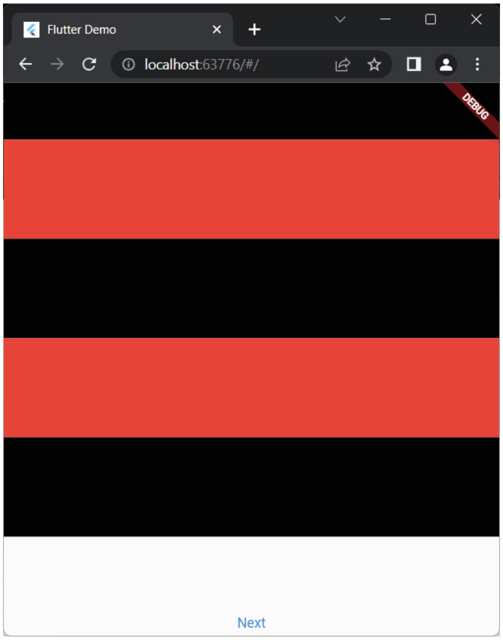


Figure 7.8: SliverFillRemaining has placed the button correctly

SliverAppBar

Another very common use of slivers is `SliverAppBar`. This is like `AppBar`, which we have previously used with `Scaffold`, but it can vary in height depending on the scroll offset of the main content and can appear or disappear depending on the user's actions.

`SliverAppBar` is just another sliver, so can be placed as the first entry in `CustomScrollView` like other slivers. For example, here is a basic `SliverAppBar`:

```
CustomScrollView(
  slivers: [
    SliverAppBar(
      expandedHeight: 100.0,
      floating: true,
      title: Text("Sliver page"),
      flexibleSpace: FlexibleSpaceBar(
        title: Text('Flexible part'),
      ),
      actions: [
```

```
          IconButton(
            icon: Icon(Icons.delete),
            onPressed: () {},
          ),
        ],
      ),
    ...
  )
```

In this example, `SliverAppBar` will expand to `100` px tall, has a title and action button like a standard `AppBar`, but also has `flexibleSpace`, which will shrink when a user scrolls, and is `floating`, which means it hides when a user scrolls down but reappears as soon as they scroll up.

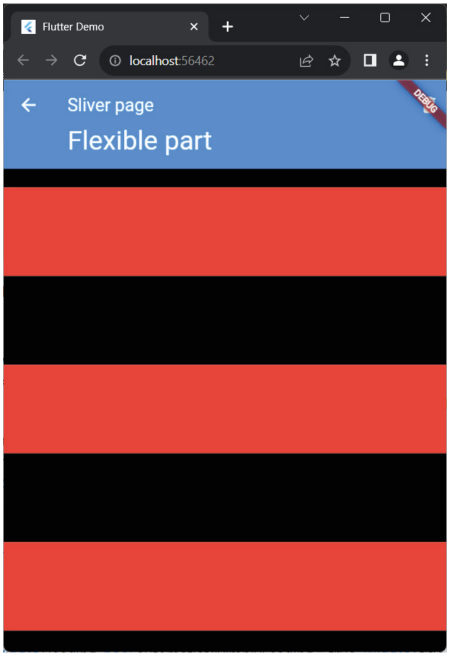


Figure 7.9: Using SliverAppBar as the first sliver

There are many different ways to control `SliverAppBar` and how it behaves on scroll events. The three main parameters for this are as follows:

- `floating`: This controls whether the app bar should appear as soon as a user scrolls up.
- `pinned`: This controls whether the app bar should stay visible even when the user scrolls down. The flexible areas can still expand and contract.
- `snap`: This controls whether the app bar will snap into view.

As you can see, `SliverAppBar` can really improve the user experience, but it is hard to explain with static images, so I highly recommend that you take a look at the *SliverAppBar* documentation to get a sense of how you can really make the top bar of your app look slick: `https://api.flutter.dev/flutter/material/SliverAppBar-class.html`.

Even if that is your only foray into slivers, it is an incredibly useful structure to make use of when you want to use scrolls and position widgets at the top and bottom of the screen.

Summary

In this chapter, we looked at some of the widgets we have already explored and how they can be made to look more enticing to the user. This started with a look at how colors are defined in Flutter and included decorations on containers and styles on text.

We learned how the `Scaffold` widget can be used to give advanced functionality to our app, including the use of drawers to hold menus and snackbars to give quick feedback to the app users.

We had a look at `ListTile`, which is a very useful widget for prototyping layouts before you get into the nitty-gritty of moving widgets a few pixels in different directions.

Finally, we had a dabble in the world of slivers and how they can be used to manage scrollable areas and advanced layouts of widgets.

In the next chapter, we will take a further look at how users interact with Flutter apps.

Questions

Making an app look pretty can be hard work, but the more you do it, the easier and more intuitive it will become. When you develop an app, working on frontend graphics can be the most rewarding because your stakeholders, testers, and users get to see your progress with you. Let's recap some of the knowledge gained from this chapter so that, as you develop your apps, this knowledge comes easily to you:

1. What's the difference between 6-digit and 8-digit hex colors?
2. Why would you use the `overflow` parameter of the `TextStyle` constructor?
3. What would you use `BoxDecoration` for on a container?
4. Do you remember why you need a global key when working with drawers on scaffolds?
5. Which inherited widget do you require to display a snackbar to a user?
6. Can you remember which image types are supported by Flutter? For bonus points, can you remember the two additional image types we discussed?
7. Which slivers did we use in our example?

Further reading

There is so much to explore from this chapter. Take a look at the GitHub repository that is a companion to this book. I've tried to put all the examples in there as usable demos, so grab the repository and then start tinkering and see whether you can understand how it is working.

We looked at the following two image-type plugins:

- `https://pub.dev/packages/lottie`
- `https://pub.dev/packages/jovial_svg`

Also, check out the Lottie files website for some great animations: `https://lottiefiles.com/`

Finally, on slivers, there are some great tutorials from the wonderful Kate Lovett at `https://docs.flutter.dev/ui/scrolling/slivers`.

Take the time to watch the videos and start to understand how slivers work. It can be a complicated area, so if you don't immediately understand it, please don't be disheartened; it is worth persevering.

8
Routing – Navigating between Screens

Mobile apps are typically organized into multiple screens or pages. You will have seen this in the mobile apps you already use. For example, perhaps an app has an initial list view of items (such as groceries or films), and, when you choose one of the items, you are taken to another screen or page where more details are shown about the item. When you do this, you have just navigated from one screen to another.

In Flutter, moving between screens is called a route and is managed by the `Navigator` widget of the application. The `Navigator` widget manages the navigation stack, pushing a new route onto the stack or popping a previous one-off. In this chapter, you will learn how to use the `Navigator` widget to manage your app routes, how to add transition animations, and how to pass information (state) between screens.

The following topics will be covered in this chapter:

- Understanding the `Navigator` widget
- Understanding routes
- Screen transitions
- Passing data between screens

By the end of this chapter, you will be able to create an app with several screens and manage the routes between them. You will be well on the way to having the skills to create a usable Flutter app!

Technical requirements

You will need your development environment again for this chapter. Look back at *Chapter 1*, *What Is Flutter and Why Should I Use It?*, if you need to set up your IDE or refresh your knowledge of the development environment requirements.

You can find the source code for this chapter on GitHub at the following link: `https://github.com/PacktPublishing/Flutter-for-Beginners-Third-Edition`.

Understanding the Navigator widget

Mobile applications will almost always contain more than one screen. If you are an Android or iOS developer, you probably know about the `Activity` or `ViewController` classes, which represent screens on those platforms.

An important class for navigation between screens in Flutter is the `Navigator` widget, which is responsible for managing screen changes while maintaining a history of screens so that the user can move back through the screens (if the app chooses to allow it).

A new screen in Flutter is just a new widget that is effectively placed on top of the existing widgets. This is managed through the concept of routes, which define the possible navigable routes a user can follow through the app. Unsurprisingly, there is a class named `Route` that is a helper for working on the navigation workflow.

The main classes in the navigation layer are as follows:

- `Navigator`: The route manager
- `Overlay`: `Navigator` uses this to specify the appearances of the routes
- `Route`: A navigation endpoint

We will explore these different classes in the next few sections, but first, we need to look at how the actual approach to navigation has changed as Flutter has evolved.

Navigator 1.0 and 2.0

As Flutter has moved to the web, and generally evolved to be a more complete app development framework, the way that app navigation between screens is structured has changed and now, there are two different available ways to navigate.

Navigator 1.0 worked in an imperative style; the code flow instructed the framework to add or remove screens from the stack. This works nicely for most apps, especially within iOS or Android environments, and is a simple approach that is easy to understand and follow.

However, the web introduces new challenges around direct links deep within the app that are designated through specific URLs. In an iOS or Android app, you generally expect a user to enter through the first screen of the app and navigate from there. However, on the web, you may share a web URL that links to a specific screen within the web app. For example, suppose you are browsing a book-selling website and share a link for a single book. You would expect the person you shared it with to be able to go directly to that web page while still having the stack of expected screens that they would have followed to get to that page (in this case, the book list page) available to them.

This is not a web-specific scenario; the same is true for deep links within iOS or Android apps, but it becomes more obvious in web apps where the Navigator 1.0 approach is not as well suited to a world where people can enter your app on any screen.

Navigator 2.0 follows a declarative style that is similar to the approach used within a widget tree; the screens available are declared upfront and the state decides which ones are shown to the user.

We will explore both approaches as both are supported and entirely acceptable ways to build your app. Many in the community believe that the naming was unhelpful because it implies that Navigator 2.0 supersedes the original navigator approach. This is generally not true and, additionally, Navigator 2.0 can be a much more complicated way to start your Flutter development. There are packages available that simplify the Navigator 2.0 approach with one specifically referenced by the Flutter documentation: **go_router**. Therefore, when we explore Navigator 2.0, we will use the `go_router` package as our guide.

Imperative versus declarative

Imperative and declarative are different ways of writing your code. There is no right or wrong choice, and different situations may suit a specific choice. In coding, you can specify code that becomes active based on world state (declarative) or you can instruct code to run (imperative).

One way to think about the difference is perhaps to think of a parent organizing lunch for a young child. The parent has effectively declared that at a set time of the day, they will make lunch. When the state of the world changes (that is, time passes), the parent assesses the state change and if it matches their declared intent, then they make lunch. Nothing has told the parent to make the lunch; it was a change in the world state that triggered their lunch-creating activity. On the flip side, the child is told to eat their lunch when it is ready, perhaps using a verb in the imperative form to instruct the child: "Eat your lunch."

To complete the example and show that either option is fine, imagine an alternative scenario where the adult has set an alarm to instruct them to make the lunch (imperative) and the child has declared that they will eat food whenever it is placed on the table (declarative). This is also an acceptable scenario.

Navigator

The `Navigator` widget is the key to moving a user from one screen to another. Most of the time, the user will change screens and need their data to be passed along to the new screen. This is another important task for the `Navigator` widget.

Conceptually, navigation in Flutter is a stack of screens:

- We have one element at the top of the stack. In `Navigator`, the topmost element on the stack is the currently visible screen of the app.
- The last element that's inserted is the first to be removed from the stack, commonly referred to as **last in, first out** (**LIFO**). The last screen that's visible is the first that is removed.
- The `Navigator` widget has `push()` and `pop()` methods to add and remove screens from the stack. This is the imperative Navigator 1.0 style; `Navigator` is being told to add or remove screens.
- The `Navigator` widget has a `pages` property where, much like a stack containing a list of widgets, the pages are listed and shown or removed based on the state of the containing widget. This is the declarative Navigator 2.0 style; the screens listed in the `pages` property are shown or not based on state rather than being told to show or not.

Let's take a look at the Navigator 1.0 approach.

Navigator 1.0

The Navigator 1.0 approach has been in use since Flutter was created, and the vast majority of code examples available use the Navigator 1.0 approach to navigate between screens. Therefore, it is important to know this approach to navigation, and in many cases, it will be the best fit for your app anyway due to its simplicity.

Let's look at how we would use this approach to navigation, first by understanding what a **Route** is.

Route

The navigation stack elements are Routes, and there are multiple ways to define them in Flutter.

When we want to navigate to a new screen, we define a new `Route` widget for it, in addition to some parameters defined as a `RouteSettings` instance.

RouteSettings

This is a simple class that contains information about the route relevant to the `Navigator` widget. The main properties it contains are as follows:

- `name`: Identifies the route uniquely. We will explore it in detail in the next section.
- `arguments`: With this, we can pass anything to the destination route.

MaterialPageRoute and CupertinoPageRoute

The **Route** class is a high-level abstraction, but different platforms may expect screen changes to behave differently. In Flutter, two main alternative implementations align with platform expectations called `MaterialPageRoute` and `CupertinoPageRoute`, which adapt to Android and iOS, respectively.

So, when you're developing an application, you must decide whether to use the Material Design or iOS Cupertino transitions or both, depending on the context.

Putting it all together

It is time to check out how to use the `Navigator` widget in practice. Let's extend the Hello World! example so that it has a basic flow that navigates to a second screen and back.

Firstly, let's create a widget that we can use as the second screen. In your `main.dart` file, add a new widget that looks something like this:

```
class DestinationDetails extends StatelessWidget {
  DestinationDetails({required this.title});
  final String title;
  @override
  Widget build(BuildContext context) {
    return Scaffold(
      appBar: AppBar(title: Text(title)),
      body: Center(
        child: ElevatedButton(
          child: Text("Back"),
          onPressed: () {
            // To be added
          },
        ),
      ),
    );
  }
}
```

This is a simple `Stateless` widget that takes a single `String` parameter named `title` and has the `build` method defined. You should be starting to become familiar with widget trees, but let's step through this `build` method as a refresher.

The `Scaffold` widget is at the top level and is used to specify the app bar at the top of the screen, the body of the screen, and can be used for other items such as floating action buttons. It also has the benefit of being a `Material` widget, which means that child widgets can also be `Material` widgets.

We have a very basic AppBar in this example that displays the title value that was passed as a constructor parameter to the widget:

```
appBar: AppBar(title: Text(title)),
```

We then have a `Center` widget, which simply centers the child widget within the `Center`'s parent widget. Finally, we have an `ElevatedButton` widget, which is where the magic will happen. It has a simple `Text` widget as a child and the `onPressed` handler, which we will look at shortly.

Now, let's add a route to allow navigation to this new page. Within the `build` method of the `_MyHomePageState` class, you will see the `Column` widget. Make a change to its `children` property to add an `ElevatedButton` widget, as shown here:

```
children: <Widget>[
  ... // Text widgets
  ElevatedButton(
    child: Text('Explore Whitby'),
    onPressed: () {
      Navigator.of(context).push(
        MaterialPageRoute(builder: (context) {
          return DestinationDetails(title: "Whitby");
        }),
      );
    },
  ),
],
```

Much like the `ElevatedButton` widget we looked at before, this `ElevatedButton` widget has a child `Text` widget and an `onPressed` handler. This time, we have added code to the handler that will change the screen. Let's look at that line by line:

```
Navigator.of(context).push(
```

You may recognize this structure from *Chapter 5, Building Your User Interface through Widgets*, where we explored `InheritedWidgets`. The `Navigator` widget is an inherited widget, which means you can find it by searching the context to retrieve it. There is an implicit `Navigator` widget created within the `MaterialApp` widget, so this is looking up the tree and finding the `Navigator` widget associated with the `MaterialApp` widget, and returning it.

We then choose to `push()` an entry onto the `Navigator` widget. As you saw previously, the `Navigator` widget is like a stack, so we are pushing a new screen onto the stack so that it appears over the existing screen.

We pass the `push` method `MaterialPageRoute`:

```
MaterialPageRoute(builder: (context) {
```

As mentioned previously, `MaterialPageRoute` extends the `Route` class and adds Material Design considerations to the standard `Route`. This holds the information about the new screen that we want to draw, and the contents of the new screen are returned as part of the `builder` property on `MaterialPageRoute`.

Finally, we return the widget for the new screen:

```
return DestinationDetails(title: "Whitby");
```

This specifies that when the route is drawn using the `builder` property, we want the `DestinationDetails` widget to be drawn.

With this all in place, you can try navigating to a new screen! Click the **Explore Whitby** button – you should navigate to a new screen with the **'Whitby'** title at the top and a **Back** button showing. However, the **Back** button has no code within its `onPressed` method, so let's go back and fix that. If you leave the code running, then you can take advantage of hot reloading.

Set the following code as the `onPressed` method on the `ElevatedButton` widget of the `DestinationDetails` class:

```
onPressed: () {
  Navigator.of(context).pop();
},
```

This looks similar to the use of `Navigator` widget from before, but instead of the `push` method, we now use the `pop()` method to remove the current screen from the navigator stack and effectively go "back" to the previous screen.

Save this change, enjoy the wonder of hot reloading, and then check whether you can get back from the second screen to the first.

> **Getting Navigator**
> You may see code examples where the `Navigator` call looks slightly different. Instead of `Navigator.of(context).pop()`, you may see `Navigator.pop(context)`. These are effectively equivalent because the first line of code in the `Navigator.pop` method is to find the `Navigator` widget using the context. Use whichever approach feels more comfortable to you.

Well done – you've set up your first navigation. The world is now your oyster! Hopefully, you can now see how a multi-screen app can be built and that, although the syntax can seem a little intimidating at first, it all makes sense. Note that this is an imperative approach to navigation; you are instructing the navigator to change pages through the use of push and pop.

There is another way to use the imperative approach, which involves using named routes.

Named routes

The route name is an important piece of navigation. It identifies the route with its manager, the `Navigator` widget.

We can define a series of routes with names associated with each of them. This provides a level of abstraction to the meaning of a route and a screen. In addition, they can be used in a path structure; in other words, they can be seen as subroutes, similar to the way a web URL is structured.

Moving to named routes

Our previous example of navigating was very simple, but we can better organize the navigation structure through the use of named routes, allowing us to do the following:

- Organize the screens in a clear way
- Centralize the creation of screens
- Pass parameters to screens

Named routes are specified on the **MaterialApp** widget, so let's modify the Hello World! code so that it uses named routes.

Firstly, update the `MaterialApp` widget so that it has a `routes` property that looks like this:

```
routes: {
  '/': (context) => MyHomePage(title: 'Flutter Demo Home
      Page'),
  '/destination': (context) => DestinationDetails(title:
    "Whitby"),
},
```

In this code, we have specified that there are two routes available within the app: the `'/'` route, which will use the `MyHomePage` widget to draw the screen, and the `'/destination'` route, which will use the `DestinationDetails` widget to draw the screen.

If you try to run the code as it is now, you will get an error because you now have both the `'/'` route and the `home` property set on `MaterialApp`. The `'/'` route is a special route that is equivalent to the `home` property of the app, so you are effectively defining `home` twice and Flutter doesn't know which one should be used.

So, go ahead and remove the `home` property and try running the app; it should work now. Note that the navigation we created earlier still works without routes because ultimately, you are still adding and removing screens to the navigation stack whether you choose to use routes or not.

So, let's change the navigation so that it uses the routes. In the ElevatedButton widget of _MyHomePageState, edit onPressed so that it looks like this:

```
onPressed: () {
  Navigator.of(context).pushNamed("/destination");
},
```

Notice how much cleaner the code feels and that the intent of the navigation is clearer. The creation of MaterialPageRoute is implicit now.

Save the update, let the hot reload work its magic, and then check that the navigation flow still works correctly. pop() continues to work as before; pushNamed still just adds a screen to the stack, so the pop will simply remove that screen as expected.

Arguments

You may have noticed that now, our title argument for DestinationDetails is always going to be the same. This often isn't the behavior you would want; you would expect the calling screen to be able to set the arguments of the screen that is being navigated to.

To solve this problem, the pushNamed method also accepts arguments that are passed to the route. Make the following change to your onPressed method in ElevatedButton:

```
Navigator.of(context).pushNamed('/destination',
  arguments: "Staithes");
```

However, passing arguments to a screen complicates the setup of routes, and the routes parameter of MaterialApp can no longer be used. Instead, we need to use the onGenerateRoute parameter to pass the settings to the DestinationDetails widget. onGenerateRoute is more powerful because you have full control over the choice of destination screen. However, it also adds a lot more complication and increases the opportunity for navigation bugs.

In your MaterialApp widget, remove the routes parameter and add onGenerateRoute so that it looks like this:

```
onGenerateRoute: (settings) {
  if (settings.name == '/') {
    return MaterialPageRoute(builder: (context) =>
      MyHomePage(title: "Flutter Demo Home Page"));
  } else if (settings.name == '/destination') {
    return MaterialPageRoute(builder: (context) =>
     DestinationDetails(title: settings.arguments
       as String));
  }
},
```

The onGenerateRoute code looks at settings.name to see which route was selected and then returns MaterialPageRoute with the details required for that route. This looks very similar to the code that we had when we were using the push method instead of pushNamed, but has the obvious disadvantage that we've lost type safety on settings.arguments and have to hope the cast to String works correctly.

> **Should I use named routes?**
>
> Whether you choose to use named routes is your choice – there is no right answer because the choice will be based on personal opinion.
>
> I prefer to use the push() method because it has strong type safety on the constructor parameters of the widget within the route. However, if you are not passing arguments to the routes, or you prefer the style of having central route management, then you may choose named routes.

So, we've seen how to move to a route using push and pushNamed, and how to pass arguments to those routes. However, there will be situations where we want to return a result to the calling screen during pop(), so let's look at that next.

Retrieving results from Route

When a route is pushed to the navigation, we may expect something back from it – for example, when we ask for something from the user in a new route, we can take the value returned via the pop() method's result parameter.

The push method and its variants return a **Future**. This Future resolves when the route is popped and the value of the Future is the pop() method's result parameter.

We have seen that we can pass arguments to a new **Route**. As the inverse path is also possible, instead of sending a message to the second screen, we can take a message when it pops back.

Let's update DestinationDetails so that the user can make a choice. In the build method, update the Center widget so that the child is a Column that holds two ElevatedButton elements, like this:

```
Widget build(BuildContext context) {
  return Scaffold(
    appBar: AppBar(title: Text(title)),
    body: Center(
      child: Column(
        mainAxisAlignment: MainAxisAlignment.center,
        children: [
          ElevatedButton(
            child: Text('Favorite'),
            onPressed: () {
```

```
              Navigator.of(context).pop(true);
            },
          ),
          ElevatedButton(
            child: Text("Close"),
            onPressed: () {
              Navigator.of(context).pop(false);
            },
          ),
        ],
      ),
    ),
  );
}
```

You will notice that, apart from the slight widget tree change to accommodate the extra `ElevatedButton`, `pop()` now takes an argument. In this case, it is a bool denoting whether the user wants to add the destination to their favorites list, but any type can be returned via the `pop()` method.

Now, we need to update the code in `onPressed` of `ElevatedButton` in `MyHomePage` so that it can receive the returned value.

Let's look at how we could do that with this example code. Note that the example has moved back to using `push` rather than `pushNamed` for navigation. Feel free to revert your code to the earlier example of routes using `push`:

```
ElevatedButton(
  child: Text('Explore Whitby'),
  onPressed: () async {
    bool? outcome = await Navigator.of(context).push(
      MaterialPageRoute(builder: (context) {
        return DestinationDetails(title: "Whitby");
      }),
    );
    ScaffoldMessenger.of(context).showSnackBar(
      SnackBar(content: Text("Favorite: $outcome")),
    );
  },
),
```

The result of `push` is a **Future**, so our code will need to wait for the result and it specifies this through the `await` keyword. This means we also need to update the method signature of the anonymous function we are supplying to `onPressed` to specify that it is an asynchronous function. We do this with the `async` keyword between the parameters list in the round brackets (which is empty) and the method body in the curly brackets.

Finally, we use a very useful Flutter feature, called `SnackBar`, to pop the result to the screen. `ScaffoldMessenger` is an `InheritedWidget` widget, so we use the now-familiar `<type>.of()` syntax to find it, and then use it to show a snack bar (a notification that slides up from the bottom of the screen). The `showSnackBar` method simply takes a `SnackBar` widget as its parameter, which we have specified as having a child widget of the `Text` type containing the `outcome` value.

If you need to refresh your knowledge of working with Futures, take a look back at *Chapter 4*, *Dart Classes and Constructs*.

As you can see, Navigator 1.0 is a full-featured and intuitive navigation system that you can easily add to your app to allow users to navigate around easily. The use of the inherited `Navigator` widget, alongside routes, is simple to understand and implement. I'll be honest and say that until very recently, I have used Navigator 1.0 for all my apps and have only occasionally found a limitation. However, there are some situations when Navigator 1.0 doesn't quite fit the requirements, especially in the world of the web, so let's take a look at Navigator 2.0.

Navigator 2.0

As mentioned previously, the Navigator 1.0 approach had some limitations around building screen stacks on deep linking, and this is most apparent in web-based apps. Therefore, Navigator 2.0 was created and takes a different, declarative, approach to navigation.

Let's start by looking at Pages, the key part of Navigator 2.0.

Pages

`Navigator` has a parameter called `pages` that takes a list of **Page** widgets. As this list changes, due to state changes, the stack of routes is updated to match the `pages` list.

This is very similar to how other widgets that compose a list of children widgets work. For example, a **Column** widget will have children widgets that it composes into a column to display on the screen. If the state changes, which means the children widgets in the **Column** change, then Flutter will redraw the column on the screen with the updated widgets.

The big advantage of this approach is that if you start with a predefined state that involves a stack of several screens (for example, a deep web URL link into your app), then this will work automatically by having several **Page** entries in the `pages` parameter right from the start. Previously, bespoke solutions such as passing the initial state from parent to child widgets would be needed with a potentially clunky startup as the app worked its way through the routes to the page that was requested.

Navigator 2.0 in action

As it is generally considered a more complicated approach to app navigation, we will not go into too much depth on the Navigator 2.0 approach, but it is useful to know it exists and to get a general feel for it so that once you are more confident in your Flutter knowledge, you can investigate the approach more fully.

In this example, we will pick out how the Hello World! app would be changed to suit a Navigator 2.0 approach. We will continue to use the `DestinationDetails` widget defined in the *Navigator 1.0* section and show how it would be accessed using Navigator 2.0.

> **Note**
> This is by no means a comprehensive look at Navigator 2.0 and will primarily serve to explain the declarative approach of Navigator 2.0 in contrast to the imperative approach of Navigator 1.0.

The first change will be to the `MyApp` widget. In the Hello World! app, it is currently a stateless widget, but with Navigator 2.0, the navigation uses state to determine which pages should be on the stack, so we need to convert it into a stateful widget:

```
class MyApp extends StatefulWidget {
  const MyApp({super.key});
  @override
  State<StatefulWidget> createState() => _MyAppState();
}
class _MyAppState extends State<MyApp> {
  String? _selectedDestination;
  …
}
```

We've also introduced a class field named `_selectedDestination`. Note the underscore at the start of the name to ensure the field cannot be accessed outside of the class. This field will hold the name of the destination selected, or null if no destination is selected.

Let's look at the `DestinationDetails` widget again. The widget is pretty standard; it has a `title` parameter and displays the title on the AppBar, and it also displays the string called `Favorite` and a **Close** button within a column:

```
class DestinationDetails extends StatelessWidget {
  DestinationDetails({required this.title});
  final String title;
  @override
  Widget build(BuildContext context) {
    return Scaffold(
```

```
      appBar: AppBar(title: Text(title)),
      body: Center(
        child: Column(
          mainAxisAlignment: MainAxisAlignment.center,
          children: [
            ElevatedButton(
              child: Text('Favorite'),
              onPressed: () {
                Navigator.of(context).pop(true);
              },
            ),
            ElevatedButton(
              child: Text("Close"),
              onPressed: () {
                Navigator.of(context).pop(false);
              },
            ),
          ],
        ),
      ),
    );
  }
}
```

It also has a navigator `pop()` method, as we used in Navigator 1.0. What this does in the navigator is very different, as we will see next.

Next, because the state is on `MyApp` and not `MyHomePage`, when a destination is selected, the buttons on `MyHomePage` will need to have a way to update the state on `MyApp`, and specifically to set the `_selectedDestination` field to the correct value.

To achieve this, we need to add a callback method within `MyApp` that can be passed to `MyHomePage` as a parameter:

```
void _setDestination(String destination) {
  this.setState(() {
    _selectedDestination = destination;
  });
}
```

This method simply takes `destination` as a parameter and uses the value to set the state of the `MyHomePage` widget.

We then need to make use of this callback in `MyHomePage` by adding it as a parameter within the constructor and a field on the class:

```
MyHomePage({required this.title, required this.
  destinationCallback});
final void Function(String) destinationCallback;
```

Then, we can use this parameter within the new destination buttons to correctly set the state. These two buttons have been added to the `Column` widget within `MyHomePage`:

```
ElevatedButton(
  child: Text('Whitby'),
  onPressed: () {
    widget.destinationCallback("Whitby");
  },
),
ElevatedButton(
  child: Text('Scarborough'),
  onPressed: () async {
    widget.destinationCallback("Scarborough");
  },
),
```

They both call the `callback` method and specify the name of the destination that has been selected, therefore setting the state on `MyHomePage`.

Finally, we need to update `MaterialApp` so that it uses two new parameters – `pages` and `onPopPage`:

```
MaterialApp(
  title: 'Flutter Demo',
  home: Navigator(
    pages: [
      MaterialPage(
        child: MyHomePage(
          title: "Press this",
          destinationCallback: _setDestination,
        )),
      if (_selectedDestination != null)
        MaterialPage(
          child: DestinationDetails(title:
            _selectedDestination!),
        ),
     ],
     onPopPage: (route, result) {
```

```
        if (!route.didPop(result)) {
         return false;
        }
        setState(() {
          _selectedDestination = null;
        });

        return true;
      },
    ),
    ...
  );
```

Let's look at the `pages` parameter first. As you can see, it holds a list of two pages: one containing the `MyHomePage` widget, which takes in the callback as a parameter, and one containing the `DestinationDetails` widget, which takes in the `_selectedDestination` value as a parameter.

What is important to note here is that the Page containing the `DestinationDetails` is only added to the `pages` list if the `_selectedDestination` value is not null. Therefore, when the `_setDestination` callback is called and a destination name is set, the flow is very much like the build flow within a widget where the pages list is re-evaluated and the `DestinationDetails` Page is added to the list.

Now, let's look at `onPopPage`. In this method, we tell the navigator what to do when a page is popped. The first action has to be to check whether the pop was successful. Assuming that is the case, then we can assume the pop came from the `DestinationDetails` screen and, by nulling the `_selectedDestination` value, the `DestinationDetails` page will be removed from the pages list and `MyHomePage` will be visible again.

Further Navigator 2.0 learning

The example shared here is incomplete because the use of the back button and changes to the route from the underlying platform are not handled. If you want to complete this example, then take a look at the *Further reading* section at the end of this chapter.

There are plugins that can simplify the Navigator 2.0 approach including the very popular `go_router` and `AutoRoute` plugins. These not only simplify Navigator 2.0 but also add extra goodies such as additional type safety and route guarding where, as an example, access to restricted screens is only available to users who have logged in.

For the examples within the rest of this book, we will focus on Navigator 1.0 as it is simpler and will allow us to focus on the area being explored without being confused by Navigator 2.0 boilerplate code.

Now that we have explored moving users between screens at the code level, let's explore the move between screens at the user interface level.

Screen transitions

Screen changes need to look smooth to the user. You want the user to enjoy their experience within your app, and jarring screen transitions can impact their enjoyment and flow.

As we have seen, `MaterialPageRoute` and `CupertinoPageRoute` are classes that add a route to the navigator. You may have noticed as we experimented with the example app that they add a transition between the old and new Route. These transitions align with the platform defaults but can be customized as well.

On Android, for example, the entrance transition for the page slides the page upward and fades it in. The exit transition does the same in reverse. On iOS, the page slides in from the right and exits in reverse.

Flutter lets us customize this behavior by letting us add transitions between screens. To do this, we need to look a little deeper at routes.

PageRouteBuilder

`PageRouteBuilder` is a helper class that can be used for custom `Route` creation, instead of using the pre-built route subclasses of `MaterialPageRoute` and `CupertinoPageRoute`.

`PageRouteBuilder` contains multiple callbacks and properties to help in the `PageRoute` definition. Here are its key parameters:

- `transitionsBuilder`: This is where we specify the callback for the transition animation. Specifically, this is a `Builder` function that returns a widget.
- `pageBuilder`: This is where we specify the callback that draws the page we are transitioning to. Specifically, this is a `Builder` function that returns a widget.
- `transitionDuration`: The duration of the transition.
- `barrierColor` and `barrierDismissible`: These define partially covered routes of the model and not for the full screen of the app. This would be used for routes that show a pop-up or side menu where the user can still see part of the previous route underneath.

`transitionsBuilder` will draw the transition to the screen until `transitionDuration` has completed. From then on, `pageBuilder` will draw the new page to the screen, with a barrier showing over any previous routes that are visible.

Using these parameters, you can create a route instance with custom transitions.

Custom transitions in practice

First, let's modify `ElevatedButton` on `_MyHomePageState` so that instead of creating `MaterialPageRoute`, we use `PageRouteBuilder`.

As a reminder, this is what the button looks like with a standard `MaterialPageRoute`:

```
ElevatedButton(
  child: Text('Explore Whitby'),
  onPressed: () {
    Navigator.of(context).push(
      MaterialPageRoute(builder: (context) {
        return DestinationDetails(title: "Whitby");
      }),
    );
  },
),
```

Within the `onPressed` parameter, we passed an anonymous function that returned `MaterialPageRoute`. Within `MaterialPageRoute`, we returned the base widget of the next screen – in this case, the `DestinationDetails` widget.

Let's change the `onPressed` argument so that it creates a custom route:

```
ElevatedButton(
  child: Text('Explore Whitby'),
  onPressed: () async {
    Navigator.of(context).push(
      PageRouteBuilder(
        pageBuilder: (context, animation,
          secondaryAnimation) => DestinationDetails(title:
            "Whitby"),
        transitionsBuilder: (context, animation,
          secondaryAnimation, child) {
          return child;
        },
      ),
    );
  },
),
```

Instead of simply pushing `MaterialPageRoute` onto the navigator stack, we have now pushed `PageRouteBuilder` onto the stack, which extends **Route**.

We have added the DestinationDetails widget as the return value from the pageBuilder anonymous function, and simply return the child widget, the result of the pageBuilder anonymous function, from the transitionsBuilder anonymous function.

If you run this code, you will see that there is no transition between pages because our transitionBuilder anonymous function doesn't do anything to the child widget. So, let's change the default transition to use a slide transition. To do this, we need to change the transitionsBuilder anonymous function:

```
PageRouteBuilder(
  pageBuilder: (context, animation, secondaryAnimation) =>
    DestinationDetails(title: "Whitby"),
  transitionsBuilder: (context, animation,
    secondaryAnimation, child) {
    return SlideTransition(
      position: Tween<Offset>(
        begin: const Offset(-1, 0),
        end: Offset.zero,
      ).animate(animation),
      child: child,
    );
  },
)
```

Here, instead of simply returning the child widget, we return a SlideTransition widget that encapsulates the animation logic for us: a transition from left to right, until it becomes fully visible. The child widget, DestinationDetails, is nested inside SlideTransition, so the contents of your new page slide over the previous page because it is contained within the SlideTransition widget. Note that when you go back to the previous screen (by popping the top route off the navigator stack), the animation runs in reverse.

You will see a little complication around the Tween and Offset classes. We have not checked out animations in detail yet, so they will look new to you. We will explore this in more detail in *Chapter 11*, *Using Widget Manipulations and Animations*.

If you are planning to use the same transition for every page, then a useful approach would be to extend the PageRouteBuilder class and create a reusable transition that you could add to the code as easily as MaterialPageRoute or CupertinoPageRoute. This will allow you to avoid duplicated code, and make it easy to make app-wide changes to page transitions.

For example, suppose you wanted to use SlideTransition throughout your app. In this case, you could make your custom MySlideTransition class and extend PageRouteBuilder:

```
class MySlideTransition extends PageRouteBuilder {
  final Widget transitionPage;
```

```
  MySlideTransition({required this.transitionPage})
      : super(
          pageBuilder: (
            BuildContext context,
            Animation<double> animation,
            Animation<double> secondaryAnimation,
          ) => transitionPage,
          transitionsBuilder: (
            BuildContext context,
            Animation<double> animation,
            Animation<double> secondaryAnimation,
            Widget child,
          ) => SlideTransition(
                position: Tween<Offset>(
                  begin: const Offset(-1, 0),
                  end: Offset.zero,
                ).animate(animation),
                child: child,
              ),
        );
}
```

In this class, we have a single constructor parameter named `transitionPage`, which is the widget of the page we are transitioning to. As part of the constructor, the class sets the argument of the parent `PageRouteBuilder` parameter, `pageBuilder`, to be an anonymous function that takes several parameters and simply returns `transitionPage`. Similarly, the class sets the `transitionsBuilder` argument as an anonymous function that takes several parameters and returns `SlideTransition` we experimented with before.

At first glance, this can seem somewhat intimidating, but if you take the time to study it, you'll realize that all we are doing is passing two anonymous functions to the parent class as constructor arguments.

Therefore, whenever an instance of `MySlideTransition` is created, it will automatically call the superclass constructor of `PageRouteBuilder` and set the two parameters to the anonymous functions we were previously specifying on each transition.

Now, within our `ElevatedButton` code, we can very easily specify the `onPressed` function, like so:

```
ElevatedButton(
  child: Text('Press this'),
  onPressed: () {
    Navigator.of(context).push(
      MySlideTransition(
        transitionPage: DestinationDetails(title:
```

```
            "Whitby"),
        ),
      );
    },
  ),
```

We just need to add a custom route widget to the navigator stack so that we automatically get `SlideTransition`.

There are many different transitions you can try that have built-in classes, such as the following:

- `ScaleTransition`: The new screen enlarges over the previous screen
- `RotationTransition`: The new screen spins as it overlaps the previous screen
- `FadeTransition`: The new screen fades in over the previous screen

You would simply replace the `SlideTransition` widget with one of these other widgets to get the desired effect.

Now that we have looked at how we move between screens, we need to explore how we take the application state with us.

Passing data between screens

In almost all apps, there is the concept of application state. This is larger than the state within one widget as it travels with the user throughout the app. If you have worked with other frameworks, you will have seen varying ways to hold application state, and Flutter doesn't have a single way to hold and share state.

We will look at options for how to store application state long term, such as in a cloud database, in *Chapter 10*, *Popular Third-Party Plugins*, but once the state has been retrieved from storage, how should you share that state among your many different application screens?

It's worth noting that there is no right or wrong answer for state management, but every approach has benefits and weaknesses and you will need to decide which approach suits you from the maintenance, code readability, and app usage perspectives.

Passing state in widget parameters

The simplest way to share state around your app, and probably the way most developers start managing state within Flutter, is simply to pass the state to each screen, within the widget's constructor parameters.

We saw this in the `DestinationDetails` widget, where we pass the state of which destination the user is viewing through the `title` parameter. As another example, suppose that you have a user login page on your app. When the user logs in, you create an instance of your `User` class that holds important information about the user. You can then simply pass that instance of the `User` class to any screen through constructor parameters.

The obvious benefit of this approach is that it is very simple to get a prototype of an app up and running quickly. When you want to try out a new framework or try out an app idea, then this approach is fine.

There are, however, many drawbacks to this approach:

- If you decide a screen needs some extra state information that is currently not available to it, then all intermediate screens will need to be updated to pass that state to the screen
- You cannot naturally listen for changes to the state and make the pages (including those already on the stack but not active) automatically update and reflect the changes
- Long-running asynchronous activities such as listening on database updates do not have a natural place to live and may get bundled into state classes

For the examples within this book, we will follow this approach as it keeps the code simple and clear, but as you create a more complex app and become more comfortable with Flutter and Dart, here are a few recommendations on where to look next for state management.

InheritedWidget

We've seen the use of `InheritedWidgets` several times within this chapter and previous chapters. Specific examples have been for finding `Navigator` and `ScaffoldMessenger`. You can achieve this using the `<type>.of(context)` syntax, which searches the context for the first instance of the specified type.

This approach can be used with state, allowing you to search the context for the state information you require. This specifically alleviates one of the drawbacks of the parameter-based approach previously mentioned because intermediate screens that have no interest in specific state information do not need to accept it in their parameters just so they can pass it to a child widget.

BLoC

The **Business Logic Components** (**BLoC**) approach uses a streams approach to sharing state information. Your widgets listen to their chosen state information streams and are told when the state has changed so that they can choose how to deal with that state change when it happens.

This fits very nicely with the Flutter declarative approach because when the app state changes, the widget is notified and can choose to update its internal state if the app state change is relevant. By updating its internal state, it will then trigger a build call and render any changes to the user.

I use the BLoC pattern for all my apps that have gone beyond proof of concept. Additionally, the BLoC pattern works well for listening on external systems such as databases or network requests because the listener logic sits within the BLoC and manages updates to the app state as needed.

Redux

The key difference between Redux and BLoC is that Redux has one state object that manages all the app state, whereas BLoC has a set of BloCs that deal with different areas of the app state.

There are three main concepts in Redux:

- **Store**: This is where the app state is stored
- **Action**: Information about an intention to change the state
- **Reducer**: This calculates the next app state based on an action

Other options

As you can see, there are already many app state management solutions available, but for completeness, here are some other key ones if you don't prefer using the ones listed previously:

- Binder
- Flutter commands
- GetIt
- MobX
- Riverpod

The latest options available are listed on the Flutter site at `https://flutter.dev/docs/development/data-and-backend/state-mgmt/options`.

Summary

In this chapter, we explored the concept of screens within an app and saw how to add navigation between them. First, we learned about the `Navigator` widget, the main player when it comes to navigation in Flutter.

We also saw another important piece of navigation, `Route`, and how to define it for use in our applications. We learned how to use named routes and how to pass arguments to the named route widgets.

We also explored the new Navigator 2.0 approach to get a feel for how this declarative approach to screen management contrasts with the Navigator 1.0 imperative approach. As part of this, we delved into the `go_router` package to see one of the recommended ways to use Navigator 2.0.

Finally, we briefly explored app state management and some of the common approaches. This is a rich area that you should explore when you become more confident with Dart and Flutter.

In the next chapter, we will start to look at another part of the framework that allows Flutter developers to get an app up and running quickly – the wonderful world of Flutter plugins.

Questions

This chapter presented several options to you both for navigation and state management. Although you are unlikely to choose to use all of the options in every app, you must be aware of what is available to you so that you can make informed decisions. As mentioned previously, if you struggle with any of the questions, then revisit the relevant sections of this chapter to refresh your knowledge:

1. Describe the different styles of Navigator 1.0 versus Navigator 2.0.
2. How do you retrieve the `Navigator` instance?
3. Name the two main page route class types.
4. Explain the benefits and drawbacks of using named routes.
5. How would you pass a result back from a route?
6. What two main parameters does `PageRouteBuilder` take?
7. Name some of the ways to pass state between widgets.

Further reading

You may want to get a better understanding of the Navigator 2.0 approach, and a very well-written article I've often referred to is available here: `https://medium.com/flutter/learning-flutters-new-navigation-and-routing-system-7c9068155ade`.

We haven't explored plugins and how they are documented yet, but this might be a good time to explore some of the plugins we mentioned for navigation and state management.

The main navigation plugin to look at is the `go_router` plugin. You can view the details of the plugin and examples of how to use it on their *pub.dev* page (we will learn more about pub.dev in the next chapter): `https://pub.dev/packages/go_router`.

In the same way, it is worth exploring the state management plugins. On the BloC solution, a good plugin to look at is `flutter_bloc`, but many options are available: `https://pub.dev/packages/flutter_bloc`.

Similarly, for the Redux approach, there is the `flutter_redux` plugin: `https://pub.dev/packages/flutter_redux`.

Take some time to understand these state management options – once you choose the one you want to use, it can become very hard to switch, both from a knowledge point of view, but also because you learn to structure your apps in a certain way that complements your state management choice.

Part 3: Turning a Simple App into an Awesome App

By using your knowledge of the previous parts, you have the ability to make a great app. In this part, we will take that great app and make it awesome in two key ways.

Firstly, you are not alone in your development endeavors; other developers want to share their work with you through plugins. These plugins allow you to get amazing functionality for your app without needing to reinvent the wheel and can massively speed up your development process.

Secondly, we can make your widgets magical through animations and manipulations, giving the user a slick experience that will make them want to come back to your app more often.

This part contains the following chapters:

- *Chapter 9*, *Flutter Plugins – Get Great Functionality for Free!*
- *Chapter 10*, *Popular Third-Party Plugins*
- *Chapter 11*, *Using Widget Manipulations and Animations*

9
Flutter Plugins – Get Great Functionality for Free!

Flutter is lucky to have an amazing community of developers who share code with each other via plugins. It is this kind of open source approach that allows frameworks such as Flutter to thrive and allows for innovation across the platform. It also means you generally don't need to reinvent the wheel, allowing you to focus on the unique aspects of your app, rather than spending a lot of time working on basic functionality.

This chapter will start by explaining what plugins are and how you can add them to your app. There is a wide range of plugins available, from user interface widget libraries to low-level messaging tooling and music management classes, so the setup is somewhat bespoke for each plugin. However, there are general rules to follow and best practices for managing versions.

Finally, we will look at some common challenges with plugins and how to resolve them. After the deep technical learnings of the previous chapters, this should be a welcome relief where you can explore how to avoid writing code by using code written by others.

The following topics will be covered in this chapter:

- What is a plugin?
- Where can I find plugins?
- How do I add a plugin to my project?
- How do plugins work on iOS and Android?
- Common issues

By the end of this chapter, you will be able to add plugins to your app, allowing you to explore some of the exciting capabilities of Flutter.

Technical requirements

You will need your development environment again for this chapter as we will add a plugin to the Hello World! project. Look back at *Chapter 1*, *What Is Flutter and Why Should I Use It?*, if you need to set up your IDE or refresh your knowledge of the development environment requirements.

You can find the source code for this chapter on GitHub at `https://github.com/PacktPublishing/Flutter-for-Beginners-Third-Edition`.

What is a plugin?

Many programming frameworks and software tools have the concept of plugins. They may go by another name, such as third-party libraries, extensions, or add-ons, but they are effectively the same thing – a self-contained, modular code deliverable that can be "plugged in" to your existing app code to bring extra functionality.

Within this chapter, you will see references to the term **packages**, which consist of a set of Dart files and optionally some assets, such as images or fonts. A plugin is a special type of package that makes functionality available to your app in a standardized way – this is what we'll be looking at in this chapter. More specifically, a plugin is used to bridge Flutter with platform-specific native code, allowing access to native functionality, while a package is a collection of Dart and Flutter code that provides reusable functionality within a Flutter project, without any platform-specific dependencies.

There are many benefits as well as drawbacks to the plugin approach. So, let's start this chapter by understanding the benefits plugins have for the Flutter framework, and also any drawbacks that should be taken into consideration.

Benefits

We might as well start with the most obvious benefits of plugins – code reuse. Creating a great Flutter app would be much harder if you had to create everything from scratch.

Code reuse

As a developer, you will understand that your time is best used when you can focus on the functionality that makes your app or website unique. It is not productive to spend your time recreating code that has already been written by other developers numerous times, especially when it does not provide any benefits to your app or website. Good examples of this would be the interaction with third-party services such as databases such as Firebase, payment providers such as Square, or mapping solutions such as Google Maps. These are very common third-party services and many different developers will have written Flutter code to interact with them.

Not only does it waste time, but it can also be a source of bugs when the code contains mistakes or doesn't take all the different execution flows that you haven't considered into account because it isn't your core focus or an area of expertise. Additionally, the code can cause maintenance headaches when fixes are required or new versions of dependencies are released because you now have a much larger volume of code that you need to maintain.

Plugins alleviate this problem by solving a specific issue (for example, linking to the device's calendar) and all your app code can reference that single plugin. If an issue is found, the plugin can be updated, and all the users of the plugin will gain the benefit of the fix. If a new version of a dependency is released (for example, a payment provider changes their API), then, again, the plugin can be updated and all users of the plugin can more easily switch to the latest dependency.

Many eyes

One of the great things about plugins is that because many people use them and find issues with them, the plugins become very stable and feature-rich.

You may feel that in some cases, it is easier just to write your own code, but it is almost impossible to test your code on all the different devices out there, all the different screen ratios, or used in all the weird and wonderful ways that users manage to find. Plugin code is effectively tested for free across devices, screen ratios, and usage patterns, allowing the plugin maintainers to adapt their plugin to all of the scenarios tested. This is also true if one of your users finds an issue and reports it to you. You can then report this to the plugin maintainers who are likely to fix the issue for you, or at least suggest a workaround that will keep your users happy.

Domain expertise

For some functionality, you will need to integrate with the base **operating system** (**OS**) of the device. This could require knowledge of Java, Swift, JavaScript, or some other language that can interface with the OS, and unless you are proficient in those languages and also knowledgeable about the APIs available within the OS, this could be quite a challenge. Fortunately, other Flutter developers do have this knowledge and can create plugins that surface that functionality in an easy-to-use way. This means that rather than needing to learn and understand low-level integration, you can spend your time becoming an expert in Dart and Flutter – at least to begin with, anyway; you may find you want to delve deeper into these areas and learn how the low-level integrations work at some point.

Similarly, there may be plugins that are specific to a domain such as security that you wouldn't feel comfortable developing code for. The Flutter community is likely to have experts in many different domains, so using their expertise via a plugin is much better than either becoming an expert yourself or spending money to outsource that part of the development to a third-party developer.

So, plugins are all sweetness and roses, right? Unfortunately, as you would expect, there are some downsides to using plugins. Let's take a quick look at those now so that we can explore how to alleviate them later in this chapter.

Drawbacks

As with any software decision, especially on such a huge scale as plugins, there will be drawbacks that you need to consider when using them. In my opinion, the benefits massively outweigh the drawbacks, but you should still be aware of them so that you can decide how to mitigate their impact.

Version management

Like any good plugin system, all plugins in Flutter are versioned using the semantic versioning scheme. This means it is easy to manage which version of a plugin you are using and ensure that you have the latest or best (not always the same) version of the plugin for your app.

However, with any versioning system, there is the potential for incompatibility, especially when you have a large number of interdependent plugins. This can cause problems, and in rare cases, block you from releasing your app.

For example, suppose that you depend on plugins A and B, which both internally depend on plugin C (known as a transient dependency). If plugin C releases a new major version that is not backward compatible, then plugins A and B may choose to move to the new version of plugin C at different times. This will mean that there may be a period when you won't be able to have the latest versions of plugins A and B. If you require something in the latest version of one of these plugins, then you will either need to stop using the other plugin or find an alternative option.

Semantic versioning

Versioning software is generally required in any software project for lots of good reasons. Semantic versioning standardizes the way versioning is done.

It uses three digits separated by a dot – for example, 1.2.3.

These follow the *major.minor.patch* structure. The major number is incremented when there is a breaking change or a big update to the software. This will likely require you to change some of the code that interfaces with the plugin. The minor number is incremented when new code that is backward compatible is released. This is likely to be performance improvements, major bug fixes, or internal dependency changes. Finally, the patch number is incremented when a bug fix is added that is low risk.

Difficult to diagnose bugs

Some plugins can be quite complicated, and when something doesn't quite work as you would expect, it can be difficult to resolve the problem. Generally, plugin writers are happy to assist if you find an issue, but sometimes, issues can be hard to recreate, or worse, only happen on release versions rather than debug versions, so you only have second-hand information about the problem.

In many ways, the issue isn't that the plugin has a bug, it's that it is hard to diagnose because you didn't write the code. On the flip side, if you did write the code instead, it would probably also contain the same bug and you would have a lot more code to maintain, so you may not have time to look at the resolution promptly.

If the bug becomes a significant problem for you, you have the option to tackle it yourself since the majority of plugin code is open source. In most cases, you can even change the plugin code on your machine to test fixes (effectively creating a local code fork) or solve urgent issues.

Breaking changes

Sometimes, a plugin developer will make a breaking (major version) change because they want to fundamentally change the way the plugin works, or they want to standardize their plugin with the approach of other plugins, or for one of many other reasons.

The plugin developer will create a new version of the plugin with the major version incremented and warn developers of the change. You don't have to take the new version of the plugin, but the developer is unlikely to maintain older versions, so it is preferable to stay on the latest version so that you can receive any bug fixes.

This can sometimes have a large impact on your code, especially if you rely heavily on that plugin. This is a relatively common occurrence for new plugins or for plugins that interact with a new third-party service. One of the biggest pain points I've had recently was with payment provider plugins when the new payment process called 3D Secure with secondary authorization came in. This was a big change that couldn't be abstracted away within the plugin code itself, requiring lots of code changes within our app code.

Similarly, the plugin maintainers may decide that restructuring the way the plugin works will give better long-term maintainability and simplicity. This happened with version 6 of AppRouter (which we saw in the previous chapter), where the identification of routes moved to annotations rather than code generation.

Abandoned plugins

Sometimes, plugin authors and maintainers abandon their plugins, no longer providing updates, resolving reported issues, or updating dependencies. In these situations, the plugin becomes outdated, forcing you to either write the feature yourself or search for an alternative plugin to use in your code. This can have a large impact on the way your code is structured. Generally, this will happen in situations where there are alternative plugin implementations available and one of those alternatives has become very popular and is the de facto plugin of choice. Also, where a plugin was written for integration with a third-party service such as payments or authentication, there may now be an "official" plugin written by the third-party development team that everyone should migrate to.

So, now that you have a feel for what a plugin is and the pros and cons of using them, let's take a look at where you can find them and what they look like.

Where can I find plugins?

The Flutter community has a very easy way to find the plugins that you may need via the `https://pub.dev` site that they maintain. This is where all plugins are registered and the primary way that developers find plugins.

This site not only allows you to search for plugins but also includes useful sections such as the following:

- **Flutter favorites**: Plugins that demonstrate the highest levels of quality.
- **Most popular packages**: The most downloaded plugins.
- **Package of the week**: This is a series of animated videos that introduce some of the plugins available. Flutter has been very successful in the use of short videos to introduce the widget of the week and has rolled out the concept of package of the week.

Now, let's take a look at the individual entries for a plugin at `pub.dev`.

Plugin entry

One of my favorite plugins is the one that introduces a new widget – the `AutoSizeText` widget. Just like its name suggests, this widget will resize the text it contains so that it fits within the bounds of the parent widget.

To find the plugin, simply type `auto size text` in the search bar. Your results will look something like this:

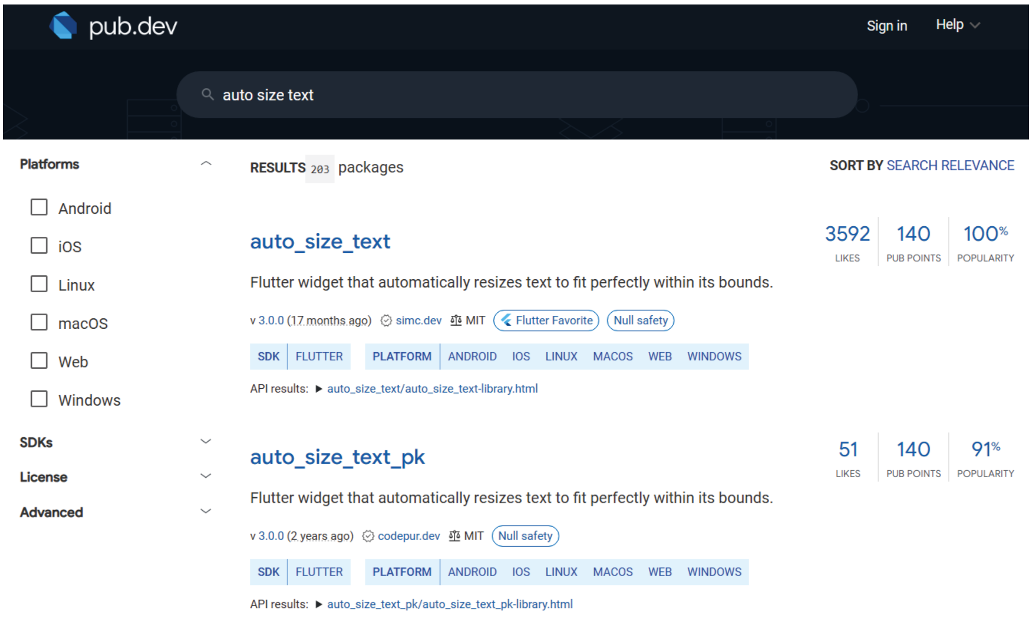


Figure 9.1 – pub.dev search results

The first thing you will notice is that there are lots of plugins that do similar things, so it used to be very tricky to work out which plugin was best maintained and most used. As you can imagine, accidentally using a plugin that is no longer maintained means that bug fixes are not actioned, and upgrading transient dependencies (other plugins that this plugin depends on) does not happen. Additionally, choosing a plugin that nobody else uses means it may not have been tested as thoroughly as the other available plugins.

However, `pub.dev` now shows a series of metrics and other information so that you can make a more informed choice.

Key information to take from this page includes the metrics on the right (which we will look at soon), but also the following:

- **The updated date**: Is the code still being maintained?
- **The list of supported platforms**: For `auto_size_text`, the supported platforms are Android, iOS, Linux, macOS, Web, and Windows.
- **Tags**: When Flutter has a big change, plugins are tagged to show whether they have completed the change. In this example, the move to *null safety* was very important, and both of the results shown have the null safety tag, showing that they have completed the move to null safety.

If we click on **auto_size_text**, we can see further details about the plugin:

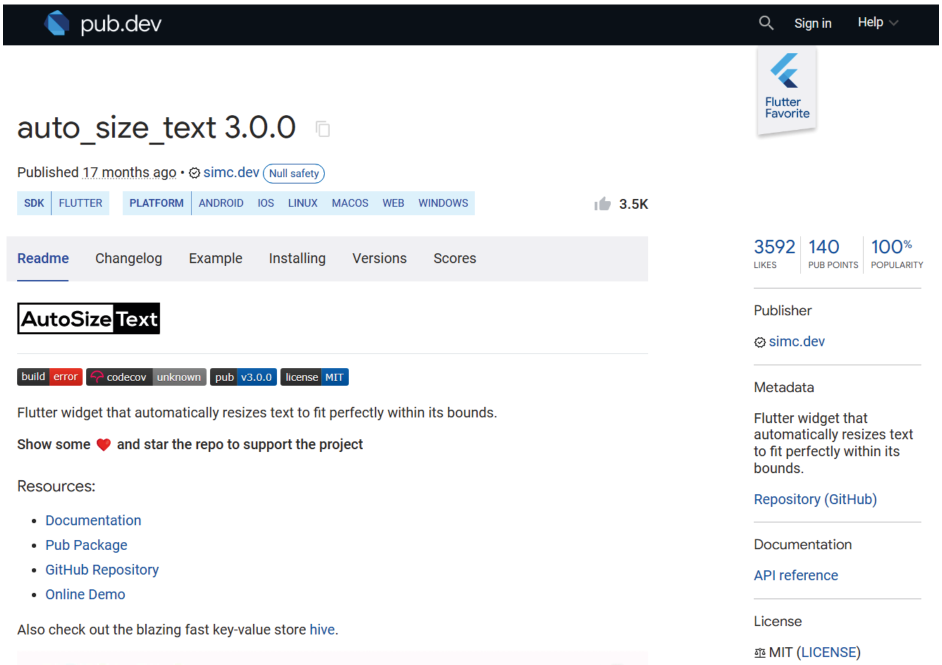


Figure 9.2 – The auto_size_text details page

Much of the details from the search page are replicated, including the metrics:

- **Likes**: As you would expect, if people like the plugin, then they can "like" it
- **Pub points**: The plugin is analyzed and assigned points (out of 140) on code maintainability, documentation, platform support, up-to-date dependencies, and so on
- **Popularity**: A measure of how many apps rely on the plugin

Used together, these are a very powerful way to assess the maturity of the plugin and how likely it is to be maintained in the future.

Other useful information on the page includes the following:

- **Readme**: This is where the information about the plugin is kept, often including installation and project configuration instructions.
- **Changelog**: This is where you can look at why a plugin version has been increased. This is especially useful when you need to upgrade a major version and want to know what breaking changes there were.
- **Example**: Most plugins come with a small example app so that you can see how the plugin is used.
- **Installing**: A high-level guide to how to install this plugin. Generally, you wouldn't need to look closely at this section as all plugins are installed in the same way.
- **Repository (GitHub)**: Most plugins are developed via a GitHub repository and link to it from this page. If you want to see how the plugin works, then this is the place to look.
- **View/report issues**: This is a hugely important link because you can see what issues other people have reported and how the resolution is progressing, and also raise your own issues. Note that most plugin maintainers volunteer to maintain their plugin and therefore have other jobs, so please be understanding if they are unable to respond to any issues immediately.

Due to the huge size of the Flutter community, there are also many video and text tutorials available for plugins across the web, on publications such as Medium and YouTube, that can give additional guidance.

So, now that we've learned how to access key information about a plugin, let's try adding the `auto_size_text` plugin to our Hello World! project.

How do I add a plugin to my project?

Adding a plugin to your project is generally surprisingly easy. However, it is crucially important that you read the **README** fully because, for some plugins, there can be platform-specific configurations that you need to set up before the plugin will run. In some extreme cases (such as `google_mobile_ads`), your app will completely fail to start unless the plugin setup has been completed correctly.

We will use the example of `auto_size_text` as a plugin we wish to add. We saw the README for this plugin, but let's look at the **Installing** section now. The following screenshot shows the instructions for installation:

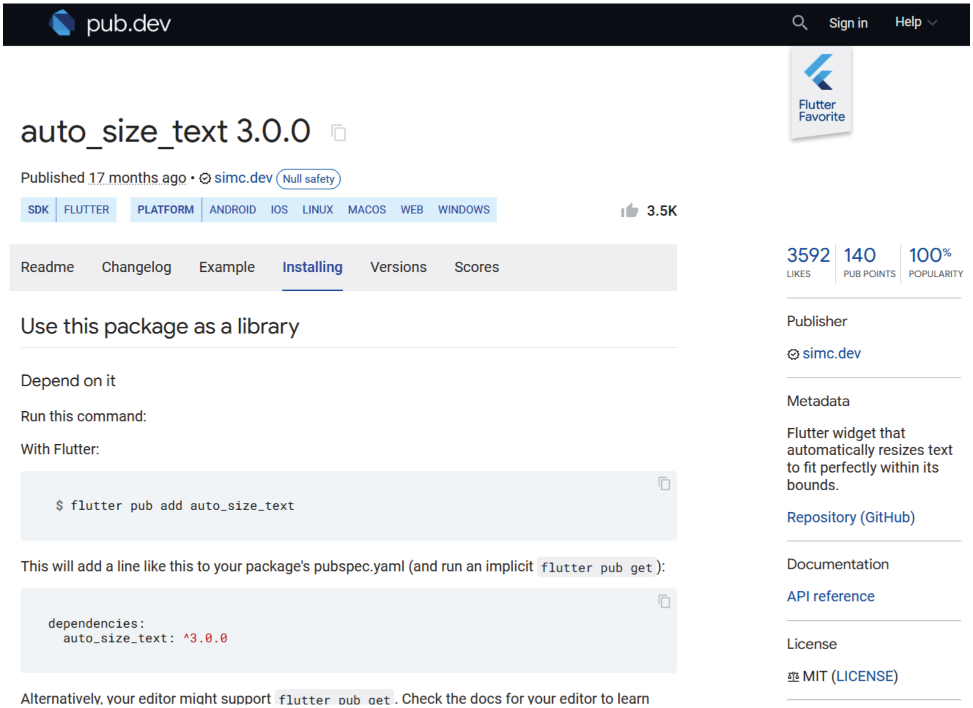


Figure 9.3 – The auto_size_text plugin's installation instructions

There are two ways to add a plugin to your project, but the outcome is the same.

The first option is to run a `flutter` command on the command line to do all the work for you:

```
flutter pub add auto_size_text
```

The other option is to replicate what that command does under the covers. I would suggest that you follow the steps in the next section to begin with so that you understand what is happening.

The pubspec.yaml file

The `pubspec.yaml` file is where dependencies and assets are configured. There is a specific section called **dependencies** that holds information about plugins that your project depends on.

It will look something like this:

```
dependencies:
  flutter:
    sdk: flutter

  # The following adds the Cupertino Icons font to your
    application.
  # Use with the CupertinoIcons class for iOS style icons.
  cupertino_icons: ^1.0.2
```

The indentation is crucial here and is what **YAML** files rely on to understand the contents. Note that `cupertino_icons: ^1.0.1` is indented by two spaces. This denotes that it is under the `dependencies` header and therefore is a dependency of the project.

Under `cupertino_icons`, add another line, indented by two spaces, which says the following:

```
  auto_size_text: ^3.0.0
```

You have now declared that your project depends on the `auto_size_text` plugin. If you are sharing your project with other developers, then they will instantly see the dependency and be able to update the project accordingly.

You have also specified the version of the plugin using the plugin's semantic version. This locks your app to a specific version of the plugin, allowing you to test and release without dependency changes sneaking in. You may have noticed the ^ character before the version number. This specifies that you are happy to receive any patch version updates to the plugin.

For example, if you specify version `3.0.0`, then only version `3.0.0` will be used by you and any other developers that are using this source code. If you specify version `^3.0.0`, then any version of `3.0.x` where `x >= 0` can be used. This means you will automatically receive patch updates (when you download the plugin). There is a risk that you may have a slightly different version of the plugin to your colleagues, but there will only be disparities at the patch level.

So far, the plugin hasn't been downloaded and isn't available for your project. To do this, we will use a very useful command called `flutter pub`, which is used to manage plugins.

flutter pub

Within the `flutter` command, there is a pub command that is specifically used for plugin management. There are several ways you can use it, so let's look at some of the most used ones.

flutter pub get

The `flutter pub get` command will read through all the dependencies in `pubspec.yaml`, retrieve the relevant plugins from `pub.dev`, and download them to a central repository on your computer, ready for your project to access.

We need to use the following command at this point to download the `auto_size_text` plugin that our project depends on:

```
PS C:\Flutter\hello_world> flutter pub get
Running "flutter pub get" in hello_world...        2,142ms
```

Occasionally, `flutter pub get` will fail due to inconsistent dependencies. We will look at how to resolve that in the *Common issues* section later in this chapter.

At this point, the plugin dependency has been declared and downloaded to your computer. You are ready to go, but let's just look at some other useful `flutter pub` commands.

flutter pub outdated

This command will check whether any of your dependencies have newer versions that you may want to upgrade to. Running this command will give you output similar to the following:

```
PS C:\Flutter\hello_world> flutter pub outdated
Showing outdated packages.
[*] indicates versions that are not the latest available.

Package Name  Current   Upgradable  Resolvable  Latest

direct dependencies: all up-to-date.

transitive dev_dependencies:
crypto        *3.0.0    *3.0.0      *3.0.0      3.0.1
vm_service    *6.1.0+1  *6.1.0+1    *6.1.0+1    6.2.0
You are already using the newest resolvable versions listed in the
'Resolvable' column.
Newer versions, listed in 'Latest', may not be mutually compatible.
```

Although this looks quite intimidating, the key part to note is that your direct dependencies are all up to date, so you don't need to do anything further.

If the command shows that there are newer dependencies, then you will first need to understand what the changes are by going to `pub.dev` and reading the changelog. Then, you can update `pubspec.yaml` to specify the new version, and finally run `flutter pub get` to download the latest version to your computer.

flutter pub upgrade

It was mentioned earlier that the version can include the ^ symbol to specify that you are happy to receive patch updates.

These patch updates do not magically appear on your computer; you still need to tell Flutter to retrieve the updates. You can do this with the `flutter pub update` command. It is much like `flutter pub get`, but you permit it to get the latest plugins within the constraints of the versions specified in `pubspec.yaml`.

So, now that you understand a bit more about Flutter plugin management, we can explore how you would use the plugin within your code.

Using a plugin in your code

Now that the plugin code has been downloaded to your computer, and you have specified that your project depends on that plugin, the next step is to import the code into the classes where you need it.

Import statements

If you look at the `main.dart` file, you will see the following `import` statement at the very top:

```
import 'package:flutter/material.dart';
```

Like virtually any other programming language, `import` statements allow you to reference code in other classes, packages, and plugins. In this example, the `material.dart` file is being imported, with all the classes and functions within that file being made available to your class. We will use an `import` statement to access the plugin code, but first, let's create a new file to hold a new stateless widget.

Adding Dart files

In your IDE, create a new file within the `lib` folder named `destination_description_widget.dart` and open it up. It will initially be empty, so let's put some code in there.

You may have a shortcut in your IDE that allows you to generate the stateless widget code. Try typing `stless` and see if the IDE gives you any hints. If it does, set the widget's name to `DestinationDescriptionWidget`. If not, simply copy the following code into the file:

```
class DestinationDescriptionWidget extends StatelessWidget {
  @override
  Widget build(BuildContext context) {
    return Container();
  }
}
```

You may notice that there are errors on the page. This is because you need to add an `import` statement. In isolation, the `StatelessWidget` class name doesn't exist; it isn't within the same Dart file, so the compiler has no idea what it is.

We need to add the same `import` statement that we saw on the `main.dart` file to import all the standard Flutter framework classes. So, at the very top, add the following:

```
import 'package:flutter/material.dart';
```

Ta-da! The errors disappeared. You now have a stateless widget that returns an empty **Container** widget from the `build` method.

Let's add a constructor parameter that takes a `String` named `description`. We will pass the contents of this parameter down to the `AutoSizeText` widget when we add it.

Your widget will look like this:

```
import 'package:flutter/material.dart';

class DestinationDescriptionWidget extends StatelessWidget {
  final String description;

  DestinationDescriptionWidget({required this.
    description});

  @override
  Widget build(BuildContext context) {
    return Container();
  }
}
```

In this example, we used a named parameter, `description`, and a shortcut assignment within the constructor using `this.description`, and specified that it is a required parameter using the `required` keyword.

Using the plugin

Now, let's use the `AutoSizeText` widget in our shiny new widget. Firstly, we need to tell the compiler that we want to access the **AutoSizeText** widget classes, so add the following `import` statement to the top of your file:

```
import 'package:auto_size_text/auto_size_text.dart';
```

Now that the code is available, we can use the widget within our `build` method. Let's return an `AutoSizeText` widget with the `String` value from our `description` parameter, and for a bit of variation let's make the text red, which will look like this:

```
@override
Widget build(BuildContext context) {
  return AutoSizeText(
    description,
    style: TextStyle(color: Colors.red),
  );
}
```

You'll notice that the `AutoSizeText` widget looks just like any other built-in widget because it is just like any of the built-in widgets. The widget takes one required positional constructor parameter (`description`) and one optional named constructor parameter (`style`). It has many other optional named constructor parameters so that you can further control the look of the widget.

Putting it all together

Finally, let's add our new widget to the `DestinationWidget` widget so that it is visible. We need to add the `import` statement for our new file so that, just like how we imported the `AutoSizeText` widget code, the code of `DestinationDescriptionWidget` is available to this class:

```
import 'package:hello_world/destination_description_widget.dart';
```

We can then modify the `DestinationDetails` widget in the main file so that it has `Column` as the body widget rather than `Center`. This will let us show `DestionationDescriptionWidget` and the button to go back together:

```
      body: Column(
        crossAxisAlignment: CrossAxisAlignment.center,
        children: [
          DestinationDescriptionWidget(
            description: "Whitby is a town in the North
            East of England where Dracula first arrived,
              taking the form of a dog.",
          ),
          ElevatedButton(
            child: Text("Back"),
            onPressed: () {
              // To be added
            },
          ),
        ],
      ),
```

If you compare our widget to the **Text** widget within `ElevatedButton` that comes afterward in `Column`, you will see that a `Text` widget has a required positional constructor parameter for the text. This is in contrast to our widget, which has a required named constructor parameter called `description`. If a parameter is fundamental to the widget, then having it as a positional parameter like it is in the `Text` widget makes sense. However, many of the built-in widgets were created before the required named constructor parameters were an available feature in Dart. In general, named parameters are preferable because they help with readability and maintainability, and they also reduce the chance of introducing bugs due to incorrect parameter ordering.

Let's run our app and check that it all works correctly. The app should appear and look like this:

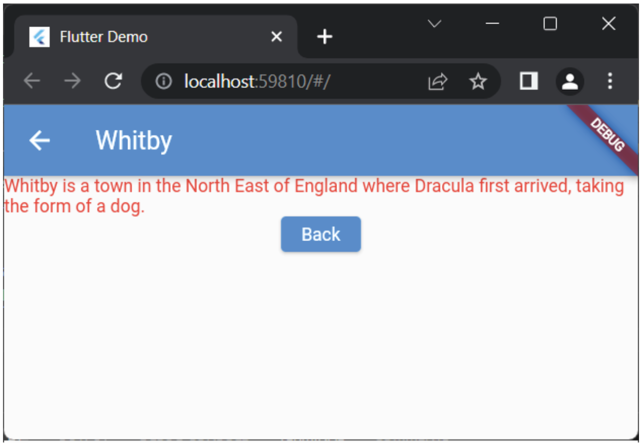


Figure 9.4 – DestinationDescriptionWidget incorporating the AutoSizeText plugin

We can see that the description of the town is now red as we hoped. Congratulations, you just used your first plugin! As an additional task, experiment with how you could pass the destination description to `DestinationDescriptionWidget` from the `MyHomePage` widget like we already do with the destination name.

You should now be starting to see the power of Flutter plugins and how they can boost the awesomeness of your app. In this section, we explored the `pubspec.yaml` file and learned about its purpose, we learned how to add plugins and ensure they are up to date, and we then experimented with adding a plugin to our app code. Using this same process, you can add whichever plugins you want to your app – the plugin world is your oyster.

The `AutoSizeText` plugin has no platform-specific code; it is purely presentational in its purpose. However, some plugins have deeper dependencies on the platform they run on. Let's explore that now.

How do plugins work on iOS and Android?

Many plugins will work with the different underlying platforms to use OS functionality. This dependency changes the way your project is built and run because there is native code within your project that interfaces with the underlying platform. Let's look at how that interfacing works.

MethodChannel

Flutter communication between the client (Flutter) and the host (native) application occurs through platform channels. The `MethodChannel` class is responsible for sending messages (method invocations) to the platform side. On the platform side, `MethodChannel` on Android (API) and `FlutterMethodChannel` on iOS (API) allow you to receive method calls and send a result back. The structure of this relationship is shown in the following diagram:

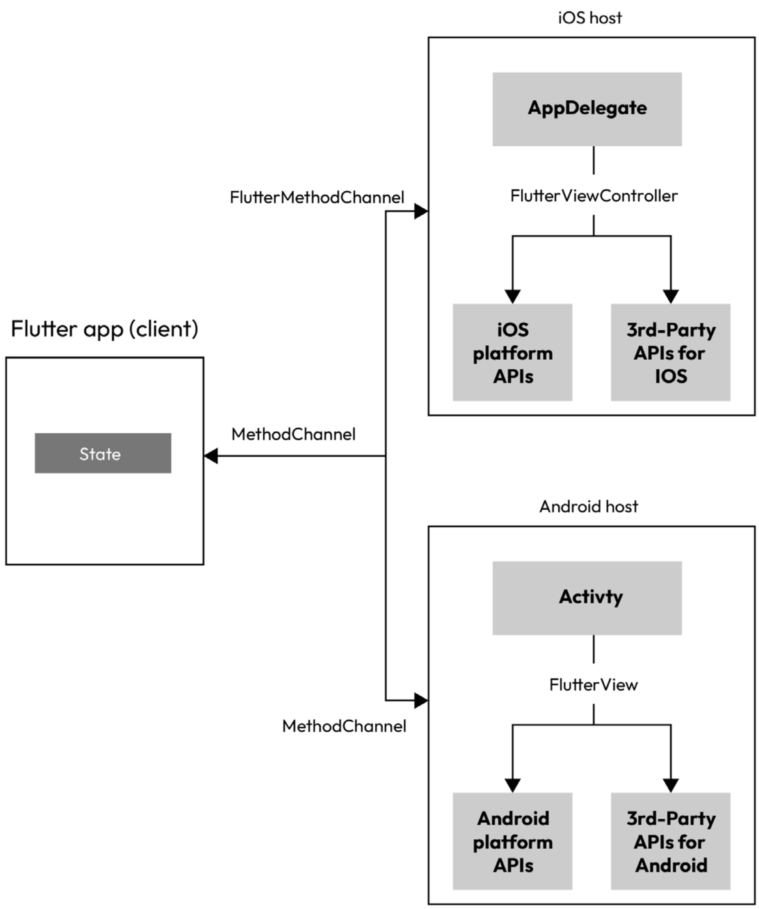


Figure 9.5 – Interface between Flutter and native

The platform channel technique allows you to decouple the UI code from the platform-specific native code. The host listens on the platform channel and receives a message request. It can use platform APIs to enact the request and then send back a response to the client – that is, the Flutter portion of the app.

In this way, the Flutter part of the app is agnostic to the host, allowing you to write code that will work across all platforms.

Having this base understanding of plugins will allow you to better diagnose issues and assess plugin suitability for your app.

Let's explore this a little further by adding a plugin to our project that uses native code. An example of such a plugin is the `device_info_plus` plugin. It retrieves information about your device from the underlying platform, such as the model and device name.

So, add the latest `device_info_plus` plugin to your `pubspec.yaml` file using the following command:

```
flutter pub add device_info_plus
```

If you want further information on the plugin, then head over to the `pub.dev` site and search for `device_info_plus`.

Take a look at the `pubspec.yaml` file – you will see that the `device_info_plus` plugin has been added within the `dependencies` section. Also, `flutter pub get` has automatically been run to pull the Flutter code into your project. However, you do not have the native code available yet.

If you run (or build) the project, Flutter will automatically retrieve the native code dependencies. These are managed by **CocoaPods** in iOS and **Gradle** in Android.

CocoaPods

For iOS native code libraries, Flutter uses the **CocoaPods** dependency manager. Flutter plugins that need iOS native code will specify a dependency on a **CocoaPods** library and the **CocoaPods** dependency manager will download the relevant library at the correct version and include it in your iOS build.

After you have run your project on an iOS emulator or device, you may notice that a file has appeared within the iOS folder within your project files. This is called `PodFile` and manages your **CocoaPods** dependencies.

When you run or build your project, the **CocoaPods** dependency manager is invoked by calling the `pod install` command within the `ios` folder. All the dependencies are retrieved at the correct versions for your project.

This part of the build process can often cause issues when you are changing your dependencies. So, in the *Common issues* section of this chapter, we will explore some solutions.

Sometimes, plugins will ask you to manage your app permissions. For example, your app may need to access the device's camera or a user's contact list. This can be set in the `ios/Runner/Info.plist` file. The device will then confirm with the user that they are happy for the app to have these permissions when they first run the app, and the permissions required by the app will be listed on the app store entry.

Gradle

Building and running Flutter apps on Android uses the **Gradle** build automation tool. You can explore some of the files in the `android` folder, but the ones that you will occasionally need to change to configure plugins will be the following:

- `android/build.gradle`
- `android/app/build.gradle`

These files manage the build process and dependencies that your project needs. Occasionally, some manipulation of versions or build flow is needed for a plugin to work correctly.

Additionally, like iOS, some plugins will require updates to app permissions. This can be done in the `android/app/src/main/AndroidManifest.xml` file.

Now that you have a basic idea of the plugin process, let's see some common issues you may encounter and how to solve them.

Common issues

Sometimes, your Flutter run or build will fail, and often, this is related to plugin issues. In this section, we will look at some of the common issues and give some hints on how to resolve them.

Plugin breaking change

When a plugin changes its major or minor version number, it can mean that there has been a breaking change and that you will need to make some changes to keep the plugin working correctly.

There are generally two reasons for breaking changes:

- A change in the way you use the plugin at a programmatic level. For example, the constructor parameters for a widget have changed, or the order of method calls to the plugin needs to be modified. These are often simply notified via compilation errors and deprecation warnings.

- A required change in the configuration of your project. These can be less obvious and checking the plugin's README on `pub.dev` is often the best way to assess whether you need to change your project configuration.

On the `pub.dev` page, there is a section specifically dedicated to explaining why version changes have happened called **Changelog**:

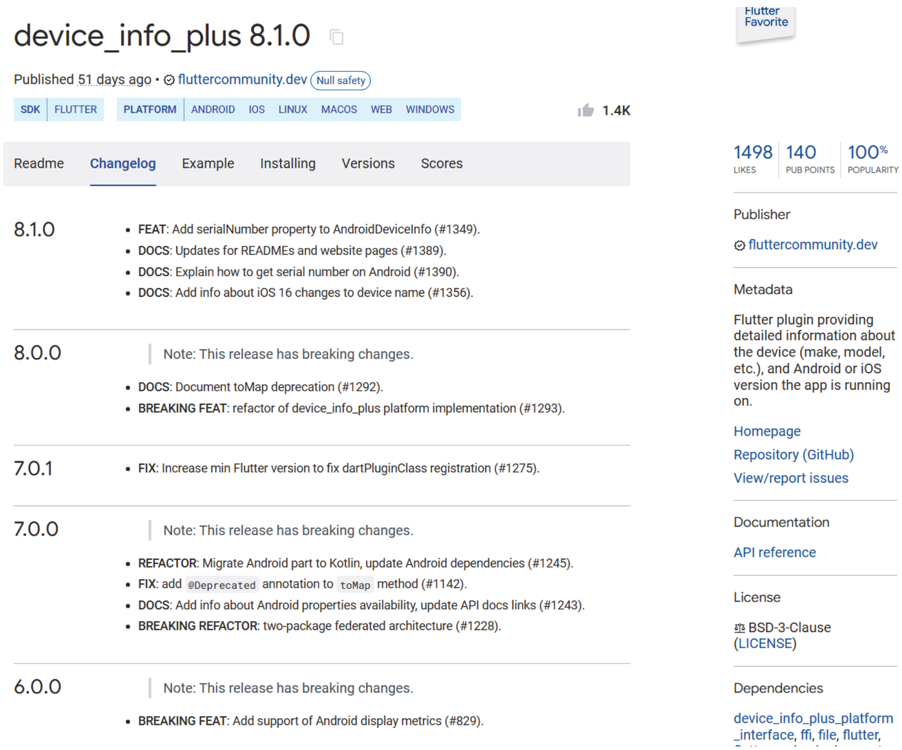


Figure 9.6 – The Changelog section of the device_info plugin

In this section, plugin developers will often call out the different types of updates that have happened during each version increment, including calling out breaking changes so that app developers can easily see what changes they need to make. As you can see from this changelog for `device_info_plus`, there have been several breaking changes during major version updates.

Rarely, plugin developers will make a mistake and release a breaking change without a major version increment. Plugin developers often give their time voluntarily to plugin development, so they may make a mistake due to a lack of time or experience. Often, when this is brought to their attention, they will back out the breaking change on the next minor version and then release a major version with the breaking change. Again, it is worth checking the README and changelog at `pub.dev` if you are having any issues so that you can check no sneaky breaking changes have made their way into an update.

Plugin not working

There will be times when you believe that a plugin is not working in the way you expect it to. There is an easy way to report issues via the **View/report issues** link on the `pub.dev` page for the plugin. Generally, this link will take you to the **Issues** tab of the plugin's GitHub repository, where you can check whether the issue has already been raised and whether a fix is in progress:

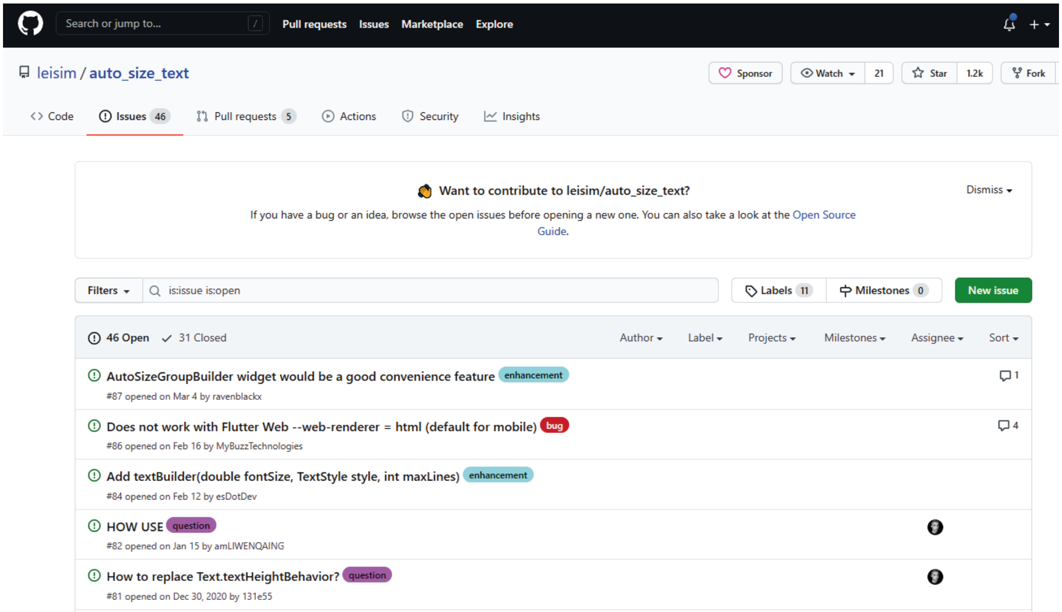


Figure 9.7 – The Issues tab of the GitHub repository

It is worth noting that because plugins are generally community-created, there are often other developers who will attempt fixes for the plugin and share the **pull request** (**PR**) with the plugin developers to help them. When you are confident with Flutter, feel free to try to help the plugin developers if you identify an issue and think you know the solution.

PR not merged

Sometimes, you will notice an issue with a plugin that someone in the community has fixed and they have issued a PR that has not yet been merged into the plugin's master code branch. This can happen often with less popular plugins, where the number of contributors is low, and the main contributors have perhaps moved on from the plugin.

However, even without the PR being merged, you can still use it in your project as a dependency. This can be very useful if you need a fix, and a developer has already fixed it but it hasn't been merged. Sometimes, you can't wait for that merge to happen because the issue is blocking your next app release.

Therefore, to take advantage of the PR before it is merged, add a new section to your `pubspec.yaml` file called `dependency_overrides` and add a link to the `git` entry. Here is an example of the `device_calendar` plugin that was required when Flutter moved to null safety and the `device_calendar` plugin PR for null safety had not yet been merged into the plugin's master branch:

```
dependency_overrides:
  device_calendar:
    git:
      url:
      https://github.com/thomassth/device_calendar_null.git
```

As you can see, you specify the plugin name and then the location of the override repository.

Inconsistent dependencies

As with any dependency management system, there are times when one plugin depends on a specific dependency that clashes with the version another plugin depends on.

Often, the resolution is to make sure that all of your plugins are at the latest version. However, if this does not resolve the problem, then you may need to raise an issue with the plugin developer, and then move back to older plugin versions where the dependencies play more nicely together.

You may also have this issue when you are running a build on iOS. The **CocoaPods** dependencies sometimes clash unexpectedly. You can often resolve this by manually tidying up your **CocoaPods** repository.

If you open a Terminal and navigate to the `ios` folder of your project, there are a few commands you can try to clean up the data. The first is to manually run `pod install` and see what error messages you get:

```
pod install
```

You can try removing the `ios/Pods` directory (all the downloaded dependencies) and the `Podfile.lock` file and then rerun `pod install` on a fresh directory.

Additionally, you will sometimes need to update the **CocoaPods** repository. This lists all of the pods and versions of libraries that are available to **CocoaPods** and can become stale. To do this, run the following command:

```
pod repo update
```

If none of these resolve the problem, then a trip to the **Issues** section on GitHub is probably your answer.

MissingPluginException

There are many other issues, including the infamous `MissingPluginException`, that can often be solved with a little cleanup of the Flutter folders.

Cleaning up is pretty easy. Firstly, run the following command:

```
flutter clean
```

This will clean up dependencies and build folders.

Then, run the following command:

```
flutter pub get
```

This will retrieve all the dependencies again.

There are many other errors that you can get, most of which people have encountered many times. An internet search will often find you the answer, with **StackOverflow** being a great resource for identifying solutions.

Summary

In this chapter, we explored the concept of plugins and what they are. We explored the benefits of using plugins, and also some of the drawbacks that you need to be aware of.

We also investigated how you can find plugins and what to look for when choosing a plugin from the many that may be available. Specifically, we looked at `pub.dev` and all the information available there to make using plugins easy.

Next, we looked at how to add a plugin to a project, how to manage versions within the `pubspec.yaml` file, and how to use the plugin within our code.

Finally, we saw some of the common issues that can be encountered when using plugins and some suggestions for how to resolve them.

In the next chapter, we will look at some of the common plugins that are used in projects. This will give you an idea of the different areas of your project where plugins can be useful and highlight the most popular plugins with Flutter.

Questions

Hopefully, this chapter felt a little lighter and less taxing on your brain than the previous code-heavy chapters. However, in many ways, the knowledge you will take from this chapter will be the most powerful because using plugins and solving any issues related to them will allow you to focus on the true value of your apps or websites. Therefore, take the time to run through these questions and identify any areas worth revisiting:

1. In which file would you add plugin dependencies?
2. What does ^ at the start of the dependency version mean?
3. Name the three useful `flutter pub` commands we explored.
4. Once you have added the plugin as a dependency and downloaded the code, how do you reference the plugin's functionality within your code?
5. For iOS native plugins, can you name the dependency manager they use?
6. Similarly, for Android native plugins, what build system is used?
7. How would you clean up your Flutter builds so that you can rebuild afresh?

Further reading

The obvious suggestion for this chapter is to explore the `pub.dev` site more deeply. Get a feel for how to identify well-supported plugins and see the breadth of plugins available.

Perhaps take a look at the GitHub repositories for a couple of the popular plugins and investigate how bugs are reported and dealt with.

Some active ones that are worth exploring are as follows:

- Firebase, known as FlutterFire: `https://github.com/firebase/flutterfire/issues`
- Device info plus: `https://github.com/fluttercommunity/plus_plugins/issues`
- And one I really love – the percent indicator project: `https://pub.dev/packages/percent_indicator`

Finally, run the `flutter pub outdated` command on your Hello World! app and see if you can understand the output and how to resolve any outdated plugin references.

10
Popular Third-Party Plugins

In the previous chapter, we learned about what a plugin is and how it is used, and we experimented with our first plugin.

Flutter has a rich set of plugins, and sometimes, it can be hard to know where to start from; you don't know what you don't know! This chapter will highlight some of the most popular plugins and give an overview of their uses.

We will start this chapter by looking into the Firebase plugins. Firebase is a set of services available on Google Cloud that you can use to create apps with advanced features. This includes authenticating users, storing data, sending push notifications, and analyzing app usage, among many other features.

We will then look at how to use Google Places for map and location information. Many apps have address lookups or show locations on a map, and the Google Places plugins help here.

Next, we will look at plugins that exercise the capabilities of the device the app is being used on, including the camera and the photo store.

Finally, we will look at plugins that allow you to create more mature and supportable apps, including the app version plugin, which surfaces the app version so that users can report their current version when asking for support.

This chapter will cover the following topics:

- Exploring Firebase plugins
- Understanding Google Maps and Google Places
- Exploring mobile device features
- Plugins to help with your app support

By the end of this chapter, you will have a wide knowledge of the plugins available to you and some good ideas about how you can use those plugins to make your app awesome.

Technical requirements

You will need your development environment set up for this chapter as we will add a plugin to the `Hello World` project. Look back at *Chapter 1*, *What Is Flutter and Why Should I Use It?*, if you need to set up your **integrated development environment** (**IDE**) or refresh your knowledge of the development environment requirements.

You can find the source code for this chapter on GitHub at `https://github.com/PacktPublishing/Flutter-for-Beginners-Third-Edition`.

Exploring Firebase plugins

In this section, we will look at one of the most common sets of plugins that are used by Flutter app developers and explain how they can be used within your apps. Firebase is a Google product that provides multiple technologies for multiple platforms. If you are a mobile or web developer, you may be familiar with this amazing platform.

Among its offered technologies, the important ones are listed here:

- **Realtime Database**: A NoSQL (non-relational) database on the cloud. With this, you can store and access data in real time.
- **Cloud Firestore**: A NoSQL database, with a focus on big and scalable applications, that provides more advanced query support compared to a real-time database.
- **Cloud Functions**: These are coded functions that are triggered by an activity that may come from another Firebase product, including the previous ones, or the user (using the **software development kit** (**SDK**)). We can develop scripts to react to changes in a database, user authentication, API requests, and more.
- **Performance Monitoring**: You can collect and analyze information about your applications from the user's perspective.
- **Authentication**: The authentication plugin facilitates the development of the authentication layer of your application, helping you maintain a good **user experience** (**UX**) while adding security.
- **Firebase Cloud Messaging** (**FCM**): Cloud Messaging enables you to exchange messages between applications and the server, predominantly used as push notifications, available on Android, iOS, and the web.
- **AdMob**: Displays advertisements to monetize applications.
- **Machine Learning Kit** (**ML Kit**): Tools to implant advanced **machine learning** (**ML**) resources in any application.

One of the main benefits of using Firebase is that all the services work tightly together. For example, databases use Firebase Authentication to manage access, Cloud Functions are triggered by Firestore or Realtime Database updates, and callable Cloud Functions use Firebase Authentication to identify users.

Flutter contains a variety of plugins to work with Firebase. We will be using some of them in the next few sections to make some updates to the Hello World application. However, your first step is to register for the Firebase services.

Firebase registration

All of the Firebase services are managed from one dashboard or console, and you will need to set up your Firebase access and then register your app before you can use the services.

Firstly, head over to Firebase to set up your login and project: `https://console.firebase.google.com/`.

> **Immutable Firebase project settings**
>
> It is worth noting that some Firebase settings are immutable, such as the project **Uniform Resource Locator** (**URL**) and Realtime Database hosting location. Therefore, take your time to understand what the settings will be, or assume in your planning that at some point down the line, you may need to create a new project once you know which settings you will need.

Once you have a project created, you will then be able to register apps for the project.

Connecting the Flutter app to Firebase

It is possible to configure multiple applications from multiple platforms to connect with a Firebase project. On the Firebase project page, we have the option to add apps for iOS, Android, and the web.

Let's go ahead and register the Hello World app for both Android and iOS, in preparation for some of the Firebase service tinkering we will be doing later.

Note that full documentation on Firebase configuration is available here: `https://firebase.google.com/docs/flutter/setup?platform=ios`.

In the following sections, we will look at the Android- and iOS-specific configurations.

Android

Here, the important setting is the package name that is checked in the Firebase SDK. The signing certificate is also important for authorization; we will cover that shortly.

You can find the package name of your Android app in the `android/app/build.gradle` file, within the `applicationId` property.

After completing registration, a `google-services.json` file is generated that contains all the information your app will need to be able to access your project on Firebase. This should be added to your application project in the `android/app` directory.

Additional configuration settings will be needed. These are changing all the time, so view the preceding documentation link to understand the additional configuration changes you will need to make.

iOS

For the iOS version, the process looks very similar, starting with the configuration in the Firebase console, where we set the package name, as we did for Android.

After that, we can download the generated `GoogleService-Info.plist` file (the iOS equivalent of the `google-services.json` file) and add it to the project's `ios/Runner` directory. Note that it is very important to do this in **Xcode** by opening the iOS project on it and dragging the file into **Xcode** so that it gets registered for inclusion during builds.

Again, additional configuration settings will be needed. These are changing all the time, so view the preceding documentation link to understand the additional configuration changes you will need to make.

Take the time to register the app for iOS and Android so that you can follow the later examples on how to use Firebase within your app.

Once you have registered your app and added the configuration to connect to your Firebase project, the addition of Firebase services simply follows the Flutter plugin model we saw in the previous chapter.

FlutterFire plugins

Note that, given the community-driven and open nature of Flutter, developers who are not directly involved in the creation of a service such as Firebase may choose to develop plugins that connect to that service. This may be due to a range of reasons, including the "official" developers of a service not yet choosing to engage with Flutter, limitations to the current "official" plugins (this can lead to a fork in the code base, with new developers improving the existing code), or it may be that the design choices made on the "official" plugins are not to everybody's taste. Regardless, if you use the `pub.dev` scores, check the last published date, and view any plugin issues, you should be able to decide which plugin is suitable.

For Firebase, the official developers of the service have fully engaged with Flutter, and the plugins are excellent in terms of quality, design, and documentation. Given that Flutter and Firebase are both Google products, you would expect that the Flutter and Firebase development teams would work closely together to create a good set of plugins. The plugins all support iOS and Android, and in most cases, they also support the web.

Before we add any plugins, we need to add the `firebase_core` plugin, which all the other Firebase plugins depend on. As its name suggests, this plugin does all the core work, such as connecting to your project on Firebase. Here's the code you'll need to add this plugin:

```
dependencies:
  flutter:
    sdk: flutter
  firebase_core: ^2.12.0 #Check for the latest version
```

Once you have this, you are free to add the plugins that you need for your app. However, the key next step is to initialize Firebase within your app.

Firebase initialization

For any of the Firebase plugins to work, you first need to initialize the Firebase instance. This is effectively the work that Firebase Core will do to set up your connection to your Firebase project that you configured on the website.

There is just one step to this process, which aims to trigger the initialization and wait for this to complete.

There are a few ways to achieve this, but probably the easiest way is to modify your `main` method so that it is asynchronous, and then add a wait for Firebase initialization to complete. The code to do this is illustrated in the following snippet:

```
void main() async {
  WidgetsFlutterBinding.ensureInitialized();
  await Firebase.initializeApp();
  runApp(App());
}
```

As you can see, we have marked the `main` method as asynchronous using the `async` keyword and then added a line of code, as follows:

```
await Firebase.initializeApp();
```

The `Firebase.initializeApp()` method returns `Future` (that is, it is asynchronous, and you have to wait for the outcome of the method). We don't care about any value that's returned, but what we do care about is that it has completed processing. Therefore, we have to use the `await` keyword to ensure our code execution waits here until the initialization has been completed. If we didn't include the `await` keyword, then code execution would continue immediately by running our app code. If we reached some Firebase service code before the initialization had been completed, then we could get some pretty nasty errors.

Note that there are more elegant ways to wait for initialization to complete (such as using the `init` method of a stateless widget), but for ease of understanding, this way seems as good as any other. Check out the online documentation for examples of other options.

Now that you have initialized Firebase, let's look at the popular Firebase options available to you.

Authentication

Firebase Authentication allows you to secure access to your application and other Firebase services through a login/register process. To make this as easy as possible for your users, Firebase Authentication enables the use of multiple authentication options, such as email/password, phone authentication, and federated **identity providers** (**IdPs**) such as Google, Apple, Twitter, and Facebook.

The plugin can be found on `pub.dev` at `https://pub.dev/packages/firebase_auth`.

The Flutter plugin that is supported by the Firebase team is `firebase_auth`. You can see the author in `pub.dev` by viewing the publisher's details. In this case, it is the `firebase.google.com` team.

Setup

To set up the plugin, you must add the dependency to `pubspec.yaml`, as follows:

```
dependencies:
  flutter:
    sdk: flutter
  firebase_core: ^2.12.0
  firebase_auth: ^4.6.1
```

Voilà – you have authentication set up on your app. OK – it's not quite that easy, but you have managed to pull in the dependency. So, next, you need to add code to your app to use the dependency correctly. Throughout this chapter, we will show snippets of the key pieces of code to give you an idea of how you would use it. Additionally, we will include code samples in our GitHub source code so that you can see the plugins in action.

To use the plugin, we first need to get an instance of `FirebaseAuth` (you'll notice that this pattern of initially retrieving an instance is used throughout the Firebase plugins), as follows:

```
FirebaseAuth auth = FirebaseAuth.instance;
```

This is because `FirebaseAuth` is a **singleton** (at most, one instance of the class will exist at any time), which you can retrieve through the `instance` field of the class.

Next, we need our code to listen on a stream that will let our code know of any changes in the authentication status of our app user.

What is a stream?

As its name suggests, a stream is simply a stream of data that your app can react to. For example, a stream is used to allow your app to respond to user authentication changes. This stream shares updates to a user's authentication status. To use the stream, you must register to listen to the stream instance and supply a function that will be called when new data is added to the stream.

Throughout third-party plugins, especially Firebase plugins, you will see the regular use of streams so that the plugins can effectively call back into your code to tell you something has changed. They are very similar in concept to the use of a callback method, which is passed to the data source and called on data changes.

The use of streams is very powerful because it allows you to create a very reactive app. Your app will not only react to user inputs, but it will also react to other external changes, such as database updates, authentication changes, third-party service updates (such as the Weather Forecast service), or device sensor updates (such as orientation), among many other things.

The authStateChanges stream

The specific stream we want to listen on is the `authStateChanges` stream, as illustrated in the following code snippet:

```
FirebaseAuth auth = FirebaseAuth.instance;
auth
  .authStateChanges()
  .listen((User user) {
    if (user == null) {
      // User signed-out
    } else {
      // User signed-in
    }
  });
```

In the preceding example, we get the instance, ask for the `authStateChanges` stream, and then specify what should happen when there is an update to the stream by supplying a callback function as an argument to the `listen` function. Whenever new data is added to the stream, our callback function will be called so that we can take action, such as showing the login page (if the user is signed out) or accessing and displaying user-specific data (if the user is signed in).

Sign-in

Finally, we need to give the user the option to sign into our app. To do this, you must either show email/password input fields or add a plugin for a federated IdP, such as Apple, Facebook, or Google, and receive their credentials that way. Ultimately, you will need to pass their credentials to Firebase. Regarding the email/password option, it would look something like this:

```
try {
  UserCredential = await
  auth.signInWithEmailAndPassword(
    email: "tom.bailey@example.com",
    password: "WeLoveFlutter!"
  );
} on FirebaseAuthException catch (e) {
  if (e.code == 'user-not-found') {
    // User not found by Firebase
  } else if (e.code == 'wrong-password') {
    // Incorrect password
  }
}
```

In this example code, we are trying to sign in the user with their supplied credentials. In this case, we have hardcoded them, but you would use a couple of `TextFormField` instances and access their data, as described previously. The `signInWithEmailAndPassword` method will, unsurprisingly, sign the user in with their email and password.

Two obvious possible failures are that the email might be incorrect or the password might be incorrect, so adding a `catch` statement that deals with those failures completes this example.

Firebase Authentication can also deal with email validation, phone number registration, and password reset to give you a fully featured authentication solution. For example, after a user has signed in, you can do something like this:

```
User user = auth.currentUser;
if (!user.emailVerified) {
  await user.sendEmailVerification();
}
```

This will first get the current user's details as a `User` instance, upon which you can get information such as whether their email is verified. If it isn't, then you can send them another verification email so that they can verify their account.

As you can see, in very little code, you can trigger the authentication flows and let the Firebase service take care of all the complications, which is why Firebase is so popular among Flutter developers.

The cloud databases form another key part of the Firebase service. Let's take a look at those next.

Realtime Database

The Firebase Realtime Database started life as the database for a chat client. It is probably the oldest part of Firebase and, although it has some unique features, you often get the feeling that the Firebase team would prefer new developers to use the Firestore (which we look at next) in preference to Realtime Database. This view was highlighted by an initial lack of web support for the plugin and was also evident in the delayed move to null safety, long after the other Firebase plugin updates had been completed.

The plugin can be found on `pub.dev` at `https://pub.dev/packages/firebase_database`.

At its core, Realtime Database is effectively an online store of a massive **JavaScript Object Notation** (**JSON**) data structure, and it is through JSON that you interact with the database, by adding, updating, and deleting data. It is also through JSON paths that you identify the area of the database you want to manipulate. Note that this is very different from a traditional relational database and is part of the NoSQL style of databases. NoSQL databases are now becoming prevalent since massive scalability and cloud-based redundancy have become more important factors than the normality of data.

> **NoSQL versus SQL databases**
>
> There are two main types of databases: **Structured Query Language** (**SQL**)-based relational databases and NoSQL databases. In relational databases, it is important that data is not duplicated, but instead normalized.
>
> A big advantage is that there is no chance of data inconsistency if the data is only stored in one place. The data feels pure, and complex information can be formed by "joining" data from multiple tables of data using the SQL language.
>
> However, this approach puts data purity above data reading speeds. A query that joins many tables can be slow, which is not a suitable situation for an app or website that needs to be responsive.
>
> Another big disadvantage in a cloud world is that ensuring data consistency across multiple servers running the same database instances can cause bottlenecks. This was fine when there was only one server running an instance of the database or multiple servers co-located with fast network connections, but when cloud computing came along, the requirement to copy every update to many other instances of a database over long distances became a huge burden.
>
> NoSQL databases aim to resolve this problem by allowing data duplication and eventual consistency. Retrieving and updating data becomes very quick and scalable. On the flip side, there is a risk that the duplicated data in the database becomes inconsistent, and the structure of the stored data can become more tightly coupled to the design of the software that accesses that data.
>
> This is a huge topic that is worth exploring more before you decide on your database solution.

One of the biggest advantages of Realtime Database is, as its name suggests, the ability to interact with it in real time. This includes setting up listeners on specific paths within the database so that your code is notified if anything changes at that path's location. This can be incredibly useful, giving your app a very dynamic and responsive feel.

It is also very useful to be able to manage very specific parts of the JSON tree through the use of paths. This allows you to manipulate very precise pieces of the JSON structure, reducing exposure to bugs and also reducing costs. The costing model is important to consider, and for Realtime Database, it is based on egress, and – specifically – how much data you retrieve from the database.

A big drawback of Realtime Database is a lack of good transaction support. Although there is a limited ability to transact on a path within the JSON tree, you cannot make changes to two places in the JSON tree within the same transaction, which leads to complex timestamping solutions to guarantee consistency.

Another drawback is the querying support within Realtime Database. You can only query on a single field (yes – one field) when retrieving data. This can be hugely restrictive to your data structure design, pushing you to create, and store data within, some kind of amalgamated field that you can query against.

Also, it is worth noting that Realtime Database has a limitation of 100,000 concurrent users, whereas Firestore has unlimited scalability. You can work around this by having multiple Realtime Database databases set up, but this will add complexity to your setup.

Setup

As with Authentication, the plugin works alongside `firebase_core` as another dependency, as illustrated in the following code snippet:

```
dependencies:
  flutter:
    sdk: flutter
  firebase_core: ^2.12.0
  firebase_database: ^10.2.1
```

Once you have the dependency, you will want to get a reference to the database. You can do this with the following code, which uses an instance singleton, as we saw with authentication:

```
final _reference = FirebaseDatabase.instance.ref();
```

This `_reference` variable is what you will use to access and update the database data.

Data manipulation

As mentioned previously, the data is stored in a massive JSON structure. For example, suppose our data store looked like this:

```
messages: {
  a3bdj2: {
    text: "Hello friends",
    viewedBy: [
      "tim@example.com",
      "jane@example.com"
    ],
    sentAt: 1621835683907,
    sentBy: "tom@example.com"
  },
  4bajfasdf: {…}
}
```

In the preceding JSON structure, we have a top-level map named `messages` that holds mappings from message **identifiers** (**IDs**) to message objects. Within the message object is the text of the message, a list of who has viewed it, when it was sent as a timestamp, and who sent it.

Suppose we wanted to mark that message as deleted. There are many ways to do that, depending on how you want to structure your client and your queries, but one way is to add a deleted flag to the object data. An example of doing that is shown here:

```
_reference.child('messages/a3bdj2/deleted').set(true);
```

In the preceding code snippet, we are asking the database to follow the path to the `messages` map, then to the message with the `a3bdj2` reference, and finally to the deleted entry. At this point, we set the value to `true`. Even though there isn't currently a path that includes `deleted` because the property doesn't exist yet, Realtime Database is clever enough to fill in the gap and complete the `set` operation, giving a structure like this:

```
messages: {
  a3bdj2: {
    text: "Hello friends",
    deleted: true,
    …
  },
  4bajfasdf: {…}
}
```

Similarly, you can make updates (where only parts of the data are changed rather than replaced) or removals in the same way.

Security

Realtime Database has a security model based on the authentication we used earlier. This is a real strength of the database because security becomes easy to set up and understand. When you set up a database, you are given access to a security configuration file that you can manage.

This security configuration file is also based on paths within the JSON. So, for example, suppose I only want the author of a message to be able to mark it as deleted. In that case, I could add a security rule that looks something like this:

```
"messages": {
  "$messageId": {
    "deleted": {
      ".write": "auth.token.email_verified == true &&
       auth.token.email == root.child("messages/" +
         $messageId + "/sentBy").val() "
    }
  }
}
```

In this example, we have defined a path (through nested map entries) of `messages/$messageId/deleted`. The `messageId` property has a `$` (dollar) sign in front to show that this is a dynamic part of the path that will change depending on the `messageId` property.

We then specified that we have a rule for any changes to data by using the `".write"` entry. Within that, we have said changes are only allowed if the user has a verified email address and if their email address matches the email address specified in the database at the path location of `messages/$messageId/sentBy`.

If they match, then the change is allowed. If there is no match (that is, the user updating the `deleted` flag is not the one who wrote the message), then the change is rejected and an exception is thrown in your application.

Security is incredibly important for cloud databases because they are accessible over the internet, so anyone can try to access them. Traditionally, databases for websites would reside alongside the web server that serves the web pages. Therefore, database access would be hugely restricted, and the web server would act as a gatekeeper. With cloud databases, you lose that web server, meaning that access must be restricted in another way. For Firebase, this is restricted using the security configuration file, so a lot of effort should be spent ensuring that the configuration is well designed and complete.

As you can see, it is relatively easy to get up and running with Realtime Database. Now, let's look at Firestore and compare the features and functionalities of the two services.

Firestore

The Firestore database is also a NoSQL database but takes a very different approach to storing and retrieving data. Unlike Realtime Database, Firestore stores data in files, much like the filesystem on your computer. So, instead of a big JSON object, Firestore follows something like a folder and file structure.

However, there are many similarities between the two databases, outlined as follows:

- Both databases store data in JSON. The files in Firestore contain JSON, so the same object data can be stored in either database.
- Both databases use paths to identify changes. In Firestore, the path is split into two parts – the file path, and then the data path within the file.
- Both databases use similar access controls. Firestore access control has more capabilities but can also be more limited in how it uses data from other files to control access.

The costing model is different from Realtime Database, where costs are based on the number of files read, written, and deleted. This model can impact applications that use small pieces of data. A prime example of this is a chat app where not only does a small snippet of data get placed in each file, but also every other member of the chat group will need to read that file. In this situation, Realtime Database is a much better fit.

Additionally, Firestore does not respond as quickly to updates, so for anything real time, such as live multiplayer games, Realtime Database is a better fit. It's not shabby in its update speed, though, but you are talking seconds rather than sub-seconds to get updates.

The plugin can be found on `pub.dev` at `https://pub.dev/packages/cloud_firestore`.

Unlike Realtime Database, Firestore has much better querying capabilities, allowing you to query across many fields. There are a couple of gotchas, though, that are worth being aware of:

- You can only query on fields that are present in all the files, so in the example for Realtime where we added the `deleted` field, in Firestore, you should already have the `deleted` field set with either a `null` or `false` value.
- If you query for more than one field, then Firestore needs to prepare an index for every combination of fields. For example, if you want to search for messages that were a) sent after midnight and b) haven't been read by the user, then you need to create an index for those two fields. If you then decide to update that query to include a third restriction that the message wasn't sent by the user, then you will need to create a new index that references all three fields. Generally, this isn't an issue but it does mean that if your queries are dynamic (for example, the user can decide to some degree which fields to query across), then you need to check that every combination of your queries is indexed.

Finally, Firestore is infinitely scalable – there is no restriction on the number of concurrent users as there is with Realtime Database.

Setup

Again, the plugin works alongside `firebase_core` as another dependency, as illustrated here:

```
dependencies:
  flutter:
    sdk: flutter
  firebase_core: ^2.12.0
  cloud_firestore: ^4.7.1
```

Once you have the dependency, you will want to get a reference to the database, as follows:

```
FirebaseFirestore _firestore = FirebaseFirestore.instance;
```

This `_firestore` variable is what you will use to access and update the database data.

Data manipulation

As mentioned previously, the data is stored in a folder and file structure. Recreating the Realtime Database example, suppose you have a single message in a file, like this:

```
text: "Hello friends",
viewedBy: [
  "tim@example.com",
  "jane@example.com"
],
deleted: null,
sentAt: 1621835683907,
sentBy: "tom@example.com"
```

Again, the message object contains the text of the message, a list of who has viewed it, when it was sent as a timestamp, and who sent it. However, note that we don't have a `messages` map holding references to each message. This is now held in the folder – or collection, as it is named in Firestore. Also, note that we added the `deleted` flag with a `null` value to allow us to query for messages that are not deleted.

To make the same update to set the `deleted` flag, we can do something like this:

```
DocumentReference messageRef = FirebaseFirestore.instance
  .doc('messages/a3bdj2')
  .update({deleted: true});
```

As you can see, the process is very similar to that for Realtime Database; find the file – or document, as it is known in Firestore – using a path, and then update the contents of the file.

Security

The security configuration is slightly different from the Realtime Database setup but is conceptually the same.

To restrict the ability to delete messages to the sender of the message, your configuration would look something like this:

```
match /messages/{document=**} {
  allow update: if request.auth.token.email ==
    resource.data.sentBy && resource.data.sentBy ==
      request.resource.data.sentBy;
}
```

In this example, we specify that this rule applies to all documents that are in the `messages` collection by using the wildcard operator.

Note that because we are controlling access to the whole file rather than one specific field, as we did with Realtime Database, we have to structure the rule slightly differently.

Firstly, we check whether the email address of the request matches the `sentBy` field of the message to ensure updates are only done by the sender of the message.

Secondly, we check that the `sentBy` value in the file update has not been changed. This effectively marks the `sentBy` field as read-only because it can never be changed. You can imagine that there would be a reciprocal rule on `create` that would ensure the `sentBy` value can only be set to the email address of the user writing the data.

Now, let's look at a slightly different area of Firebase around the management of your app in the real world – Analytics and Crashlytics.

Analytics and Crashlytics

Understanding how your app is being used is crucial in deciding where to focus new development to improve your app. Firebase Analytics allows you to see how users move around your app, while Firebase Crashlytics allows you to receive the stack traces of errors when they are thrown within your app.

The plugins can be found on `pub.dev` at `https://pub.dev/packages/firebase_analytics` and `https://pub.dev/packages/firebase_crashlytics`.

Add them using standard dependency entries, as follows:

```
dependencies:
  flutter:
    sdk: flutter
  firebase_core: ^2.12.0
```

```
  firebase_crashlytics: ^3.3.1"
  firebase_analytics: ^10.4.1
```

Ensure that you check the latest versions of the plugins on `pub.dev`.

Crashes

To record a crash using Crashlytics, you would insert code like this:

```
await FirebaseCrashlytics.instance.recordError(
  error,
  stackTrace,
  reason: 'bad times',
  fatal: true // or false for non-fatal crashes
);
```

In the preceding code snippet, we called the `recordError` method on the `Crashlytics` instance to send crash information back to the Firebase server so that it can be reviewed there.

The Crashlytics dashboard is shown in the following screenshot:

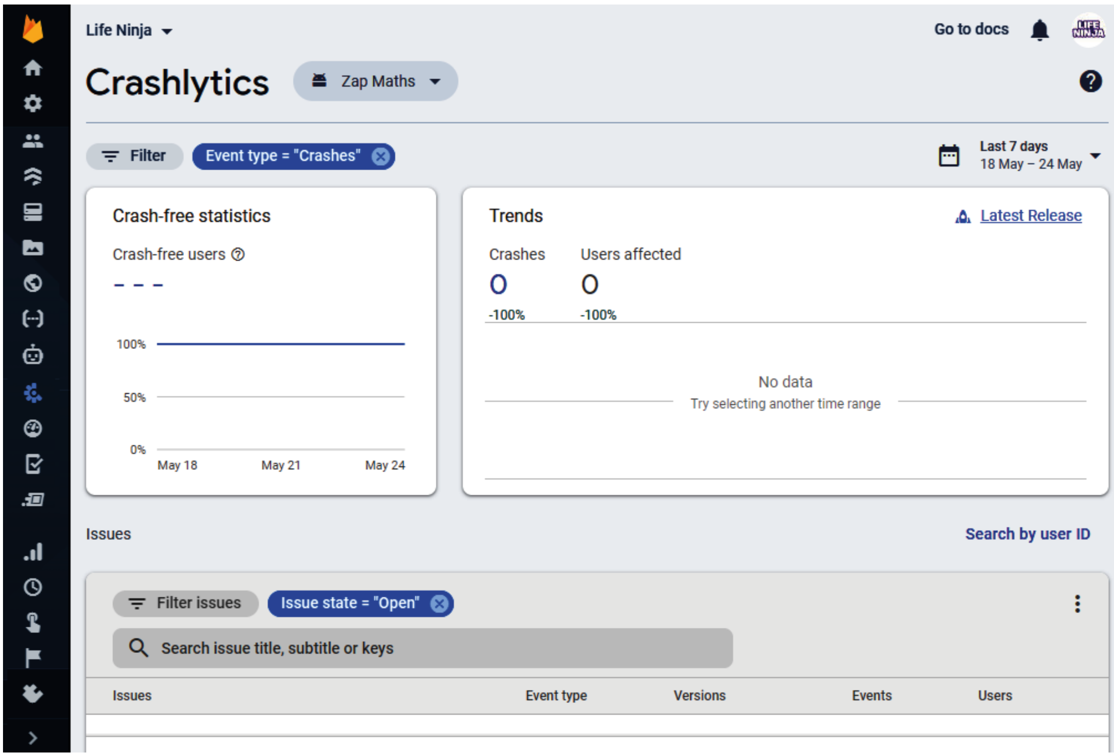


Figure 10.1 – The Crashlytics dashboard

Unfortunately, more extreme crashes can occur that we might not be able to catch within our code. To report these crashes, simply add an entry to the app's `main` method, as follows:

```
FlutterError.onError = FirebaseCrashlytics.instance.
recordFlutterError;
```

This, unfortunately, still does not catch all errors, but there are options to use **Zones** (an advanced Flutter topic) to catch errors. Check out the Crashlytics documentation for further information: `https://firebase.google.com/docs/crashlytics/get-started?platform=flutter`.

Analytics

Much as with reporting crashes, as just discussed, Analytics involves reporting all the other events that happen in the app. For example, to log that someone has opened the app, you would run the following code:

```
Analytics.observer.analytics.logAppOpen();
```

This would then be sent to the Firebase server so that you can analyze how many times your app has been opened.

Additionally, for general navigation around the app, this can be added to the Navigator so that the analytics are automatically uploaded.

In the widget where you create `MaterialApp`, simply define a new observer, as follows:

```
static FirebaseAnalytics analytics = FirebaseAnalytics();
static FirebaseAnalyticsObserver observer =
  FirebaseAnalyticsObserver(analytics: analytics);
```

Then, attach the observer to `MaterialApp` through the `navigatorObservers` constructor parameter, as illustrated in the following code snippet:

```
  @override
  Widget build(BuildContext context) {
    return MaterialApp(
      title: 'Flutter Demo',
      navigatorObservers: <NavigatorObserver>[observer],
      ...
    );
  }
```

Every time the user moves pages through the use of the Navigator, the move will be logged on Google Analytics.

Cloud Storage

As you have seen, the Realtime and Firestore databases are designed around storing JSON data. What if you need to store something else, such as a text document or an image? This is where Cloud Storage comes into play. Files are stored in a folder structure, and some basic security controls are available that are similar to Firestore and Realtime Database access control. Additionally, some metadata can be attached to the file to assist with access control.

The plugin can be found on `pub.dev` at `https://pub.dev/packages/firebase_storage`.

The plugin to add to your dependencies is `firebase_storage`.

AdMob

When you play apps and see adverts on part of the screen, or sometimes have to watch a fullscreen video advert, then you are interacting with something such as Google AdMob. App developers need a way to monetize their apps, and one of the options is to add advertising.

There are several types of adverts available, outlined as follows:

- **Banner**: This is a rectangular advert that appears on part of the screen and refreshes after a set period
- **Interstitial**: A full-page advert that appears at a natural break in the game, perhaps on completion of a level
- **Rewarded**: An advert that a user chooses to view in exchange for benefits within the app such as additional coins, points, or lives

The Flutter AdMob plugin supports all of these types. The plugin to add to your dependencies is `google_mobile_ads`. You will need to register for an `adUnitId` variable from Google AdMob so that you can request adverts. You can get this via the Firebase console.

The plugin can be found on `pub.dev` at `https://pub.dev/packages/google_mobile_ads`.

Showing an advert requires several steps. The first step is requesting an advert from Google in preparation to show it. Here's the code you'll need to do this:

```
RewardedAd.load(
  adUnitId: _adUnitId,
  request: AdRequest(),
  rewardedAdLoadCallback: RewardedAdLoadCallback(
    onAdFailedToLoad: (LoadAdError error) async {
      print("Failed to load ad ${error.message}");
    },
    onAdLoaded: (RewardedAd ad) {
      myRewarded = ad;
```

```
    },
  ),
);
```

In this example, we request a rewarded advert using our `adUnitId` variable and specify a callback when the advert is loaded. We store the loaded advert in a variable named `myRewarded`.

Next, we set up callbacks in preparation for a user interacting with the advert, as follows:

```
myRewarded.fullScreenContentCallback =
  FullScreenContentCallback(
  onAdShowedFullScreenContent: (RewardedAd ad) {
    print('$ad onAdShowedFullScreenContent');
  },
  onAdDismissedFullScreenContent: (RewardedAd ad) async {
    print('$ad onAdDismissedFullScreenContent');
    await ad.dispose();
  },
  onAdFailedToShowFullScreenContent: (RewardedAd ad,
  AdError error) async {
    print('$ad onAdFailedToShowFullScreenContent: $error');
    await ad.dispose();
  },
);
```

In the preceding code snippet, we set up callbacks for when the advert is shown, dismissed, or failed to show. These are important so that your app can take the necessary steps to move on to the UX after the advert flow has been completed.

Finally, we show the advert to the user, as follows:

```
myRewarded.show(
  onUserEarnedReward: (RewardedAd ad, RewardItem
  rewardItem) {
    print('$ad onUserEarnedReward $rewardItem');
  },
);
```

In the preceding code, we request that the rewarded advert is shown, and specify a callback when the user has earned their reward.

It is worth noting that there is risk in issuing any rewards to the user from your app code because someone malicious can write code to emulate your app and issue themselves lots of rewards. Therefore, Google also supports a server-to-server approach for rewards. The Google AdMob server will contact your server and tell you that the user has received a reward, removing the risk of an attack.

Cloud Functions

Throughout this book, we have looked at client technologies, the technology that will run on the client device: phone, tablet, web page, or computer. However, most apps also need to run some code on a server. There are many reasons for this, including the following ones:

- **Trusted integration code**: Code that runs on a server can include security secrets such as integration with payment providers or email servers. These secrets cannot be included in an app because malicious users could decompile your app code and take the secrets, allowing them to impersonate your company.
- **Elevated privileges**: There may be something that needs to run with elevated privileges – for example, accessing parts of your database that you do not want to give general access to.
- **Batch processing**: Perhaps you need to do some intense work to update your database (for example, hourly leaderboards) that would not make sense on a per-user basis.

And there are many other reasons, especially around security and performance, that mean you will need to have a server for many app designs.

If you use Firebase services, then the Firebase Cloud Functions framework makes a lot of sense to use for executing your server code. These functions link to your databases directly, including allowing you to trigger server code when certain database updates happen. They also work directly with Firebase Authentication, allowing you to control who has access to the functions.

Cloud Functions are currently written in JavaScript (or TypeScript), so we will not look at examples here. There appear to be options to use Dart for Cloud Functions, but it is not a supported route to take yet.

You can directly call Cloud Functions from your Flutter app by using the `cloud_functions` plugin.

The plugin can be found on `pub.dev` at `https://pub.dev/packages/cloud_functions`.

Let's look at an example of making a call to a Cloud Function to record the reward from our rewarded advert:

```
final HttpsCallable callable = FirebaseFunctions.instance.
 httpsCallable('storeReward', options: HttpsCallableOptions
   (timeout: Duration(seconds: 30)));
try {
  await callable.call({
    "email": email,
    "reward": 30,
  });
} catch (errorMessage) {
  print(errorMessage);
}
```

In the preceding example, the first line defines the name of the Cloud Function we wish to call, and the timeout we will allow for the call (`30` seconds).

Then, within a `try/catch` block, we attempt the call to the Cloud Function with our parameters – in this case, an email address and the reward value. If the call fails, then we can mitigate the issue in the `catch` block.

ML with Google ML Kit

Google ML Kit helps us add ML features to our app without the need for an ML experience. There's no need to have deep knowledge of neural networks or model optimization to get started.

Google ML Kit provides multiple tools, which are outlined as follows:

- **Text recognition/optical character recognition** (**OCR**): Recognize text on photos. Available as an on-device and cloud-based functionality.
- **Face detection**: Detect faces in an image, identify key facial features, and get the contours of detected faces. Available as an on-device functionality.
- **Barcode scanning**: Scan multiple types of barcodes. Available as an on-device functionality.
- **Image labeling**: Recognize entities in an image. Available as an on-device and cloud-based functionality.
- **Landmark recognition**: Recognize well-known landmarks in an image. Available as a cloud-based functionality.
- **Language identification**: Determine the language of a string of text. Available as an on-device functionality.
- **Custom model inference**: Use a custom TensorFlow Lite (`https://www.tensorflow.org/lite`) model with ML Kit. Available as an on-device functionality.

The on-device tools are **application programming interfaces** (**APIs**) that run offline and process data quickly. Cloud-based APIs, on the other hand, rely on **Google Cloud Platform** (**GCP**) to provide results with high accuracy. To do this on a device, you would use the `google_ml_kit` plugin.

The plugin can be found on `pub.dev` at `https://pub.dev/packages/google_ml_kit`.

Messaging

Firebase can also manage push notifications. You would use a server or the Firebase dashboard to push out push notifications, but you may want to allow your app to take certain actions when it receives a push notification or if it's opened through an action on a notification.

Push notifications can be hard to get right, mainly because a lot of the configuration is on the server side, and if a message fails to be received, it is often a configuration issue, with the failure being hidden in the Firebase or App/Play Store servers. You will see lots of documentation on the web where other developers have had issues and resolved them. The best answer is to be diligent when configuring this section. Ultimately, you will be able to get push notifications to work, but only if you pay attention to the details. Again, the documentation from the Firebase team is excellent.

If you want to use push notifications in your app, then the plugin you will need is `firebase_messaging`.

To be able to send messages to a device, you will need to get and store the device's registration token. This token is then used when sending a message to a device. To get the token, you should use this code:

```
final fcmToken = await FirebaseMessaging.instance.
  getToken();
```

When you receive the token, you should store it somewhere such as the Firebase Firestore so that it's ready for when you need to push a notification to that device.

Let's take a look at an example of an app that responds to a push notification when it receives one:

```
FirebaseMessaging.onMessage.listen((RemoteMessage msg) {
  print('on message $msg');
});
```

In the preceding code example, you register to receive updates from the `onMessage` stream. Whenever an update is placed on the stream, the callback code in the argument is called – in this case, a simple function that prints the message.

The plugin can be found on `pub.dev` at `https://pub.dev/packages/firebase_messaging`.

Hopefully, this section on Firebase has given you a taste of both the power of Firebase and the way it seamlessly integrates with Flutter. We explored the two databases, authentication, analytics, storage, advertising, Cloud Functions, and messaging, and have seen a glimpse of the power of ML Kit.

Let's continue our exploration of plugins by moving to some more popular plugins, starting with everyone's favorite, Google Maps.

Understanding Google Maps and Places

You will have likely used Google Maps for navigation, but the use of Google Places is not so obvious. This is generally used when you enter an address into a text box, and while you are entering it, there are suggestions for the full address.

Simply put, Google Places is where you find an address, and Google Maps is where you display that address. Many plugins support Google Maps and Places, so when choosing, make sure you look at the `pub.dev` scores.

A very good Google Maps plugin is `google_maps_flutter`, which was created by the Flutter development team. In `pub.dev`, you can click on the author – in this case, `flutter.dev` –and view all the plugins that the development team has created. Looking through the `flutter.dev` team's plugins is a great way to get a feel for all the different plugins available.

There are plugins for Google Places, but an alternative is the `google_maps_webservice` plugin, which is a wrapper on the Google Maps web services and allows access to the Places API and many other APIs, such as Directions, Time Zone, and Distance Matrix.

Note that when using Google Maps in any of its forms, you will need to request an API key. Unfortunately, Google Places is a paid-for service, so your API key will link to how much you are charged for the service.

To register for an API key, follow this link: `https://developers.google.com/maps/documentation/places/web-service/get-api-key`.

Once you have an API key, you will need to include that in any calls you make to the APIs so that Google can identify who you are.

Let's look at an example of displaying a map from a place ID:

```
final places = GoogleMapsPlaces(apiKey: "__API_KEY__");
PlacesDetailsResponse placeDetailsResponse = await places.
getDetailsByPlaceId(_placeId);
Widget mapWidget = GoogleMap(
  mapType: MapType.hybrid,
  markers: Set.from([
    Marker(
      position: LatLng(
        _placeDetails.geometry?
        .location.lat ?? 0,
        _placeDetails.geometry?
        .location.lng ?? 0,
      ),
      markerId: MarkerId(_placeDetails.placeId))
  ]),
  initialCameraPosition: CameraPosition(
    zoom: 15,
    target: LatLng(
      placeDetails.geometry?.location.lat ?? 0,
      placeDetails.geometry?.location.lng ?? 0,
    ),
  )
);
```

In this example, we use a `placeId` property to retrieve information about the place. We then use a `GoogleMap` widget to display the place marked on the map, using the geometry details about the place.

Additionally, we can specify information about a map, such as its type – in this case, `hybrid`, meaning it has satellite images and a road overlay – and zoom level. This means we can tailor the map so that it fits the needs of our app.

Next, let's look at some plugins that give us access to the features and functionality of the device where the user is viewing our app.

Exploring mobile device features

There are a lot of features in devices, especially mobile phones or tablets, that your app can use to make the UX better. Normally, you would need to write device-specific code to access these features, but in Flutter, access to the features is generally available within a plugin. In this section, we will take a whistle-stop tour of some of these features, including the camera, web browser, local storage, and video playback, so that you can enhance the usability of the apps you create using the plugins that are already available to you.

Camera and QR codes

A key feature that mobile phones and tablets have is the camera. This can be used for photos, but it can also be used for other functionality, such as **Quick Response** (**QR**) scanning.

A couple of plugins to check out are `camera` (built by the `Flutter.dev` team) and `qr_code_scanner`.

The `qr_code_scanner` plugin contains the following two key things:

- A `QRView` widget that you place in your widget tree, which will show the view from the camera
- A `QRViewController` controller that you attach to the `QRView` widget and supplies a stream of `ScanData` you can listen on to receive details of any QR codes that are identified

Note that if you use the QR code scanner or the camera plugin, you will need to specify the reason why your app will need access to the camera. You can do this by updating `info.plist` and adding the entry, as follows:

```
<key>NSCameraUsageDescription</key>
<string>Why my app needs to use the camera</string>
```

This will pop up for the user when the app tries to access the camera so that the user can make an informed decision on whether they will give the app access to their camera.

Let's see an example of the `QRView` widget and the `QRViewController` controller in action:

```
// Widget fields
final GlobalKey _qrKey = GlobalKey(debugLabel: 'QR');
QRViewController? _qrController;
String? _scanCode;
    // Widget tree in build method
    ...
      QRView(
        key: _qrKey,
        onQRViewCreated: _onQRViewCreated,
      )
    ...
  // Widget method
  void _onQRViewCreated(QRViewController controller) {
    this._qrController = controller;
    controller.scannedDataStream.listen((scanData) {
      setState(() {
        // Record the scan data
        _scanCode = scanData.code;

      });
    });
  }
  // Widget dispose
  @override
  void dispose() {
    _qrController?.dispose();
    super.dispose();
  }
```

There are a few parts to this example, so let's explore each part in turn:

- Two fields are defined – the first to hold a global key so that on a rebuild of the widget – a new `QRView` widget – is not created, while the second is used to hold a reference to the `QRViewController` controller when it is created.
- A `QRView` widget is created in the widget tree. When it is first created, it will call the method specified in the `onQRViewCreated` parameter.
- A method is defined to be called when the `QRView` widget is created. This method, `onQRViewCreated`, receives a controller, which it stores in the `qrController` field, and then sets up a stream listener to receive updates on scanned data. When we receive the results of a QR scan, we store the code in the `_scanCode` field.

- Finally, in the `dispose` section, we clean up the `_qrController` variable so that we are not still scanning for QR codes after we have left this screen.

If you are scanning QR codes, then you probably also need a way to generate them. The `qr_flutter` plugin does an excellent job of this. Simply give it the data you want to embed in the QR code as part of the `QrImage` widget construction and your app will show a QR code, as illustrated in the following code snippet:

```
QrImage(
  data: "Whitby",
  version: QrVersions.auto,
  size: 200.0,
)
```

In this example, the `"Whitby"` data will be embedded in the QR code that's displayed.

Opening web pages

Sometimes, you need to open a web page from within your app. This might be for license agreements, further information, advertising links, and many other possible reasons. Devices will generally have a web browser available, so all you need to do is pop open the web browser at a specified URL.

A plugin that allows you to do this very easily is the `url_launcher` plugin. To pop open the web browser, create a method that looks something like this:

```
void _launchURL(url) async =>
    await canLaunch(url) ? await launch(url) :
    print('Failed to launch $_url');
```

This method will take any URL, check whether the device can launch the URL, and, if it can, launch it.

You would then call this method from any button or `InkWell` within the `onPressed` or `onTap` methods, and the browser will pop open. Note that the app will not be closed, just moved to the background while the user browses the website.

Local storage

Sometimes, you don't want to – or cannot – use online storage such as the Firebase databases. Another option is to use local storage on the device, and many plugins will facilitate that, including the `shared_preferences` plugin.

Generally, these plugins will allow you to save data to the local device storage in a map structure. For example, storing a name to a device using the `shared_preferences` plugin would look something like this:

```
SharedPreferences prefs = awaitSharedPreferences.getInstance();
await prefs.setString('name', name);
```

If you want to store more data on the local device, then you may want to use a database that allows you to structure the data. One very popular plugin is `sqflite`. This plugin uses the SQLite database and has full support for insert, query, update, and delete operations. It also has powerful features such as transaction and batch support. Note that it doesn't currently have support for the web.

Video

Devices generally can play video, and embedding videos in your app can increase engagement. The `video_player` plugin is simple to set up and allows you to play videos that you have included in your `assets` folder or that are stored as files on the network.

If you want to stream videos, especially from YouTube, then you will need to use a dedicated YouTube plugin. The most popular is `youtube_player_flutter`, which allows you to manage which controls are shown to the users, whether the video auto-plays, the colors of the controls, and many other things.

Payment providers

If you want to take payments in your app, then you will need to use one of the payment providers that have support for Flutter. The two most prominent of these are Stripe and Square. Both will need you to set up server processing for payments, so it is a non-trivial setup process.

Both providers support integration with Apple and Google Pay, allowing you to create a very smooth customer payment flow.

In-app purchases

If you are planning to have in-app purchases in your app, then you have a couple of options. You can go for the `in_app_purchase` plugin, which is well suited to one-off purchases where renewal and cancellation of subscriptions are not an issue. If you were to do subscriptions, you would need some server-side coding to cope with the renewal and cancellation flows from Apple and Google.

Alternatively, if you want to have a more complex purchase process, perhaps including subscriptions, and purchases outside of the App or Play Stores (which helps you avoid the 15% or 30% in-app payment charges), then you may want to look at RevenueCat. This service takes care of all the management of your purchases, including subscription renewal and cancellation, and has Stripe integration, giving you the option to sell your purchases on the web. Their plugin is `purchases_flutter` and requires that you have registered for the RevenueCat service in advance.

Opening files

Unlike on the web, where file opening is generally done on computers that have great support for a range of file types, app users are generally on more restricted devices and need a way to open files. The `open_file` plugin can manage this flow for you. Add a button or `InkWell` that a user can tap to open the file, and then in the `onPressed` or `onTap` method, add the following code:

```
OpenFile.open("fileLocation");
```

Check out the `open_file` plugin page on `pub.dev` to see all the different file types that are supported.

Plugins to help with your app support

Finally, I wanted to make a special mention of plugins that help you support your app once it is in the wild. We saw the Crashlytics plugin earlier, and it cannot be said strongly enough that any live app must have a way to report crashes. On Android, there are so many different devices by so many different manufacturers that it is impossible to test across all of them.

Let's look at some other plugins that will make your life easier.

App version

While the majority of individuals have automatic app updates enabled in their device settings, some prefer manual installation or may be using an older app version due to factors such as limited internet connectivity. If someone encounters an issue with your app and provides you with details, it is crucial to have a convenient method of determining the specific app version they are using.

The `package_info_plus` plugin is perfect for this. It will read the information from your `pubspec.yaml` file and make it available for you to surface in a widget. Adding this information to your app's settings page is a must, but it is also worth showing this information before any login screens in case the user is unable to log into the app.

The `PackageInfo` class needs to be initialized first, so you will probably want to create a version string asynchronously and then refresh the display using `setState` to display the version string. The code to do this is illustrated in the following snippet:

```
_initialiseVersionInfo() async {
  PackageInfo info = await PackageInfo.fromPlatform();
  String version = "${_packageInfo.version}-
    ${_packageInfo.buildNumber}";
  setState(() {
    _version = version;
  });
}
```

In this example, we built a version string from the app version and build number.

Device information

Another piece of key information when you're trying to diagnose issues is to know about the device they are on. Often, users will know their device's make and model but not the software version that is running.

The `device_info_plus` plugin can get that information for your app so that you can surface that information in a place that will help you diagnose any issues. If you can get a user to send you a screenshot of a page that holds the app and device information on it, then you will be in a much better place to start diagnosing any issues.

Suppose we want to print the name of the device so that is shown on the screen. As with the app version, we need to get the data asynchronously using code like this:

```
_initialiseDeviceInfo() async {
  DeviceInfoPlugin deviceInfo = DeviceInfoPlugin();
  if (defaultTargetPlatform == TargetPlatform.windows) {
    WindowsDeviceInfo info = await deviceInfo.windowsInfo;
    print("Computer name ${info.computerName}");
  } // and other platforms...
}
```

For each platform, you can choose the information you want to surface.

Summary

In this chapter, we explored a wealth of Flutter plugins and have hopefully given you a taste of all the options available to you as you develop your Flutter apps.

We started by looking at the Firebase service and all the plugins available within that. Firebase is certainly an easy way to get up and running with features that can often take months to develop, and if created bespoke will probably cost more and be less secure. These plugins included all the core capabilities that are needed within an app, including authentication, data and document storage, push notifications, analytics, and server-side functions. Additionally, we looked at how we can monetize our app through the AdMob plugin.

Next, we looked at some plugins that exercise the features of the device they are running on. This is certainly an area that could be explored a lot further via the `pub.dev` site. These plugins allow you to create a great UX, from using media such as videos, cameras, documents, and the web browser, to simplifying the user's interactions with the app via QR code scanners, local storage, payments, and in-app purchases.

Finally, we saw a couple of plugins that will help with supporting your app once you have released it. If there are issues, you can respond quickly using crash reports, often before users even report the problem, using analytics to identify areas of the app that receive higher or lower usage.

In the next chapter, we will move back into coding mode and look at adding some animations to our Hello World application.

Questions

Most of this chapter was an exploration of the plugins that are already available for you to add to your app, so just try answering a few questions as a quick reminder of what you have learned:

1. How do you listen to authentication state changes in Firebase Authentication?
2. What are the two main types of databases and the pros and cons of each approach?
3. Name the two Firebase NoSQL databases and their differences.
4. Think about why, from a security point of view, you may need to use server-side functions within your app solution.
5. What information would be useful to display within your app for support purposes

Further reading

We've lifted the lid on lots of new functionality that you can add to your app, so there are lots of further reading opportunities for this chapter.

Firstly, it is worth gaining a deeper understanding of the difference between SQL and NoSQL databases. There are many articles on the web, one of which is this offering on Upwork: `https://www.upwork.com/resources/nosql-vs-sql`.

We explored a lot of the Firebase plugins and I highly recommend that, unless you already have project requirements in place, your starting point for authentication, data storage, and analytics/monitoring is Firebase. Take some time to explore Firebase further because a bit of time invested now could save you a huge amount of time later in your project: `https://firebase.google.com/`.

An area that is outside the scope of this book but will be crucial to most production-ready apps is the use of server-side functions, known as Cloud Functions for Firebase. It is worth trying to add a Cloud Function to your Hello World! app so that you can get a feel for the use cases of server-side functions. This tutorial is a good place to start: `https://quickcoder.org/firebase-functions/`.

11
Using Widget Manipulations and Animations

The built-in widgets and those available via plugins help you create a great-looking app, but Flutter allows you to manipulate these widgets with layout transformations, such as opacity, rotations, and decorations, allowing you to further improve the **user experience** (**UX**) of your app. In this chapter, you will learn how to add these transformations to widgets.

Taking this widget manipulation a step further, Flutter has great support for animations that can be combined and extended to bring the **user interface** (**UI**) to life. You will learn about animations, including the use of `Tween` animations to manage an animation timeline and curve and using `AnimatedBuilder` to add and combine beautiful animations.

Finally, we will look at some widgets that have animation built directly into them, allowing you to skip the added complication of animation setup and management. They don't fit every situation, but when just a touch of animation is required, they can be perfect.

The following topics will be covered in this chapter:

- Transforming widgets with the `Transform` class
- Introducing animations
- Using animations
- Using `AnimatedBuilder`
- Implicitly animated widgets

Technical requirements

You will need your development environment again for this chapter as we will explore animations for the `Hello World` project. Look back at *Chapter 1*, *What is Flutter and Why Should I Use It?*, if you need to set up your **integrated development environment** (**IDE**) or refresh your knowledge of the development environment requirements.

You can find the source code for this chapter on GitHub at `https://github.com/PacktPublishing/Flutter-for-Beginners-Third-Edition`.

Transforming widgets with the Transform class

We have looked at lots of widgets throughout the previous chapters, but sometimes, we may need to change a widget's appearance to improve the UX. In response to user input or to make cool effects in the layout, we may need to move the widget around the screen, change its size, or even distort it a little bit.

If you've ever tried to achieve this in native programming languages, you may have found it difficult. Flutter, as mentioned previously, is highly focused on UI design and aims to make the developer's life easier by simplifying what could easily have been a complicated area.

In this section, we will first look at the `Transform` widget because it is an incredibly useful widget when you look at widget manipulation. We will then delve deeper into the widget to see the kinds of manipulations it allows us to do.

The Transform widget

The `Transform` widget is one of the best examples of the Flutter framework's power and consistency. It's a single-purpose widget that simply applies a graphic transformation to its child, and nothing more. Having widgets focused on one single purpose is fundamental to a better layout structure, and Flutter does this very well.

The `Transform` widget, as its name suggests, does a single task – it transforms its underlying child. Although its task is very complex, it hides most of this complexity from the developer. Let's have a look at one of its constructors:

```
const Transform({
  Key? key,
  required Matrix4 transform,
  Offset? origin,
  AlignmentGeometry? alignment,
  bool transformHitTests = true,
  FilterQuality? filterQuality,
  Widget? child
})
```

As you can see, besides the typical `key` property, this widget does not need many arguments to do its job. Let's see these arguments:

- `transform`: This is the only required property and is used to describe the transformation that will be applied to the `child` widget. The type is a `Matrix4` instance, a **four-dimensional** (**4D**) matrix that describes the transformation mathematically. We will look at this in more detail in the next section, *Understanding the Matrix4 class*.
- `origin`: This is the origin of the coordinate system at which to apply the transform matrix. The `origin` property is specified by the `Offset` type, representing, in this case, a point (`x`,`y`) in the Cartesian system that is relative to the top-left corner of the `render` widget.
- `alignment`: As with `origin`, it can be used to manipulate the position of the applied `transform` matrix. We can use this to specify `origin` more flexibly since `origin` requires us to use real positional values. Nothing prevents you from using both `origin` and `alignment` at the same time.
- `transformHitTests`: This specifies whether hit tests (that is, taps) are evaluated in the transformed version of the widget.
- `filterQuality`: The `FilterQuality` enumeration is used to specify the visual quality of the child widget as it is reproduced in the transformed state. Leaving it `null` will leave the child widget in its original visual state.
- `child`: This is the child widget to which the transformation will be applied.

The `Matrix4` transform is critical to the `Transform` class, so let's look at that in more detail.

Understanding the Matrix4 class

In Flutter, transformations are represented by a 4D matrix. Although it sounds very intimidating, a 4D matrix is simply a matrix that has four rows and four columns, as shown here:

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Figure 11.1 – 4D identity matrix

The value of the matrix shown is the **identity** matrix. This is a special value because it effectively says to make no changes in the transformation. As the values in the matrix are changed, then the widget is transformed in different ways.

Often, we don't need to know the specific values of the matrix to make a transformation. The `Matrix4` class contains constructors and methods that help with manipulating a matrix without the need to understand geometric transformations. Some of them are listed here:

- **Identity**: The Matrix 4 `identity()` constructor will create an identity matrix, just like the one shown in *Figure 11.1*.
- **Rotation**: To construct a rotated matrix, you can use the `rotationX()`, `rotationY()`, and `rotationZ()` constructors, or you can modify an existing matrix using the `rotateX()`, `rotateY()`, and `rotateZ()` methods. These will produce a matrix that has been rotated through a specific axis.
- **Scale**: The `scale()` method is used to apply a scale to the matrix using double values of the corresponding axes (`x`, `y`, and `z`) or through vector representations with the `Vector3` and `Vector4` classes.
- **Translation**: We can translate the matrix using the `translation()` constructor or the `translate()` method with specific `x`, `y`, or `z` values and `Vector3` and `Vector4` instances. This is used to move a widget concerning a parent widget.

Let's see how we can use the `Transform` and `Matrix4` classes to enact different types of transformations.

Exploring the types of transformations

The `Transform` class provides facilities to the developer through its factory constructors. There are many of them for each of the possible transformations, making it extremely easy to apply a transformation to a widget without any deeper knowledge of geometric calculations. They are listed here:

- `Transform.rotate()`: Constructs a `Transform` widget that rotates its child around its center
- `Transform.scale()`: Constructs a `Transform` widget that scales its child uniformly
- `Transform.translate()`: Constructs a `Transform` widget that translates its child by an `x`,`y` offset

Let's look at each of the transformation types in more detail.

Rotate transformation

The `rotate` transformation appears in situations where we want to simply make our child widget rotate. By using the `Transform.rotate()` constructor, we can get a rotated widget. It does not differ too much from the default `Transform` constructor. The differences are listed here:

- **Absence of the `transform` property**: We are using the `rotate()` variant because we want to apply a rotation, so we do not need to specify the whole matrix for this. We simply use the `angle` property instead.

- **Angle**: This specifies the desired rotation in clockwise radians.
- **Origin**: By default, the rotation is applied relative to the center of the child. However, we can use the `origin` property to manipulate the origin of the rotation, as if we were translating the center of the widget by the `origin` offset, causing the rotation to be relative to another point if we want to.

When we are working with rotations, we are likely to need to access the π (pi) constant constant. To do this, we need to add an import from the Dart Math package:

```
import 'dart:math';
```

Often, to give clarity on where your constants or library functions are imported from, you can specify a name for the import:

```
import 'dart:math' as math;
```

We can then access the π constant by referring to `math.pi` in our code, as shown here:

```
Transform.rotate(
  angle: -45 * (math.pi / 180.0),
  child: ElevatedButton(
    child: Text("Rotated button"),
    onPressed: () {},
  ),
);
```

In this example, we have specified `angle` in radians (315° clockwise is the same as -45° anti-clockwise), and the `child` widget that will be rotated – in this case, an `ElevatedButton` widget.

The output, depending on the other widgets surrounding the rotated button, will look something like this:

Figure 11.2 – Rotated button example

The same result can be achieved using the `Transform` widget's default constructor and a `Matrix4` transformation constructor instead, as illustrated in the following code snippet:

```
Transform(
  transform: Matrix4.rotationZ(-45 * (pi / 180.0)),
  alignment: Alignment.center,
  child: ElevatedButton (
    child: Text("Rotated button"),
    onPressed: () {},
  ),
);
```

The arguments that we need to provide to get the same result are a `transform` property with the rotation through the `z` axis and an `alignment` property of the transformation specifying the center of the `child` widget.

Scale transformation

The scale transformation appears in situations where we want to simply cause our widget to change its size, either by increasing or decreasing its scale. Just as with the `rotate()` factory constructor, this variant does not differ too much from the default one. Here are some further details regarding this:

- **Absence of the `transform` property**: Here, again, we use the `scale` property instead of the whole transformation matrix.
- **Scale**: This is what we use to specify the desired scale in double format, with `1.0` being the widget's original size. It represents the scalar to be applied to each `x` and `y` axis.
- **Alignment**: By default, the scale is applied relative to the center of the child. Here, we can use the `alignment` property to change the origin of the scale. Again, we can combine the `alignment` and `origin` properties to get the desired result.

For example, to scale up a widget, we can run the following code:

```
Transform.scale(
  scale: 2.0,
  child: ElevatedButton(
  child: Text("Scaled button"),
    onPressed: () {},
  ),
);
```

Here, we have specified a `scale` property of `2.0`, which doubles the size of the `child` widget, and again specified that the `child` widget is `ElevatedButton`. You could just set the size of `ElevatedButton` to avoid having a transformation.

The output, depending on the other widgets surrounding the scaled button, will look something like this:

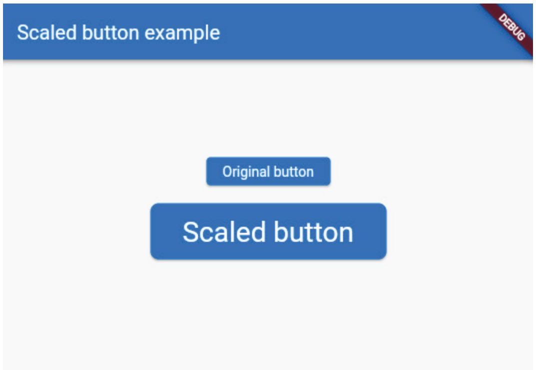


Figure 11.3 – Scaled button example

To get the same result using the default `Transform` constructor, we can use the following code:

```
Transform(
  transform: Matrix4.identity()..scale(2.0, 2.0),
  alignment: Alignment.center,
  child: ElevatedButton(
    child: Text("Scaled button"),
    onPressed: () {},
  ),
);
```

In a very similar way to the rotation, we must specify both the origin of the transformation with the `alignment` property and the `Matrix4` instance describing the `scale` transformation.

The cascade operator

You probably spotted that in the previous example, we used two dots, `..`, to access the `scale` method of the matrix. We've seen the single dot operator being used often to access a method or field on a class, so what does the double dot, known as the **cascade** operator, do for us?

The cascade operator allows you to create an object to return while also running a set of operations on that same object, removing the need to create a temporary variable.

In the preceding example, we created the identity matrix that we wanted to pass as the argument to the `transform` parameter. However, we also wanted to make an amendment to the matrix using the `scale` operator. Therefore, we used the cascade operator to manipulate the object before we returned it. If we had used the single dot operator, then the code would have passed the output from the `scale` method to the `transform` parameter, but the `scale` method has a return type of `void`, which doesn't match the expected type of the `transform` parameter.

Translate transformation

The translate transformation is likely to appear in animations, as described later in this chapter in the *Using animations* section.

Here, we have even fewer properties compared to previous transformations. The differences are listed as follows:

- **Absence of the `transform` and `alignment` properties**: The transformation will be applied by the `offset` value, so we do not need the transform matrix.
- **Offset**: This time, `offset` simply specifies the translation to be applied on the `child` widget; this is different from the previous transformations, where it affects the origin point of the applied transformation.

By using the `Transform.translate()` constructor, we can move the widget around the screen by adding a `Transform` widget as a parent of the widget we want to move around, as illustrated in the following code snippet:

```
Transform.translate(
  offset: Offset(30, 30),
  child: ElevatedButton(
    child: Text("translated button"),
    onPressed: () {},
  ),
);
```

The output, depending on the other widgets surrounding the translated button, will look something like this:

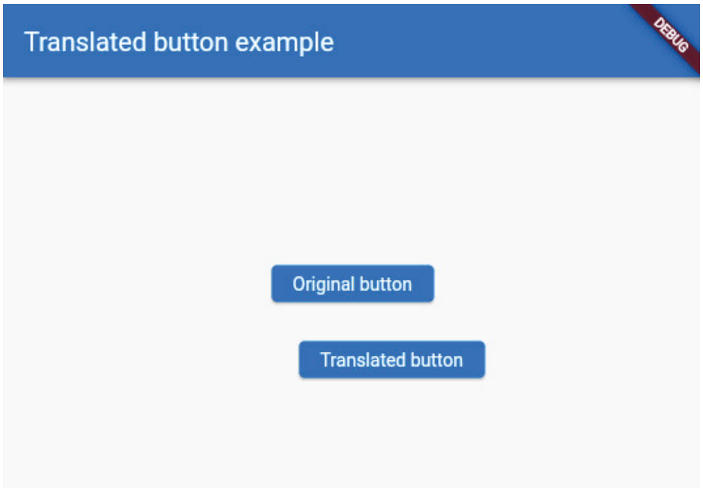


Figure 11.4 – Translated button example

The default constructor can also be used with `Matrix4` specifying the translation, as follows:

```
Transform(
  transform: Matrix4.translationValues(30, 30, 0),
  child: ElevatedButton(
    child: Text("Translated button"),
    onPressed: () {},
  ),
);
```

We only need to specify the `transform` property with the `Matrix4` instance describing the translation.

Composed transformations

We can – and most probably will – combine a number of the previously seen transformations to achieve unique effects, such as rotating at the same time as we move and scale a widget.

Composing transformations can be done in two ways, as follows:

- Using the default `Transform` widget constructor and generating our desired transformation using the `Matrix4` provided methods to compose the transformations
- Using multiple `Transform` widgets in a nested way with the `rotate()`, `scale()`, and `translate()` factory constructors, achieving the same effect

For clarity, let's look at how we would nest multiple `Transform` widgets:

```
Transform.translate(
  offset: Offset(70, 200),
  child: Transform.rotate(
    angle: -45 * (math.pi / 180.0),
    child: Transform.scale(
      scale: 2.0,
      child: ElevatedButton(
        child: Text("multiple transformations"),
        onPressed: () {},
      ),
    ),
  ),
);
```

As you can see, we added a `Transform` widget as a child to another `Transform` widget, composing the transformation. Although simpler to read, this method has a drawback: we add more widgets than needed to the widget tree.

When we add multiple transformations to a widget at the same time, we have to pay attention to the order of transformations. Experiment by yourself – exchanging the `Transform` widgets' positions will cause different results.

The output from this example, depending on the other widgets surrounding the transformed button, will look something like this:

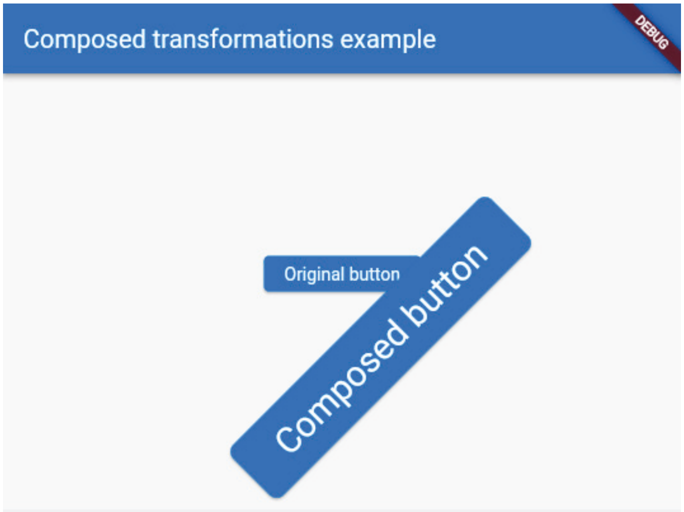


Figure 11.5 – Composed transformations example

As an alternative, we can use the default `Transform` constructor with the composed transformation with the `Matrix4` object instead, as follows:

```
Transform(
  alignment: Alignment.center,
  transform: Matrix4.translationValues(70, 200, 0)
    ..rotateZ(-45 * (math.pi / 180.0))
    ..scale(2.0, 2.0),
  child: ElevatedButton(
    child: Text("multiple transformations"),
    onPressed: () {},
  ),
);
```

Just as before, we specify the transformation's `alignment` as the center of the `child` widget and then the `Matrix4` instance to describe it. As you can see, it is very similar to the multiple `Transform` widgets version but without the need to nest widgets.

Now that we have explored how to manipulate widgets statically, let's look at making an animation to allow a widget to move from one state to another smoothly.

Introducing animations

In Flutter, animations are widely supported, and the framework provides multiple ways of animating widgets. Additionally, there are built-in ready-to-use animations that we only need to plug into widgets to make them animate. Though Flutter abstracts many of the complexities that animations involve, there are some important concepts we need to understand before diving into the subject of animations.

The Animation<T> class

In Flutter, the `Animation` class consists of a status and a value of the `T` type, where `T` is defined on the instantiation of the `Animation` class. The animation's status corresponds to the animation's state (that is, if it's running or completed); its value changes while the animation runs, and it is this value that is intended to drive any widget changes during the animation's execution.

This class also exposes callbacks so that other classes can know the animation's current status and value.

An `Animation<T>` class instance is only responsible for holding and exposing the status and value properties. It does not know anything about visual feedback, what is drawn on the screen, or how to draw it (that is, the `build()` functions). The values produced by the `Animation` class at timely intervals will be used by other widgets to manage their animations.

One of the most common kinds of animation you will see is the `Animation<double>` type representation since a double value can easily be used to track the progression of an animation and manipulate any kind of value in a sense of proportional space.

The `Animation` class generates a sequence of values between determined minimum and maximum values. This process is also known as interpolation and does not just give a linear value progression – the progression can be defined as linear, a step function, or a curve. Flutter provides multiple functions and facilities for operating animations. These are listed here:

- `AnimationController`: Despite what its name suggests, it is not used to control the `animation` objects. Instead, it inherits from `Animation<T>` and allows control over the generation of animation values.
- `CurvedAnimation`: This is an animation that applies a **curve** to another animation. There is a whole range of built-in curves available that will manipulate the animation values that have been generated to fit different needs.
- `Tween`: This helps create a linear interpolation between a beginning and ending value.

The `Animation` class exposes ways of accessing its state and value during a running cycle. Through status listeners, we can know when an animation begins, ends, or goes in the reverse direction. By using its `addStatusListener()` method, we can, for example, manipulate our widgets in response to animation start or end events. In the same way, we can add value listeners with the `addListener()` method so that we are notified every time the animation value changes so that we can rebuild our widgets using the `setState` method.

AnimationController

`AnimationController` is one of the most used Flutter animation classes. It is derived from the `Animation<double>` class and adds some fundamental methods for manipulating animations. As mentioned previously, the `Animation` class is the basis of animation in Flutter, but it does not have any animation control-related methods. `AnimationController` adds various controls to the animation concept, such as the following:

- **Play and stop controls**: `AnimationController` adds the ability to play an animation forward or backward or to stop it
- **Duration**: Real animations have a finite time to play – that is, they play for a while and finish or repeat
- **Allows you to set the animation's current value**: This causes the animation to stop and notifies the status and value listeners
- **Allows you to define the upper and lower bound of the animation**: This is done so that we can know the range of expected values before and after playing the animation

Let's check out the `AnimationController` constructor and analyze its main properties:

```
AnimationController({
  Double? value,
  Duration? duration,
  Duration? reverseDuration,
  String? debugLabel,
  double lowerBound: 0.0,
  double upperBound: 1.0,
  AnimationBehavior:
    animationBehavior = AnimationBehavior.normal,
  required TickerProvider vsync
})
```

As you can see, some properties are self-explanatory, but let's review them:

- `value`: This is the initial value of the animation, and it defaults to `lowerBound` if not specified.
- `Duration`: This is the duration of the animation.
- `reverseDuration`: This is the duration of the animation when running in reverse.
- `debugLabel`: This is a string to help during debugging. It identifies the controller in the debug output.
- `lowerBound`: This cannot be `null`; it is the smallest value of the animation in which it is deemed to be dismissed – typically, the start value when running. This defaults to 0.0.

- `upperBound`: This also cannot be `null`; it is the largest value of the animation at which it is deemed to be complete – typically, the end value when running. This defaults to 1.0.
- `animationBehavior`: This configures how `AnimationController` behaves when animations are disabled, normally for accessibility reasons. If it's `AnimationBehavior.normal`, the animation duration will be reduced, and if it's `AnimationBehavior.preserve`, `AnimationController` will preserve its behavior.
- `vsync`: This is a `TickerProvider` instance that the controller will use to obtain a signal whenever a frame triggers.

You may be wondering what `TickerProvider` is, so let's take a deeper look at this concept.

TickerProvider and Ticker

The `TickerProvider` interface describes classes that are capable of issuing `Ticker` objects. They issue a `Ticker` object whenever a new frame is triggered so that other objects can react to the new frame and, in our example, change the animation value so that an animation can progress. Frame rebuild is triggered on the interval of the device's refresh rate, so Tickers refresh in sync with the screen refresh rate, which is commonly 60 frames per second. Animations that utilize this have the most optimal user experience and animations that run slower than the refresh rate may cause the screen to not be updated on some frames.

The `Ticker` objects are used indirectly via any `AnimationController` instances. Therefore, stateful widgets that include animation (and it will be stateful because it will hold the animation state) need to become TickerProviders. To do this, the `State` class can be extended with `TickerProviderStateMixin` or `SingleTickerProviderStateMixin`. These mixins implement `TickerProvider` and can be shared with `AnimationController` objects. If you are going to have multiple animations, then you will need `TickerProviderStateMixin`, but if you are only going to have one animation, then `SingleTickerProviderStateMixin` is the right choice to improve efficiency.

If the ticker thing feels a little confusing, that's because it is a completely new concept for you to understand. However, we will look at some examples in the *Using animations* section to help explain the idea after we have reviewed some more concepts, starting with `CurvedAnimation`.

CurvedAnimation

The `CurvedAnimation` class is used to define the progression of an `Animation` class and the values it produces as a non-linear curve. We can use this to modify an existing animation by changing its interpolation method.

You would use curves in your animation values to do things such as make a rotation change speed, a translation bounce into view, or a scale, initially growing quickly but slowing down at the end of the growth.

We may want to use a different curve when playing an animation in reverse mode by using the `curve` and `reverseCurve` properties, respectively.

The `Curves` class defines many curves that are ready to use in our animation rather than the `Curves.linear` one. Let's look at some of the options that are listed on the Flutter documentation web pages:

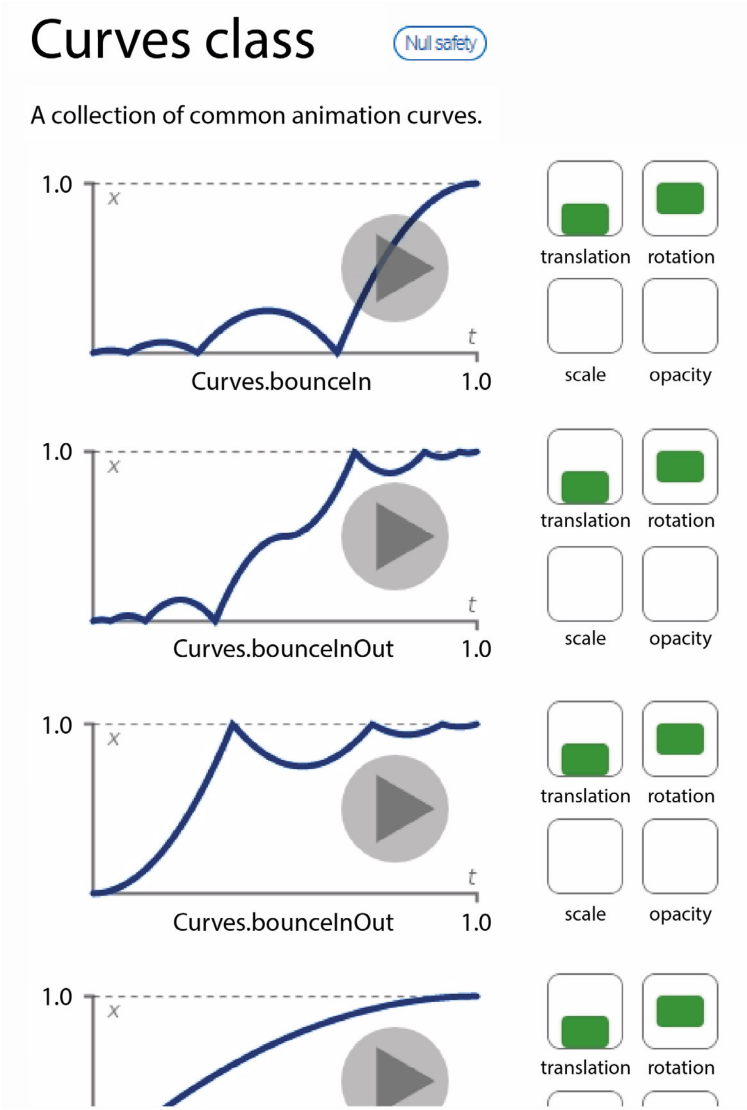


Figure 11.6 – Flutter Curves documentation

Check out the Curves documentation page to see, in detail, how each of the curves behaves: https://api.flutter.dev/flutter/animation/Curves-class.html.

Tween

As we have seen, by default, the simple start and end values of animation are 0.0 and 1.0, respectively. We can, by using a Tween class, change the range or type of AnimationController without modifying it.

Tween classes can be of any type, and we can also create custom Tween classes if we want. The point is that a Tween class returns modified animation values between the beginning and the end of the animation, which you can pass to whatever you're animating. For example, we can change the size of a widget and its position, opacity, color, and so on by using specific Tween classes for each one.

We also have other Tween descendant classes such as the CurveTween class available so that we can modify an animation curve, or ColorTween, which creates interpolation between colors.

Now that you have a base knowledge of animations, let's see them in action.

Using animations

When working with animations, we are not going to always be creating the same animation objects, but we can find some similarities in use cases. Tween objects are useful for changing the type and range of an animation. We will, most of the time, be composing animations with AnimationController, CurvedAnimation, and Tween instances.

Before we use a custom Tween implementation, let's revisit our widget transformations from the *Transforming widgets with the Transform class* section by applying the transformation in an animated way. We will get the same final effect but it will be smoother and more dynamic.

Rotate animation

Instead of changing the button rotation directly, we can make it progressive by using the AnimationController class. An example of this kind of animation is shown in the following screenshot:

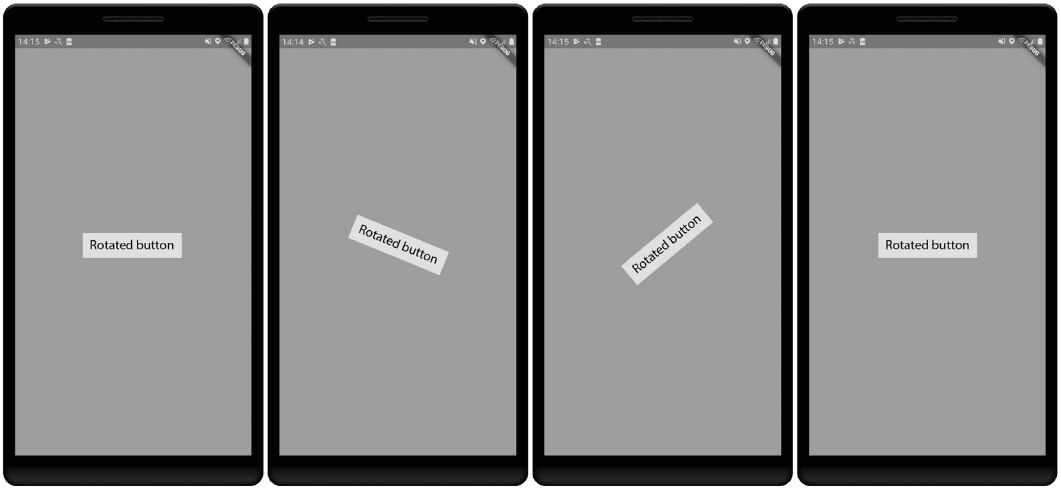


Figure 11.7 – Using animation to rotate a button

In the following example, we are creating our widget in a very similar way to how we did in the *Rotate transformation* section:

```
_rotationAnimationButton() {
  return Transform.rotate(
    angle: _angle,
    child: ElevatedButton(
      child: Text("Rotated button"),
      onPressed: () {
        if (_controller.status == AnimationStatus.
          completed) {
          _controller.reset();
          _controller.forward();
        }
      },
    ),
  );
}
```

As you can see, there are two important things to notice:

- The `angle` value is now defined with an `_angle` property instead of directly assigning a literal
- In the `onPressed` property, we check whether `_animation` is completed, and if it is, we restart it from the beginning

Now, let's see how the animation part is done. We need to know how to create our `AnimationController` object and make it run. Let's take a look at our example class first:

```
class _RotationAnimationsState extends
    State<RotationAnimations> with
    SingleTickerProviderStateMixin {
  double _angle = 0.0;
  late AnimationController _controller;
  ...
}
```

A few things are important to notice in this class:

- We have created a `StatefulWidget` object called `RotationAnimations` to make use of the `SingleTickerProviderStateMixin` class and provide the required `Ticker` object for our controller to run.
- Besides that, we have the `_angle` property, which is used to define our button's current angle. We can use the `setState()` method to cause it to be built with a new angle.
- And finally, we have our `_controller` object, which holds an animation controller and allows us to manage it.

The `initState()` function from our `State` class is the perfect place to set up the animation and start it. This function is illustrated in the following code snippet:

```
@override
void initState() {
  super.initState();
  _controller = _createRotationAnimation();
  _controller.forward();
}
```

As you can see, we define our animation through the `createRotationAnimation()` method and make it run by calling its `forward()` function. Now, let's see how the animation is defined:

```
AnimationController _createRotationAnimation() {
  var controller = AnimationController(
    vsync: this,
    debugLabel: "animations demo",
    duration: Duration(seconds: 3),
  );

  controller.addListener(() {
    setState(() {
```

```
      _angle = (controller.value * 360.0) *
        (math.pi / 180);
    });
  });

  return controller;
}
```

We can break up the creation of the animation into two important parts:

- There's the `AnimationController` definition itself, where we set the animation's `debugLabel` property for debugging purposes, the animation's duration, and finally, the `vsync` property so that the animation can have `Ticker` and know when to produce a new animation value. The value for `vsync` is `this` because we have specified that the state class uses `SingleTickerProviderStateMixin` and therefore will emit `Ticker` objects for the animation to use to trigger animation value updates.
- A second important step is to listen for the animation value changes. Here, whenever the animation has a new value, we get it, multiply it by 360°, and then convert it into radians so that we get a proportional rotation value. This is wrapped in a `setState` method call so that the `build` method of the stateful widget is called and the widgets can update their state based on the animation value.

As you can see, we can generate our desired values based on double animation values, so, most of the time, `Animation<double>` will be enough to play animations.

If we wanted to, we could add a different curve to the animation by using a tween such as `CurveTween`, as you can see in the `createBounceInRotationAnimation()` method shown here:

```
AnimationController _createBounceInRotationAnimation() {
  var controller = AnimationController(
    vsync: this,
    debugLabel: "animations demo",
    duration: Duration(seconds: 3),
  );

  var animation = controller.drive(
    CurveTween(
      curve: Curves.bounceIn,
    )
  );

  animation.addListener(() {
```

```
    setState(() {
      _angle = (animation.value * 360.0) * (math.pi / 180);
    });
  });

  return controller;
}
```

Here, we created another `animation` instance by using the controller's `drive()` method and passing the desired curve with a `CurveTween` object. Notice that we have added listeners to the new `animation` object instead of `controller` since we want our animation values to be relative to the curve.

An important point to notice is that we have to dispose of our `AnimationController` class instance at the end of the lifetime of our `State` class to prevent memory leaks, as illustrated in the following code snippet:

```
@override
void dispose() {
  _controller.dispose();
  super.dispose();
}
```

This must be done for every kind of animation we do since we will always be working with `AnimationController`.

Hopefully, animations are starting to make some sense to you. So, let's learn how to create scale animations as a way to cement that understanding.

Scale animation

To create a scale animation and have a more fluid UI than changing the `scale` attribute directly, we can once again use the `AnimationController` class to achieve a result similar to this:

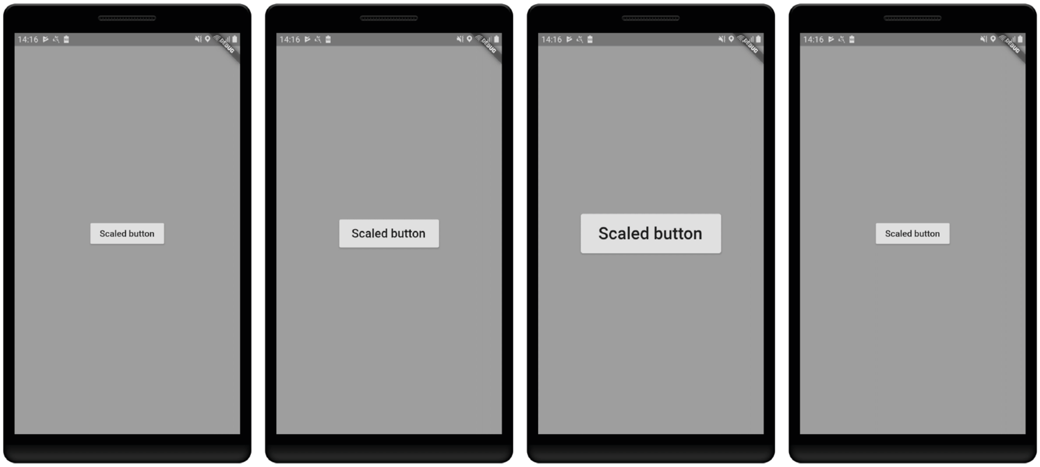


Figure 11.8 – Using animation to scale a button

This time, to build our `ElevatedButton` widget with a scale, we must define a `Transform` widget with the well-known `Transform.scale` constructor, as follows:

```
_scaleAnimationButton() {
  return Transform.scale(
    scale: _scale,
    child: ElevatedButton(
      child: Text("Scaled button"),
      onPressed: () {
        if (_controller.status == AnimationStatus.
          completed) {
          _controller.reverse();
        } else if (_controller.status ==
        AnimationStatus.dismissed) {
          _controller.forward();
        }
      },
    ),
  );
}
```

Notice that we now use a `_scale` property and take a look at the change in the `onPressed` method. Here, we play the animation in reverse mode by using the `reverse()` function of `AnimationController` if it is completed and play forward if it is at its initial state (that is, after reversing it).

The creation of a `_controller` object occurs in a very similar way to rotation animation, but there are slight modifications to the controller construction, as illustrated in the following code snippet:

```
createScaleAnimation() {
  var controller = AnimationController(
    vsync: this,
    lowerBound: 1.0,
    upperBound: 2.0,
    debugLabel: "animations demo",
    duration: Duration(seconds: 2),
  );

  controller.addListener(() {
    setState(() {
      _scale = controller.value;
    });
  });

  return controller;
}
```

As you can see, we now change the controller's `lowerBound` and `upperBound` values to make more sense in our case as we want the button to grow until its size is twice as big, and we do not want it to be smaller than its initial size (scale = `1.0`). Besides that, we changed our animation value listener just to get the value from the animation without any calculations.

Translate animation

Just as we have done with the rotate and scale animations, we can accomplish a better look for our translation transformation and make it smoother by using `AnimationController`, as illustrated in the following screenshot:

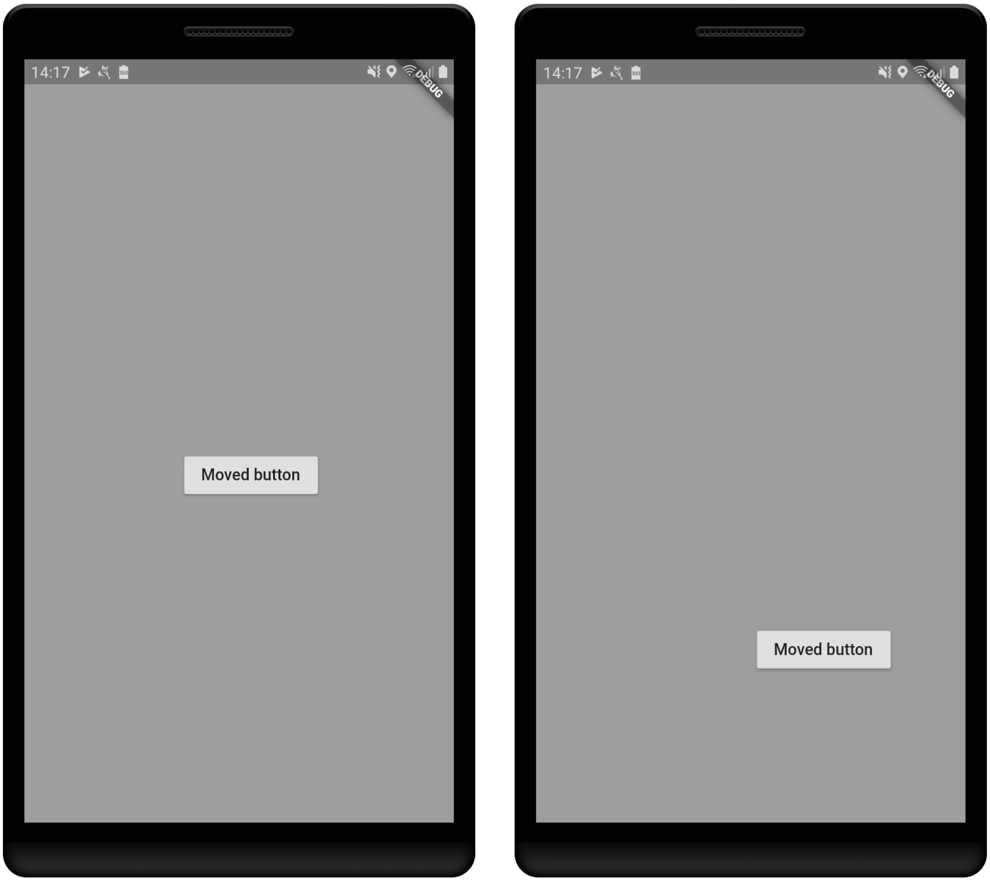


Figure 11.9 – Using an animation to move a button

The construction of our widget is similar to the rotate and scale animations; the only exception is the usage of the `Transform.translate()` construction. Now, we have a different value type than `double`. Let's see what we need to change to make an `Offset` animation. Here's the code you'll need:

```
AnimationController _createTranslateAnimation() {
  var controller = AnimationController(
    vsync: this,
    debugLabel: "animations demo",
    duration: Duration(seconds: 2),
  );

  var animation = controller.drive(
    Tween<Offset>(
      begin: Offset.zero,
```

```
      end: Offset(70, 200),
    ),
  );

  animation.addListener(() {
    setState(() {
      _offset = animation.value;
    });
  });

  return controller;
}
```

As you can see, here, we used a different approach to modify our `Offset` widget. We used a `Tween<Offset>` instance and passed it down to the `AnimationController` object through the `drive()` method, just like we did with `CurveTween` before. This works because the `Offset` class overrides mathematical operators such as subtraction and addition. The code is illustrated in the following snippet:

```
// part of geometry.dart file from dart:ui package
class Offset extends OffsetBase {
  ...
  Offset operator -(Offset other) => new Offset(dx -
  other.dx, dy - other.dy);
  Offset operator +(Offset other) => new Offset(dx +
  other.dx, dy + other.dy);
  ...
}
```

This makes calculating intermediate offsets (animation values) possible so that we can achieve interpolation between two `Offset` values.

Remember, these code examples are in the GitHub repository mentioned at the start of this chapter. It will make sense if you take a look at the classes in their entirety so that you can gain an appreciation of how animation works in Flutter.

Now that we have explored animations, let's look at how we can use the `AnimatedBuilder` class to improve the quality of our code.

Using AnimatedBuilder

Looking at the code that we wrote in the previous section, we can see a small problem with it – our button animation is mixed up with other widgets. So long as our code does not scale and become more complex, this is fine, but we know this is not the case most of the time, so we might have a real problem.

The AnimatedBuilder class can help us with the task of separating responsibilities. Our widget, whether it is ElevatedButton or anything else, does not need to know it is rendered in animation, and breaking down the build method to widgets that each have a single responsibility can be seen as one of the fundamental concepts in the Flutter framework. Let's look at the AnimatedBuilder class and then revisit our animation with our new knowledge.

The AnimatedBuilder class

The AnimatedBuilder widget exists so that we can build complex widgets that wish to include animation as part of a larger build function. Just as with any other widget, it is included in the widget tree and has a child property. Let's check out its constructor:

```
const AnimatedBuilder({
  Key? key,
  required Listenable animation,
  required TransitionBuilder builder,
  Widget? child
})
```

As you can see, we have a few important properties here, besides the well-known key property. Let's have a look at these in more detail:

- animation: This is a reference to our animation controller as a Listenable object. Listenable is a type that holds a list of listeners and notifies them whenever the object changes; AnimationController inherits from the Listenable class. This means that AnimatedBuilder will do its own listening for animation updates, so we do not need to do it manually with the addListener() method anymore.
- builder: This is where we modify the child widget based on the animation values.
- child: This is the widget that exists regardless of the animation object. So, we construct this widget as we would do without animation.

Revisiting our animation

To break down our code, modify our animation, and make it more maintainable, we must start separating what we need for each responsibility. Typically, the following three things are needed:

- The animation itself. Here, we do not need to change anything. Our AnimationController class will still be the same.
- We must add the AnimatedBuilder widget to our build() method. We will be extracting much of the code related to the animation of the button to make it clearer.
- The child widget. In our case, this is just ElevatedButton, which changes according to the progress of the animation.

Now, let's update the translation animation code we created in the *Rotate animation* section so that it uses the `AnimatedBuilder` concept. The first section that changes is the `_createBounceInRotationAnimation` method, as illustrated in the following code snippet:

```
(AnimationController, Animation)
   _createBounceInRotationAnimation() {
  final controller = AnimationController(
    vsync: this,
    debugLabel: "animations demo",
    duration: Duration(seconds: 3),
  );

  final animation = controller.drive(CurveTween(
    curve: Curves.bounceIn,
  ));

  return (controller, animation);
}
```

This method now creates a controller and animation but does not define a `setState` action. This is no longer the responsibility of the parent widget. We now need to return `animation` as well because the animation value will be accessed within the `build` method rather than when we set a listener in this method. We make use of the Dart 3 `Record` return type to return both objects.

We still need the `dispose` method to clear up the animation when the parent widget is disposed of, as illustrated in the following code snippet:

```
  @override
  void dispose() {
    _controller.dispose();
    super.dispose();
  }
```

There is no change here, but it is worth noting that disposal is still required.

We still trigger the creation of an animation and its controller from the `initState` property and store the variables in two fields of our widget, as follows:

```
class _RotationAnimationsState extends State
<RotationAnimations> with SingleTickerProviderStateMixin {
  late AnimationController _controller;
  late Animation _animation;

  @override
  void initState() {
```

```
    super.initState();
    final (localController, localAnimation) =
      _createBounceInRotationAnimation();
    _controller = localController;
    _animation = localAnimation;
  }
```

Again, this is very similar to the previous examples. The key change occurs in the `build` method, as illustrated in the following code snippet:

```
  @override
  Widget build(BuildContext context) {
    return AnimatedBuilder(
      animation: _animation,
      child: ElevatedButton(
        child: Text("Rotated button"),
        onPressed: () {
          print("Rotating");
          print("${_animation.status}");
          if (_animation.isCompleted ||
          _animation.isDismissed) {
            _controller.reset();
            _controller.forward();
          }
        },
      ),
      builder: (context, child) {
        print("Building");
        return Transform.rotate(
          angle: _animation.value * 2.0 * math.pi,
          child: child,
        );
      },
    );
  }
```

As mentioned previously, the `setState` property is no longer in the parent widget – the `AnimatedBuilder` class takes care of that and constrains the redraw to just the children of the `AnimatedBuilder` class.

Two key things to notice in the code are outlined here:

- The `_animation` variable is now passed to the `AnimatedBuilder` class so that the `setState` property can be triggered within the widget's scope

- The child widget is defined within the `child` parameter of the `AnimatedBuilder` class and the same child is returned as an argument to the `builder` method, allowing you to manipulate the same widget in both the `child` and `builder` methods

With these changes, the redraw on the `setState` property is more efficient because potentially far fewer widgets are being re-evaluated on an animation update. Only the animated widget is being redrawn as part of the animation.

Now that we've looked at the fundamentals of animation, let's briefly look at some widgets that hide all the complexity and give us an easy way to set up animations that fit many situations.

Implicitly animated widgets

Flutter has a whole set of widgets that have animation built directly into them. These animated widgets also mirror lots of widgets we have already seen, allowing a very easy drop replacement in your widget tree to get some great animations.

These widgets work by animating any changes to their internal state. For example, if a widget has been drawn to the screen in one color, and then a `setState` property changes the widget's color, the color change is animated rather than a single frame color switch. First, let's take a look at the `AnimatedContainer` widget, after which we will explore the other implicitly animated widgets that are available.

AnimatedContainer

The first widget to look at, and probably the most powerful, is the `AnimatedContainer` widget. This is very similar to the `Container` widget we first saw in *Chapter 5*, *Building Your User Interface through Widgets*, but adds some key properties that allow it to animate changes.

Suppose in our widget tree we have an entry like this:

```
Container(
  width: _winner ? 50 : 400,
  child: Image.asset('assets/trophy.png'),
),
```

As you can imagine, if the `_winner` variable is initially set to `false` and then a `setState` call changes it to `true`, the `trophy` image will suddenly jump from `50px` wide to `400px` wide.

This would potentially be quite jarring to a user, and would not look like the action of a high-quality app. To solve this, adding an animation would make this image enlargement look much more professional.

We could animate the size change, as we saw in the *Scale animation* section, where we could use a controller, curved animation, and tween. However, this time, let's use `AnimatedContainer` to do the same thing:

```
AnimatedContainer(
  width: _winner ? 50 : 400,
  child: Image.asset('assets/trophy.png'),
  duration: Duration(seconds: 2),
),
```

Firstly, you'll see how similar the creation and constructor parameters are. The notable difference is the `duration` parameter. This parameter denotes how long any animations should take.

Now, when the `setState` property is called and `_winner` is changed from `false` to `true`, the `trophy` image will grow smoothly from `50px` to `400px` in `width` value over `2` seconds. All interpolation (transitioning between the old and new `width` values) will be done by the widget itself.

However, it gets even better – the `AnimatedContainer` widget can also take a `curve` parameter, allowing us to change the animation from a simple linear growth in `width` value to something much more interesting such as a `bounceOut` curve, which feels like the `trophy` image is dropping onto the screen and bouncing until it settles.

Once we add the curve to the code, it will look like this:

```
AnimatedContainer(
  width: _winner ? 50 : 400,
  child: Image.asset('assets/trophy.png'),
  duration: Duration(seconds: 2),
  curve: Curves.bounceOut,
),
```

Adding the `curve` parameter allows you to set the animation curve to any of the curves supported by Flutter.

AnimatedFoo

The implicitly animated widgets that come with Flutter are often referred to as `AnimatedFoo`, where `Foo` is the name of the non-animated version of the widget.

There are a vast number of them, but some key ones to use are listed here:

- `AnimatedAlign`: This animates changes in alignment, such as changing `alignment` of the widget from one position on the screen (for example, `topRight`) to another part of the screen (for example, `bottomLeft`).

- AnimatedOpacity: This animates the opacity of the widget. It's great for fading a child widget in or out.
- AnimatedPadding: This animates how a widget sits within a parent widget.
- AnimatedPositioned: This can only be used within a stack but it allows a widget to animate a change in screen position and size.
- AnimatedSize: This animates the change in the size of a widget.

These widgets can be great fun to play around with, so try plugging some of them into the Hello World app and see how you can animate them. They are also a great way to prototype any designs that require animations. Ultimately, you may need to use more complex animation management, but you will at least be able to see whether a design will work without investing lots of time in its development.

Summary

In this chapter, we learned how to change our widget's look by using the Transform class and its available transformations, such as scaling, translating, and rotating. We also saw how we can compound transformations by using the Matrix4 class directly.

We learned the fundamental concepts of animation and how to apply them to child widgets to make changes smooth and dynamic.

We also saw the important framework classes – that is, AnimationController, CurvedAnimation, and Tween. We revisited our Transformation examples and added animations to them by using the concepts learned in this chapter. Next, we learned how to create our own custom Tween objects, and we looked at how to clean up our code through the use of the AnimatedBuilder widget.

Lastly, we saw the AnimatedFoo classes that have animation embedded inside them, allowing you to develop slick animations without complicated code.

In the next chapter, we will look at the app as a whole program and how we can test and debug it in preparation for user trials and finally release it to the world!

Questions

Hopefully, you found this chapter pretty exciting, especially at the end, where I showed you just how easy it is to add animation to Flutter. We are now exploring some interesting concepts that will make your app look banging!

However, some tricky sections are worth revisiting, so use these questions as a prompt to ensure you have understood all the content in this chapter:

1. Can you remember what Matrix4's identity looks like?
2. What are the three main transformations that can be used?

3. Can you recall what the main controls of `AnimationController` are?
4. How would you modify your stateful class so that it can tell `AnimationController` when a new frame is being drawn to the device's screen?
5. What is the purpose of curves within animations?
6. What is the benefit of using `AnimatedBuilder` within your widget tree?
7. How do you trigger the animation of an `AnimatedContainer` or `AnimatedFoo` class?

Further reading

With new concepts such as animations, the best way to get your new knowledge to stick is to explore and experiment with it more.

There are some great animation tutorials out there, and one I found and have used in the past is this from developer Sandro Maglione: `https://www.sandromaglione.com/techblog/how-to-use-tween-learn-all-about-flutter-animations-part-2`.

As mentioned in this chapter, animation curves can make your application look polished, so it is worth taking the time to understand the different types of curves available: `https://api.flutter.dev/flutter/animation/Curves-class.html`.

Experiment with changing the curves in your code to see what changes it makes. Ultimately, the best further reading for this chapter is to go and play with some code and see what amazing things you can make happen with animations.

Part 4:
Testing and Releasing Your App

You now have the skills to create an awesome app, but how do you share it with the world? And perhaps more importantly, how do you make sure that the world is also loving your app?

In this part, we will look at how to test your app and debug any issues so that your users are not the ones finding the bugs. We will then explore the steps required to get your app into the App Store, Play Store, or web-ready for everyone to access. Finally, we will look at how to monitor your app and ensure that it is behaving itself.

This part contains the following chapters:

- *Chapter 12*, *Testing and Debugging*
- *Chapter 13*, *Releasing Your App to the World*

12
Testing and Debugging

Flutter provides great tools to help developers manage their app development and ensure that it is ready for production – from a test API to IDE tools and plugins. This is especially crucial in app development where, unlike in some scenarios such as web pages, a bug fix can take several days to be reviewed by the relevant store, and then be updated on user devices.

In this chapter, you will learn how to add tests to identify bugs within your app, use debugging tools to identify where an issue is within your code, profile your app performance to find bottlenecks, and inspect UI widgets.

We will start this chapter by exploring how you can unit test your Dart code. This can be useful if you create a reusable library of functions that you are using across many apps and want to ensure that any changes to the library code continue to function as intended.

The following topics will be covered in this chapter:

- Unit testing
- Widget testing
- Debugging your app
- DevTools

Technical requirements

You will need your development environment again for this chapter if you want to practice testing and debugging the `Hello World` project. Look back at *Chapter 1*, *What Is Flutter and Why Should I Use It?*, if you need to set up your IDE or refresh your knowledge of the development environment requirements.

You can find the source code for this chapter on GitHub at `https://github.com/PacktPublishing/Flutter-for-Beginners-Third-Edition`.

Unit testing

It is generally agreed that writing bug-free software is impossible, especially when your code runs on third-party hardware, such as a mobile phone, and needs to interact with users, who can (and will) do all kinds of unexpected things.

For some situations, such as reusable function libraries, the requirements can be well defined, and the data inputs and outputs known in advance. In these situations, not only is a strong set of tests a great way to ensure the library is as bug-free as possible, but you can make changes to the code (for example, performance improvements and memory optimizations), knowing that your changes have not affected the expected behavior of the library.

Unit tests are one of the tools that can help us write modular, efficient, and bug-free code. A unit test, as the name implies, tests the smallest logical unit of code that can be meaningfully executed in isolation. The unit test is not the only way of testing code, of course, but it's a crucial part of testing small pieces of software in a manner that isolates it from other parts, helping us focus on specific characteristics of that unit of code.

Covering all of the application code with unit tests does not guarantee that it's 100% bug-free; however, it helps us achieve mature code progressively, and this is one of the steps to ensuring a good development cycle, with stable releases from time to time.

Dart also provides some useful tools to work with tests. Let's take a look at the starting point of unit testing Dart code: the Dart `test` package.

The Dart test package

The Dart test package is not part of the **Software Development Kit** (**SDK**) itself, so it has to be added as a dependency using the `pubspec.yaml` file, which we did often in *Chapter 9*, *Flutter Plugins – Get Great Functionality for Free!*.

Unlike with the previous plugins that we depended on, this is a dependency that is required only during development, not at runtime. Therefore, it is added to another part of the `pubspec.yaml` file, specifically the area in `dev_dependencies`.

The plugin we want to use is named `test`, but rather than adding that plugin to our `pubspec.yaml` file, there is a testing library that wraps the `test` plugin and is included in the Flutter SDK. This is the `flutter_test` package and it can be imported like this:

```
dev_dependencies:
  flutter_test:
    sdk: flutter
```

This looks slightly different from our other dependencies because it specifies that the version included in the Flutter SDK must be used. Just like the standard dependencies, development dependencies such as `test` are listed on the `pub.dev` site, and the installation section will advise you how to add the plugin to the correct part of the `pubspec.yaml` file.

Including this dependency enables us to use the test package's provided libraries to write unit tests.

Writing unit tests

Now, let's suppose that we want to create a function that sums two numbers:

```
class Calculator {
  num sumTwoNumbers(num a, num b) {
    return 0; // TODO
  }
}
```

We would probably choose to put the file holding this function in a sub-folder, allowing us to manage our code structure. Let's say we put it in the `lib/maths/calculator.dart` location.

We can now write a unit test to evaluate this method's implementation by using the test package:

```
import 'package:flutter_test/flutter_test.dart';
import '../lib/maths/calculator.dart';

void main() {
  late Calculator _calculator;

  setUp(() {
    _calculator = Calculator();
  });

  test(
    'calculator.sumTwoNumbers() sum both numbers',
    () => expect(_calculator.sumTwoNumbers(1, 2), 3),
  );
}
```

In the preceding example, we started by importing the test package's main library, which exposes functions such as `setUp()`, `test()`, and `expect()`. Each of the functions has specific roles, as follows:

- `setUp()` will execute the callback we pass to it before each of the tests in the test suite.
- `test()` is the test itself; it receives a description and a callback with the test implementation.
- `expect()` is used to make assertions about the test. In the preceding example, we are just asserting a sum of 1 + 2, which should result in 3.

Tests should be stored in their own `test` folder, separate from the `lib` folder. Let's say we put this file in `test/calculator_test.dart`.

To execute a test, we can use the following command:

```
flutter test <test_file>
```

In the preceding example, the command would be (from the root of the project) as follows:

```
flutter test test/calculator_test.dart
```

Before we correctly implement the `sumTwoNumbers()` method, let's run the test to see what output we get:

```
PS C:\Apps\hello_world> flutter test test/calculator_tests.dart
00:01 +0 -1: sumTwoNumbers() sum both numbers [E]
  Expected: <3>
    Actual: <0>

  package:matcher                                         expect
  package:flutter_test/src/widget_tester.dart 459:16  expect
  test\calculator_tests.dart 14:11                        main.<fn>
To run this test again: C:\flutter\bin\cache\dart-sdk\bin\dart.exe
test C:/Apps/hello_world/test/calculator_tests.dart -p vm --plain-name
"sumTwoNumbers() sum both numbers"
00:01 +0 -1: Some tests failed.
```

This is a little intimidating, but there are four key pieces of information here:

- `00:01 +0 -1: Some tests failed`: This states that the tests took 1 second to run, that 0 tests passed (`+0`), and that 1 test failed (`-1`). At this point, you know you have some investigating to do!
- The test that failed is called `calculator.sumTwoNumbers() sum both numbers` because it has `[E]` after its name.
- The test failed because the `expect()` statement was expecting a result of 3 but received a result of 0.
- The failure occurred in the `calculator_tests.dart` file on line `14`, character `11`. This is exactly where the `expect()` statement is defined.

With this information, you should be able to identify where your test is failing and start to diagnose what bug you have uncovered (which could potentially be a bug in your test code rather than the code it is testing).

Let's change the implementation of the `sumTwoNumbers()` method, and then rerun the test to check everything is correct:

```
class Calculator {
  num sumTwoNumbers(num a, num b) {
    return a + b;
  }
}
```

Now, we must return the two numbers added together. Rerunning the test gives us the following:

```
PS C:\Apps\hello_world> flutter test test/calculator_tests.dart
00:01 +1: All tests passed!
```

The test's name is not shown because this time, there is no error, just an `All tests passed!` message.

Note that we could have made this test pass by simply returning `3` from the `sumTwoNumbers()` method, which shows that creating a range of tests is necessary to be confident of the quality of your function.

You can also create groups of tests so that it is easy to manage and report on specific parts of the code being tested. Let's suppose that we create a new file to hold a test suite with a group of tests, as follows:

```
import 'package:flutter_test/flutter_test.dart';
import '../lib/maths/calculator.dart';

void main() {
  late Calculator _calculator;

  setUp(() {
    _calculator = Calculator();
  });

  group("calculator tests", () {
    test(
      'sumTwoNumbers() sum both numbers',
      () => expect(_calculator.sumTwoNumbers(1, 2), 3),
    );
    test(
      'sumTwoNumbers() sum negative number',
      () => expect(_calculator.sumTwoNumbers(1, -1), 1),
    );
  });
}
```

The preceding code should look very similar to the single test example, with a `main` method containing a `setup` method. However, instead of also containing a `test` method, the `main` method contains a `group` method that itself will contain the tests.

In this example, we call the `group` method with two parameters: the name of the group of tests, and an anonymous function that will run the tests. The anonymous function simply calls the `test()` method twice with two tests.

Note the output for the preceding tests:

```
PS C:\Apps\hello_world> flutter test test/calculator_group_tests.dart
00:01 +1 -1: calculator tests sumTwoNumbers() sum negative number [E]
  Expected: <1>
    Actual: <0>

  package:matcher                                        expect
  package:flutter_test/src/widget_tester.dart 459:16     expect
  test\calculator_tests.dart 18:13                       main.<fn>.<fn>
To run this test again: C:\flutter\bin\cache\dart-sdk\bin\dart.exe
test C:/Apps/hello_world/test/calculator_tests.dart -p vm --plain-name
"calculator tests sumTwoNumbers() sum negative number"
00:01 +1 -1: Some tests failed.
```

There was one successful test (`+1`) and one failure (`-1`) – with the details of the failure noted as an incorrect expectation. With this in mind, we can investigate the location of the failure and realize that our `expect()` statement is incorrect. We were expecting `1 + -1 = 1`, which is incorrect. Modifying the test to expect 0 and then rerunning the test group gives us the following output:

```
PS C:\Apps\hello_world> flutter test test/calculator_group_tests.dart

00:01 +2: All tests passed!
```

In this output, we can see `+2` because the second test now passes.

Unit tests can help us prevent logical errors in our functional libraries from occurring in production. Of course, generally, tests can't be exhaustive, but using techniques such as boundary value analysis and equivalence partitioning can allow us to test most of the possible scenarios that our library function will have to deal with. These topics are outside the scope of this book, but a search on the internet for these terms will give further explanation and help you write a strong set of tests for a function.

Unit test mocking

Sometimes, our unit tests may rely on accessing a service or reading live data from a database. This can be troublesome in a unit test because the service may not be available from the test environment, you don't want to be manipulating live data from a test, and the test may not be repeatable if the service or database returns unexpected results.

To solve this problem, unit testing generally replaces, or mocks, these services or databases so that the dependency is removed. You can either choose to write these mocks yourself by replacing a live service class with your custom mock class, or you can use a framework such as Mockito.

Mockito is available as a plugin, so adding it to your project is as easy as updating your `pubspec.yaml` file so that it includes the `dev` dependency. Exploring the use of mocks is beyond the scope of this book, but a great place to start your investigation is to investigate the **Mockito** framework on the `pub.dev` page at `https://pub.dev/packages/mockito`.

As mentioned at the start of this section, unit testing is great for testing a library function that has well-defined inputs, outputs, and requirements. As we start to involve outside actors such as users, networks, and devices, we need to look at other testing options. Let's start that exploration with a look at testing widgets.

Widget testing

Getting the right mix of tests is important so that you can test your app optimally without reducing iteration and development velocity. Writing unit tests for well-defined library functions makes sense, but when it comes to user interactions, you often want to iterate and understand user interactions before settling on a design, which then may change as fashion or best practices change. Therefore, your test itself should be more high-level, looking at components rather than specific functions. One example of this is widget tests, and Flutter helps us write widget tests to test that widgets work as expected.

Widget tests are used to validate widgets in an isolated way. They look very similar to unit tests but focus on widgets. The main goal is to check widget interactions and whether widgets visually match expectations. As widgets live in the widget tree inside the Flutter context, widget tests require the framework environment to be executed. That is why Flutter provides tools for writing widget tests through the `flutter_test` package.

The WidgetTester class

As we saw in the *Unit testing* section, the `flutter_test` package is shipped with the Flutter SDK. It is built on top of the `test` package, and, in addition to the unit testing tools, it also provides a set of tools that help us write and run widget tests.

As mentioned in the previous section, widget tests need to be executed in the widget environment and Flutter helps with this task with the `WidgetTester` class. This class encapsulates the logic for us to build and interact with the widget being tested and the Flutter environment.

We do not need to instantiate this class by ourselves as the framework provides the `testWidgets()` function. The `testWidgets()` function is similar to the Dart `test()` function that we saw in the *Unit testing* section. The difference is the Flutter context – this function sets up a `WidgetTester` instance to interact with the environment.

The testWidgets function

The `testWidgets()` function is the entry point of any widget test in Flutter:

```
void testWidgets(
  String description,
  WidgetTesterCallback callback,
  { bool skip: false,
    Timeout timeout,
    TestVariant<Object?> variant = const DefaultTestVariant
      ()},
)
```

The method takes two required parameters. Three optional parameters are also worth exploring:

- `description`: This required parameter helps document the test; that is, it describes what widget features are being tested.
- `callback`: This required parameter is `WidgetTesterCallback`. This callback receives a `WidgetTester` instance so that we can interact with the widget and make our validations. This is the body of the test, where we write our test logic.
- `skip`: We can skip the test when running multiple tests by setting this optional flag. The default value is `false`.
- `timeout`: This optional parameter is the maximum time the test callback can run. The default value is to have no limitation.
- `variant`: This parameter will allow you to run the tests multiple times with different input values.

Let's look at an example of how we could use this method.

Widget test example

When we generate a Flutter project, the `flutter_test` package dependency is added for us automatically and a sample test is generated in the `test/` directory.

First, in the `pubspec.yaml` file, we can see that the `flutter_test` package dependency was added to our `Hello World` project when it was created:

```
dev_dependencies:
  flutter_test:
    sdk: flutter
```

Note that the package version is not specified. This is because the origin is configured as the Flutter SDK, so it matches whatever version of Flutter we have installed on our system.

Next, let's take a look at the basic widget test in the `test/widget_test.dart` file:

```
import 'package:flutter/material.dart';
import 'package:flutter_test/flutter_test.dart';
import 'package:hello_world/main.dart';

void main() {
  testWidgets(
    'Counter increments smoke test',
    (WidgetTester tester) async {
      // Build our app and trigger a frame.
      await tester.pumpWidget(MyApp());
      // Verify that our counter starts at 0.
      expect(find.text('0'), findsOneWidget);
      expect(find.text('1'), findsNothing);
      // Tap the '+' icon and trigger a frame.
      await tester.tap(find.byIcon(Icons.add));
      await tester.pump();
      // Verify that our counter has incremented.
      expect(find.text('0'), findsNothing);
      expect(find.text('1'), findsOneWidget);
  });
}
```

This sample widget test validates the behavior of the famous Flutter counter app. Some of the key features of the test are as follows:

- The test is defined with a description of *Counter increments smoke test* and the `WidgetTesterCallback` property. Also, note the callback has the `async` modifier because the `WidgetTester` methods that interact with the widget are asynchronous and return a `Future` type.
- We want to test a widget, so the test fires up the widget we want – in this case, `MyApp` – by running the `pumpWidget` method on `WidgetTester`: `await tester.pumpWidget(MyApp());`. This renders the widget so that we can test it.
- If we need to rebuild the widget at any point, we can use the `tester.pump()` method. This is needed because, although the code in the widget may initiate a `setState()` request, Flutter will not automatically rebuild the widget in a test environment.
- In widget tests, three additional pieces are important and very common: `expect()`, `find`, and `Matcher`.
- The `expect()` method is used in conjunction with `finder` and `Matcher` to make assertions on widgets found – just like the `expect()` function we looked at in the *Unit testing* section.

- The `Finder` class is what allows us to search specific widgets in the tree. The `find` constant provides Finders that search the widget tree for specific widgets.
- The `Matcher` class helps validate the found widget characteristic with an expected value.

> **Important note**
> You can check out all the available Finders provided by `find` at `https://api.flutter.dev/flutter/flutter_driver/CommonFinders-class.html`.

Let's step through the test code that is run after the widget is pumped via `WidgetTester` so that we can better understand the test.

The first assertions check for the presence of a single widget with the `'0'` text and none with the `'1'` text. This is done by using the `find` function, `find.text()`, to find a widget with specific text, and then using the two Matchers, `findsOneWidget` and `findsNothing`, to specify the expectation of how many widgets should be found, as shown here:

```
expect(find.text('0'), findsOneWidget);
expect(find.text('1'), findsNothing);
```

Then, `tap()` is executed on `WidgetTester`, followed by a `pump()` request to refresh the widget. The tap occurs on a widget that contains the `Icons.add` icon by using the `find.byIcon()` function to find the correct widget. This replicates a user tapping on the floating plus button to increment the counter:

```
await tester.tap(find.byIcon(Icons.add));
await tester.pump()
```

This tap should have incremented the counter, and the pump should have allowed the widget to redraw, with the counter now showing 1. Therefore, the final step is to verify the correct counter text is shown again. But this time, the `findsOneWidget` constant is used to verify that only the text `'1'` is visible and that there are no widgets that now have the `'0'` text:

```
expect(find.text('0'), findsNothing);
expect(find.text('1'), findsOneWidget);
```

Like the `find` constant, which has multiple `find` functions, there are multiple Matchers in addition to `findsNothing` and `findsOneWidget`. You can check out all the available Matchers in the `flutter_test` library documentation: `https://api.flutter.dev/flutter/flutter_test/flutter_test-library.html`.

Running a widget test

To run a widget test, we can use the same command as we did for the unit tests:

```
flutter test <testFile>
```

So, in our example, we would run this command:

```
flutter test test/widget_test.dart
```

Let's just change the test so that it will fail. In this case, we will change the final assertion to see if the widget has `'2'` as the text instead of `'1'`. If we run the test, we'll get the following output:

```
PS C:\Flutter\hello_world> flutter test test/widget_test.dart
00:05 +0: Counter increments smoke test
══╡ EXCEPTION CAUGHT BY FLUTTER TEST FRAMEWORK ╞═══
The following TestFailure object was thrown running a test:
  Expected: exactly one matching node in the widget tree
  Actual: _TextFinder:<zero widgets with text "2" (ignoring offstage
widgets)>
   Which: means none were found but one was expected

When the exception was thrown, this was the stack:
<Stack trace here>
This was caught by the test expectation on the following line:
  file:///C: /Apps/Flutter/hello_world/test/widget_test.dart line 28
The test description was:
  Counter increments smoke test
════════════════════════════════
00:05 +0 -1: Counter increments smoke test [E]
  Test failed. See exception logs above.
  The test description was: Counter increments smoke test
<Details on how to run the test again>
00:05 +0 -1: Some tests failed.
```

As you can see, the test runner wasn't very happy. Although there is a lot of information, the format is very similar to what we saw in the *Unit testing* section. We can see the difference between what was expected and what happened, the name of the test, and the line that the test failed on.

Let's run the test again with the correct expectation:

```
PS C:\Flutter\hello_world> flutter test test/widget_test.dart
00:11 +1: All tests passed!
```

When the tests passed, the output was very minimal, just reporting `All tests passed!`.

Even with lots of testing, apps will fail or exhibit incorrect behavior. In these cases, you will need to inspect the execution of the app code to find the issues. This activity, known as debugging, is our next topic.

Debugging your app

Debugging is an important part of software development. Small mistakes, strange behaviors, and complex bugs can be solved with the help of debugging. With debugging, we can do the following:

- Make logic assertions
- Determine the required improvements
- Find memory leaks
- Perform flow analysis

Flutter provides multiple tools to help you debug your app, but the easiest way to debug is via the IDE, so let's start there.

Debugging in the IDE

To be able to debug within your IDE, you first need to run your app from within your IDE. If you are running Visual Studio Code, then you will see a **RUN AND DEBUG** button on the left-hand side of the IDE, which looks like an arrow with a bug on it. Click this; at the top of the section, you will see a **Run debugging** button beside the name of the Flutter project, **hello_world**:

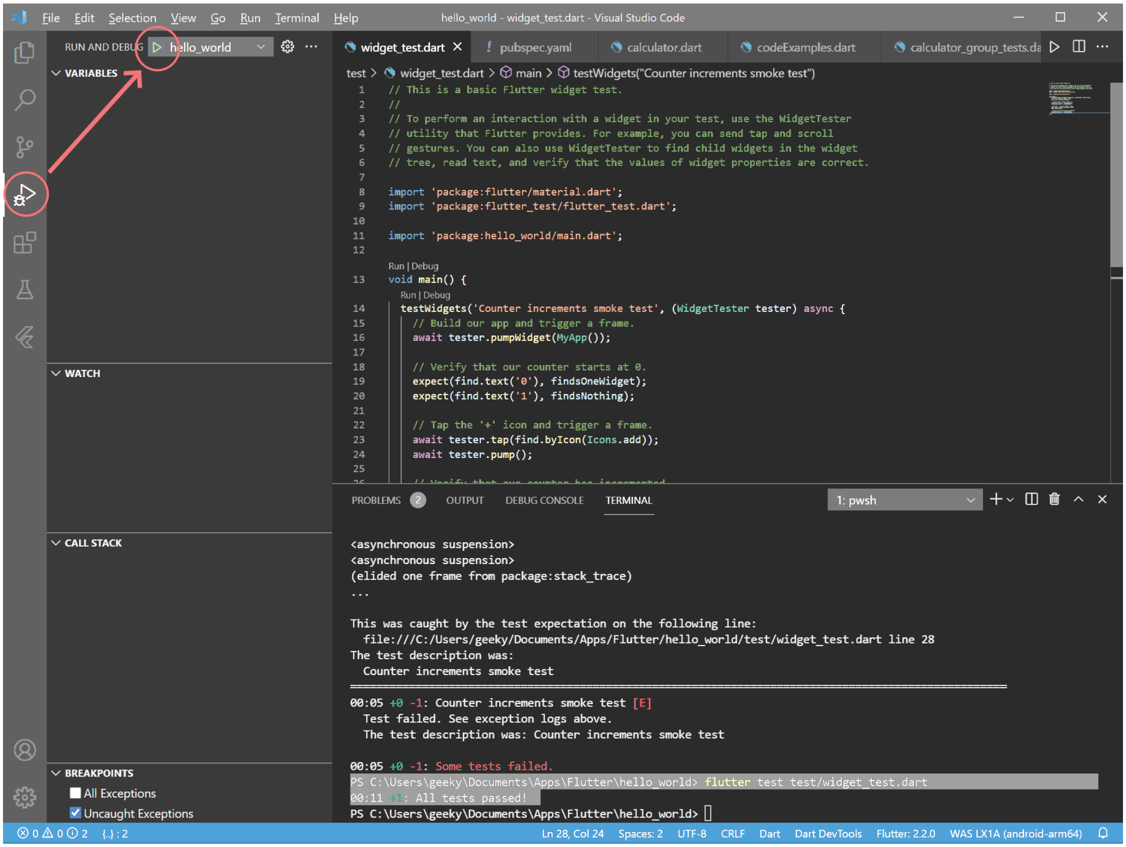


Figure 12.1 – Running Flutter from Visual Studio Code

Note that you may need to add a reference in your launch configuration to the `main.dart` file you want to run if it is not in the standard location or you have multiple `main.dart` files available.

The `launch.json` file can be opened via the cog icon next to the `hello_world` name. If this is the first time you are attempting to launch your app, then you may be invited to generate a `launch.json` file. You can then add a line similar to this to point to the `main.dart` file that you wish to run:

```
"program": "lib/Chapter01/main.dart"
```

If you are using Android Studio/IntelliJ, then make sure you run in debug mode so that you have access to all the tooling.

Once you have the app running in the IDE, you can add breakpoints. Try adding a breakpoint to the `_MyHomePageState` class within the `main.dart` file. Specifically, add a breakpoint within an `onPressed` function of a button. To do this in Visual Studio code, simply click to the left of the line number of the line you want as the breakpoint. A red dot will then appear to show that a breakpoint has been set, and on the left pane at the bottom, you will see the list of breakpoints that have been set.

When you are running your app and press the button that has a breakpoint set on it, your IDE will pause the execution of the code and show something like this:

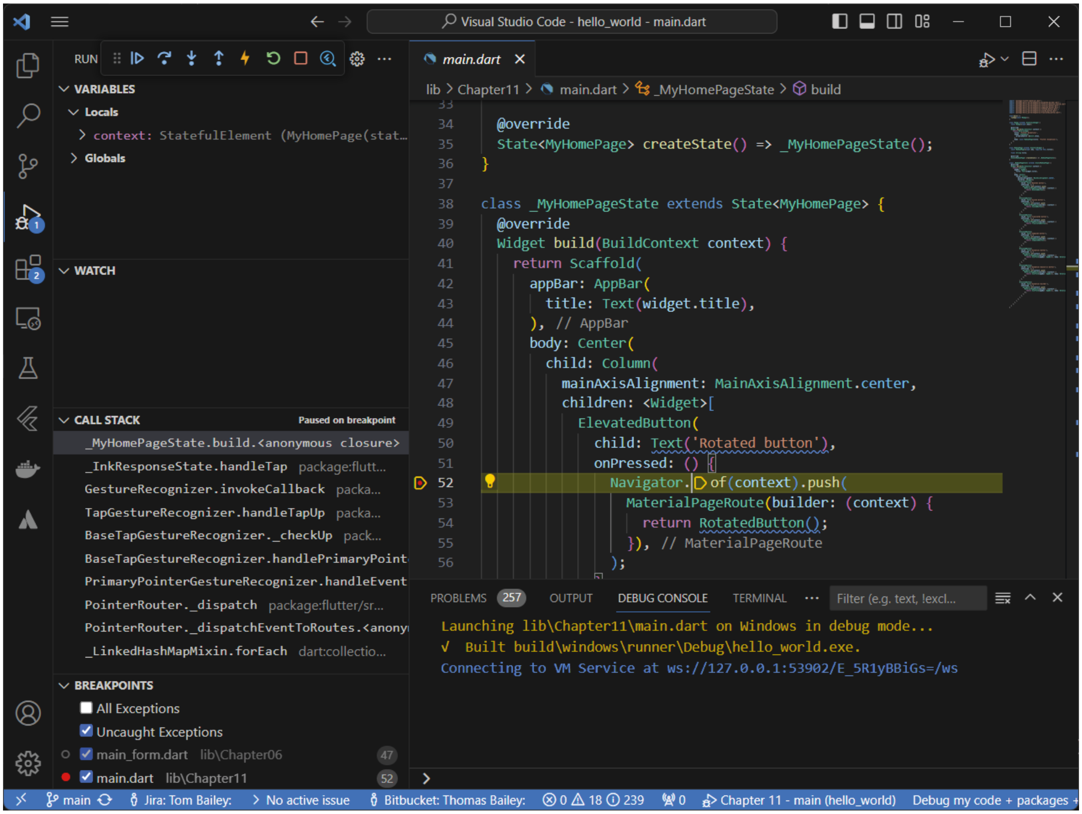


Figure 12.2 – Visual Studio Code pausing execution at a breakpoint

A lot is going on here, so let's take it a piece at a time:

- The main pane highlights the line in yellow where the code execution is paused.
- The top-left pane shows the **VARIABLES** values that are currently set.
- The **CALL STACK** pane shows the current call stack (that is, all the method calls that allowed the code to reach this point).

- The bottom-right pane shows the **DEBUG CONSOLE** area and any log statements that have come from the app.
- The bottom-left pane shows all the **BREAKPOINTS** values that have been set on your code; you can enable or disable them using the checkboxes. Note the two additional entries of *All Exceptions* and *Uncaught Exceptions*. The latter breakpoint is especially useful as it will pause the execution of your app whenever an exception is thrown that your code doesn't handle.

The next step is to use the debug controls (top left) to either step the execution to the next line, step into a method/function call, step out of a method/function, or continue the execution of the code.

As you can imagine, this gives you a great ability to see exactly what is happening within the code and understand where there may be issues.

One warning is that when you reach an asynchronous section of code, you may need to set another breakpoint so that you can catch the execution again after the asynchronous work is done. Also, asynchronous sections can lead to an incomplete call stack, potentially making it difficult to understand how a piece of code was reached. However, generally, the debugger is a lifesaver and should be used as much as possible!

Debugging your app is incredibly important, so ensure you revisit this section whenever you have issues with your app code so that you can get adept at using the debugger. However, there are also other tools available that will help you investigate how your app is running from both a layout and performance perspective, so let's look at those next.

Additional debugging features

Dart provides additional features to help with advanced debugging through variants of the common tools that can make the debugging process even more useful. These are as follows:

- The `debugger()` statement: Also called programmatic breakpoints, this is where we can add a breakpoint if an expected condition is true:

  ```
  void login(String username, String password) {
    debugger(when: password == null);
    ...
  }
  ```

  In this example, a breakpoint will occur only if the condition specified in the `when` parameter is true – that is, only if the `password` argument is `null`. Let's say this is an unexpected value: pausing the execution at this point may help to see why it occurs and how to react to it. This is very useful for tracing unexpected states and logic fails.

- Printing logs: `print()` is a method for logging information into the Flutter log console. When we use the `flutter run` command, its log output is redirected to the console and we can see anything that comes from `print()` calls. There is also the `debugPrint()` method, which behaves just like the `print()` method but throttles the rate of message creation to avoid data loss on Android.
- Asserts: `assert()` is used to break app execution when some condition is not satisfied. It is similar to the `debugger()` method, but instead of pausing execution, it interrupts the execution by throwing `AssertionError`. If you look at plugin or built-in widget code, you will often see `assert` statements on the constructors to ensure the widgets are being constructed correctly.

It's worth noting that `debugger()` and `assert()` function calls are ignored in production code.

Now, let's look at an area where Flutter excels in inspecting your app: the Flutter DevTools.

DevTools

DevTools is defined as follows in the documentation:

> *"DevTools is a suite of performance and debugging tools for Dart and Flutter."*

DevTools can be accessed via the web browser; you may have seen the DevTools URL printed to the console when you did a `flutter run` command. However, most people will use DevTools from within their IDE, so let's explore that option further, specifically two areas that you will use often – widget and performance inspection.

If you still have the Hello World app running, then you will see a magnifying glass on the debug controls. Click this button to open up the wonderful world of DevTools.

The widget inspector

We are currently in debug mode, so the widget inspector will be opened for us, allowing us to inspect the layout of our app. The widget inspector allows us to check whether our widget tree is taking more space than needed, whether it has more widgets than needed, or whether a widget is being created at the right time/level.

Open up the widget inspector – you will have a view similar to this:

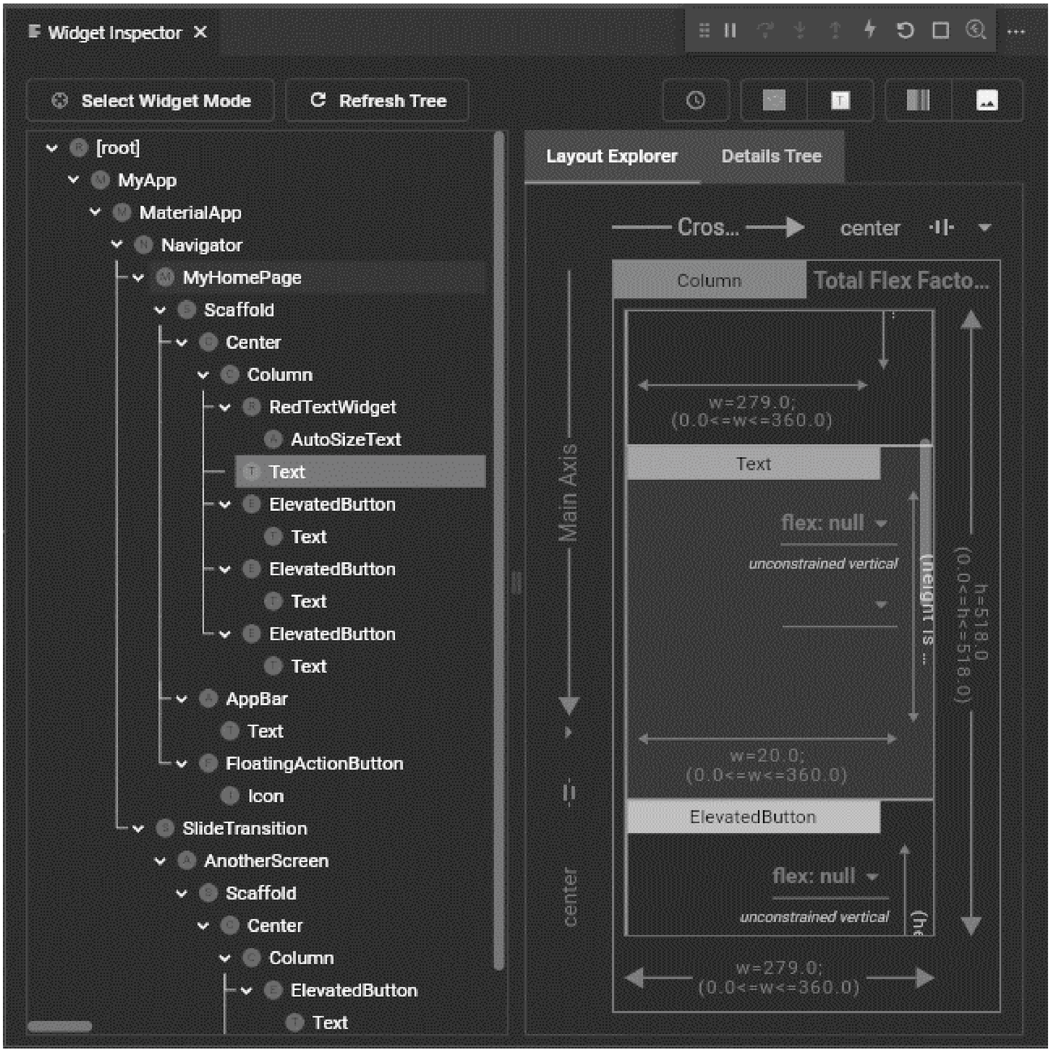


Figure 12.3 – Widget inspector in Visual Studio Code

As you can see, the widget tree is presented and we can access all the details about each widget. For web developers, this will look very similar to element explorers in web developer tools, such as the one in Chrome.

You can also manipulate the widgets by changing properties such as `flex` and `fit` to experiment with layout changes. Whenever you click on a widget in the tree, Visual Studio Code will show you the relevant code that created the widget in the `code` pane, allowing you to quickly identify why the tree is structured as it is.

The widget inspector has some powerful capabilities to assist with understanding why the widgets are positioned and behaving as they are.

The **Overlay guidelines** button will draw all of the layout rules directly onto the screen so that you can see why a widget is positioned the way it is:

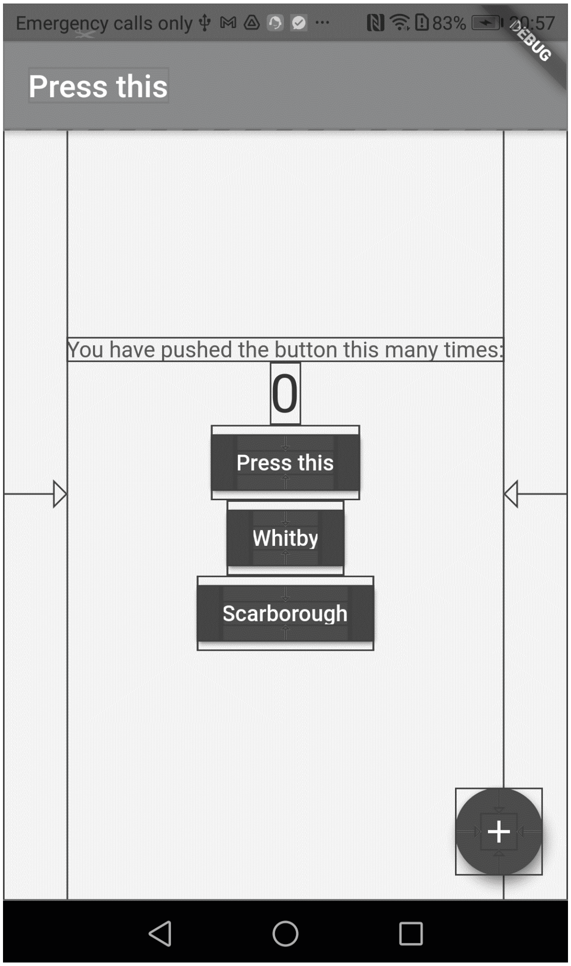


Figure 12.4 – The Hello World app with Show debug paint enabled

As you can see, **Overlay guidelines** shows arrows explaining how the layout is defined and boxes to show the boundaries of the widgets. In this example, the `buttons` column has been centered, as shown by the two arrows on the side pushing in the column. You can also see that the text box is the widest widget in the column. Therefore, the column's width is defined by the width of the `text` widget because the `column` widget resizes to match the size of its children.

Similarly, the **Show baselines** button will show how the test is positioned, which can be useful to ensure text alignment matches your expectations.

For performance improvements, the **Show borders** and **Highlight images** buttons allow you to spot excessive redraws or memory-intensive images, respectively.

For animations, the **Run animations 5 times slower** button allows you to better investigate if animations are behaving as you expected.

Finally, the **Toggle select widget mode** button allows you to tap a widget on your app and instantly see where that widget is in the widget tree. And vice versa, you can click a widget in the widget tree and instantly see the widget highlighted on the app.

Profile mode

When we execute our Flutter application in default debug mode, we cannot expect the same performance as the release mode. As we already know, Flutter executes in debug mode using the JIT Dart compiler as the app runs, unlike the release and profile modes, where the app code is pre-compiled using the AOT Dart compiler.

To make performance evaluations, we need to make sure the app is running at its maximum capability; that's why Flutter provides different execution methods – debug, profile, and release.

In profile mode, the application is compiled in a very similar way to release mode as we need to know how the app will perform in real-world scenarios. The only overhead that's added to the app is required to enable profiling (that is, DevTools can connect to the application process).

Another important aspect of profiling is the necessity of a physical device. Simulators and emulators do not reflect the performance of real-world devices. As the hardware is different, app metrics can be influenced, and the analysis might be correct. This includes running your app as a Windows app if you are developing on a Windows machine, or as a Mac app if you are developing on a Mac.

To run an app in profile mode, we should add the `--profile` flag to the `run` command (remember, it's only available on real devices):

```
flutter run --profile
```

Running in this mode, we have all of the required information to inspect the app's performance in general. Another part of DevTools is a performance analysis tool that can be used in profile mode and enables a performance overlay.

To achieve this in Visual Studio Code, click the settings cog to the right of where you would run the app in debug mode, to open the `launch.json` file. Alternatively, find the `launch.json` file in the `explorer` pane, within the `.vscode` folder.

You will see `configurations` like this:

```
"configurations": [
    {
        "name": "hello_world",
        "request": "launch",
        "type": "dart"
    }
]
```

This will run in the default `flutterMode`, which is debug mode. To add another option, update the `configurations` list so that it includes a `profile` option, like this:

```
"configurations": [
  {
    "name": "hello_world",
    "request": "launch",
    "type": "dart"
  },
  {
    "name": "hello_world_profile",
    "request": "launch",
    "type": "dart",
    "flutterMode": "profile"
  }
]
```

Once you save this file, you will see an additional option in the dropdown of run targets. This time, run the `hello_world_profile` profile version.

When the app is running, you will notice that the magnifying glass for DevTools is now a wave. Click on this to open the **Performance** page. Flutter aims to provide high-performance apps with a high frame rate and smoothness. Like debugging can help you find bugs, profiling is a useful tool that helps developers find performance bottlenecks in their applications, prevent memory leaks, or improve app performance.

When you open the **Performance** page, you will see a display similar to this:

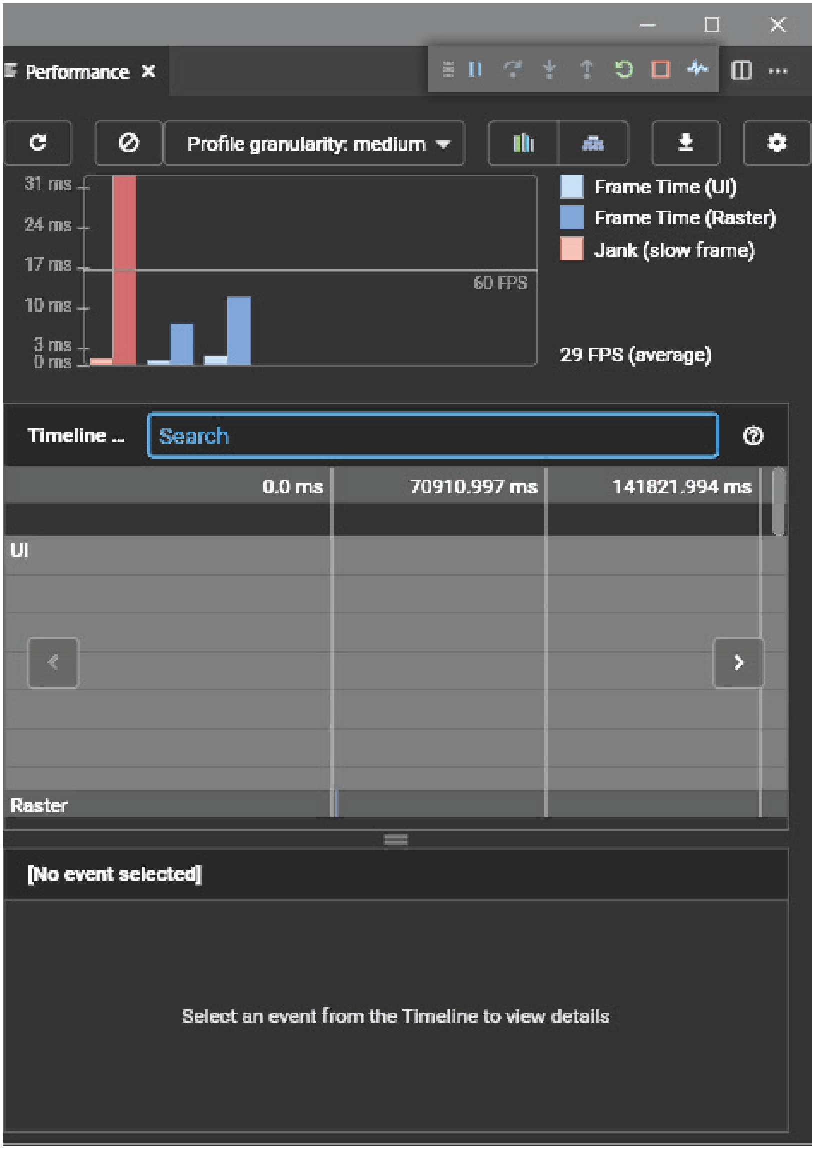


Figure 12.5 – The Performance page in Visual Studio Code

Memory, CPU usage, and other information are available through the monitor so that we can evaluate different aspects of the application.

One very useful button is the **Overlay a performance chart** button.

Performance overlay

When you use the **Overlay a performance chart** button, the performance overlay is shown on the app. The visual feedback displayed provides multiple helpful performance statistics. Specifically, it displays information about rendering time. Here is an example of the performance overlay being displayed:

Figure 12.6 – The Hello World app with performance overlay

Two graphs are displayed, representing the time to render frames taken by the two threads, UI and Raster. The current frame is displayed by a full-height vertical green bar, seen in the preceding screenshot about a quarter of the width of the screen from the left overlaying the two performance graphs. Additionally, we can see the last 300 frames and get an idea of the critical rendering stages.

Flutter uses multiple threads to do its job. UI and Raster contain the display work of the framework, and that's why both are shown in the performance overlay.

UI thread

The UI thread is where your Dart code is executed, and any Flutter framework code required to execute on behalf of your app. Any user interface requirements you specify in your code are converted into a layer tree, a set of painting commands that are sent to the raster thread.

The raster thread

This thread is where the graphics are brought to life. It does this by taking the layer tree and working with the **graphics processing unit** (**GPU**) to draw the painting commands on the screen. The thread generally includes a graphics library named Skia, although recent changes to Flutter mean that iOS apps (and soon Android apps) will use a shiny new solution called Impeller, which improves the quality of the graphics displayed to the user. You will never directly interact with this thread, but if the app appears to be running slowly, then it will often be because of something that is happening in the UI thread.

Other threads

In addition to those threads, Flutter also contains the platform thread, where the plugin code runs, and the I/O thread, where expensive I/O tasks are run. Neither of these threads appears on the platform overlay.

Summary

In this chapter, we learned about unit testing Dart so that we can be confident that our library functions are following the requirements under a range of data inputs.

We provided an introduction to Flutter widget tests and how they can be used to test widgets individually. We also looked at how they are structured with the `WidgetTester` class in the `testWidgets` function.

We also learned how to debug our app, first by looking at the debugging facilities of the IDE and then the method calls of debugging and assert.

Finally, we investigated how we can use Flutter's DevTools to explore the widget tree in debug mode and application performance in profile mode.

In the next chapter, we will finish the journey of our app by looking at how we can release it into the world for everyone to use!

Questions

This chapter was mainly provided to make you aware of the tools and techniques that are available to you, rather than any specific knowledge that needs to be retained, so use these questions as a way to check your awareness:

1. Why would you write a unit test?
2. What method would you call to check that the outcome of a test matches the expectation?
3. Describe the concept of mocking when testing code.
4. Which class would you use to test a widget?
5. There are two ways to set a debugger breakpoint – one in the IDE and one in code. Can you remember how to do this?
6. We looked at two inspectors within DevTools. Can you remember how to open them in your IDE and what their purposes are?
7. A cheeky bonus question – Flutter has traditionally used the Skia graphics library for rendering, but can you name the new rendering library that Flutter is transitioning to?

Further reading

A very interesting part of the progression of Flutter is its new rendering runtime – Impeller. Flutter has suffered from a symptom known as **jank**, where a new sequence of draw commands could slow the frame rate due to the way the **Skia** graphics library copes with these new draw commands.

Impeller, a custom-built solution, aims to solve this by pre-preparing the draw commands in advance so that frame rate reduction is avoided. If this interests you, then it is worth investigating further, starting with the Flutter docs video on the topic: `https://docs.flutter.dev/perf/impeller`.

Another topic that is worth investigating further is the Flutter **DevTools**. We only touched on the widget and performance inspectors, but there are loads of other cool tools you can use. Find out more on the Flutter docs site: `https://docs.flutter.dev/tools/devtools/overview`.

13

Releasing Your App to the World

You've written the code, run some tests, debugged some issues, and you've reached a point where your app is ready! Ultimately, you want to release your app to the world – that's why you embarked on your **Flutter** journey in the first place.

This chapter explores how you will achieve that within the **Apple App Store**, **Google Play Store**, and on the **web**. Each route to market brings its own challenges, so this chapter will act as a guide by pointing out the key steps in your release process and identifying any pain points you may need to overcome.

In *Chapter 10*, *Popular Third-Party Plugins*, we touched on how you can track the usage and issues users are seeing within your app. In this chapter, you will build on that knowledge with a deeper look at the **Firebase** tools for usage analysis and crash reporting.

The following topics will be covered in this chapter:

- Preparing your app for deployment
- Releasing your app on **Android**
- Releasing your app on **iOS**
- Releasing your app on the web
- Tracking app usage and crashes

Technical requirements

You will need access to your development environment again for this chapter, as we will add a plugin to the `Hello World` project. Look back at *Chapter 1*, *What is Flutter and Why Should I Use It??* if you need to set up your **Integrated Development Environment** (**IDE**) or refresh your knowledge of the development environment requirements.

You can find the source code for this chapter on GitHub at the following link:

`https://github.com/PacktPublishing/Flutter-for-Beginners-Third-Edition`

Preparing your app for deployment

At this point, you may be thinking that you've been successfully running your app on simulators, emulators, and devices, so the job is done! From a Flutter point of view, you are virtually ready for production – but there is one piece we need to revisit as a refresher.

Let's remind ourselves of a couple of Flutter's aims. One key aim is to ensure that app development is optimized for developers as far as possible to ensure the following:

- Reduce the feedback loop so that developers can see how their changes have changed the app without a lengthy compile time. Hot reloading is an example of this.
- Have great debugging tools that allow the developer to really understand what is going on within the app. The widget tree in **DevTools** is an example of this, allowing you to manipulate the widget tree in real time and see exactly how it aligns with your code.

An app framework that can allow these features is likely to have very slow-running apps because the code must be compiled **just in time** (**JIT**) to allow for code changes, and must share lots of information with the outside world to allow the debugging and manipulation of widgets to take place.

On the flip side, Flutter has a key aim to be incredibly performant, rivaling the speed and responsiveness of native apps. You may remember from *Chapter 2*, *An Introduction to Dart*, that **Dart** has a killer feature that allows these two contradictory aims to make sense, and that is because Dart has two different ways in which it builds code.

When preparing an app for release, things such as on-the-fly compiling provided by Dart **JIT** do not make sense – instead, the best thing is to have a smaller, optimized, and performant app provided by the Dart **ahead-of-time** (**AOT**) compiler. In release mode, debugging information is stripped out of the app and compilation takes place with performance in mind. Remember, in release mode, like in profile mode, the application can only be run on physical devices (for the same reasons too), although on the web (and also for Windows, Mac and Linux builds), the laptop you are writing the code on can be the device.

Interestingly, it is possible to run the app in release mode. We just need to add the `--release` flag to the `flutter run` command and have a physical device to run the app on. Although we can do so, we typically do not use the `flutter run` command with the `--release` flag. Instead, we use this flag with the `flutter build` command to have a built app file in the target Android/iOS/web formats for distribution.

However, Flutter has optimized this step for each platform you are releasing to, so we will take a look through how to create a release build for the three platforms (iOS, Android, and web) in detail later in the chapter.

It's worth noting that it wasn't really until this point in the development process that we had to start getting platform-specific. Flutter has done an incredible job of ensuring that 99% of what you work on is platform-agnostic, and even during the next step, there has been lots of work to minimize the amount of platform-specific work needed.

Preparing the stores

Before you can release your app, you may have to do a little bit of admin to ensure you are able to use each of the platforms.

The first step is to ensure you are a registered developer on the mobile app stores because releasing an app on the Google Play Store and App Store requires valid publisher accounts. Refer to the documentation of both platforms to learn how to publish to their stores after creating a release version of your app.

Something to bear in mind when looking at how to distribute an Android app is that the Play Store isn't the only game in town and there are other Android stores available. However, only the Play Store has the Google client services that your app may depend on (such as Google Maps). Also, many of the plugins, such as in-app purchases, do not support other stores (such as **Amazon Appstore**). Therefore, this guide focuses on the Google Play Store because most releases will follow that route.

Registering as a developer

To register with the Play Store as a developer, and therefore be able to upload your app, Google requests a one-off $25 registration fee. You can register at the following link:

`https://play.google.com/apps/publish/signup`

Similarly, the Apple App Store requests a $99 membership fee per year, which you also need to pay before you can upload an app. You can find details and register at the following link:

`https://developer.apple.com/programs/enroll/`

There are generally no other direct costs associated with releasing your app on the two stores. Hosting your app in the stores is free because the stores make their money from sales fees.

A business model

It is worth highlighting at this point that there are sales fees that both platforms impose. If you are building a business plan around the sales of your app, then it is important that you know upfront the kind of sales fees you will encounter on the two mobile platforms. These tend to fall into three areas:

- **App purchases**: If you require a one-off charge from the users of your app for them to either use the app or to continue using it after a free trial period, then both stores will charge you a fee of 30% on the sale. So, if you sell your app for $1 on the store and make a sale, Apple or Google will take 30¢ of that sale as a sales fee, leaving you with 70¢.

- **Subscriptions**: Some apps follow a subscription model to take regular payments from users to use their app. This is generally for apps that constantly add new content (for example, a wellness app that regularly adds new meditation videos) or have an ongoing service that users can access (for example, a workout app with regular live workouts). Again, the stores will take 30% of a new subscription for the first year, and then 15% if you keep a customer for more than 12 months.
- **In-app purchases**: An in-app purchase is a sale made within the app that is designed around unlocking new content or new parts of the app. All in-app purchases are charged at 30%. You may think that you could just push the user to another purchase channel (for example, a link to a website to make the in-app purchase); however, both app stores are very strict and will not allow alternative purchase routes to be advertised within the app. Any attempt to do so will lead to rejection at the app review stage. Note that this 30% fee only applies to digital goods or services, so physical goods such as clothing or physical services such as a taxi ride will not incur the fee.

Some interesting changes are developing in this space, as some commentators are suggesting monopolistic practices may be at play. Apple has already dropped its 30% sales fee to 15% for companies making less than $1 million in revenue from App Store sales per year, and other changes may be likely in the future.

As a cautionary note, there are very strict guidelines around what your app can contain, especially on the app stores, and the documentation is long and difficult to read. The best advice is to try and look at the documentation as much as possible when your business model relies on a certain fundamental feature but also to try and release prototypes as soon as possible so that you can go through the review process and identify issues early.

A cautionary tale

A feature of one of our apps is to allow parents to donate to a fundraising cause that a school has set up. We spent lots of time developing the feature by integrating a payment provider and making an intuitive and gamified flow for the parents. Proud of our work, we submitted it to the two stores for review and were mortified when it was rejected by Apple due to a hidden-away requirement that only apps from charities can have fundraising features. If we had made a quick prototype, we would have encountered this issue in an early review, but we didn't even know it could be a reason for rejection, so we didn't follow this advice!

Preparing for the web

Releasing your app to the web has quite different preparation requirements. There is no ubiquitous store that all web users will visit first, there is no over-arching company that you register to, and there are no strict payment models or development guidelines to follow. Therefore, the guidance here will have to be more general, but some of the key things to think about are as follows:

- **Hosting**: Your app will need to live somewhere on the web, and generally this will require getting a third-party company to host your code in a way that other web users can access. One easy option is to use Firebase hosting, especially if you are using other Firebase services.

- **Domain**: For users to be able to find your app, you will need a web address, or domain, which users type into their web browser to access your site. There are plenty of companies willing to sell you a domain. Once you have one, link it up to your hosting supplier using **DNS** magic.
- **Payments**: In mobile stores, you have the simplicity of taking payments using the store services, such as in-app payments and subscriptions. These services are not so easily available on the web, but on the flip side, when you do find a payment solution, you are unlikely to incur such high sales fees. Options here include the large payment providers of **Stripe** and **Square**, which have plugins for Flutter.

So, let's assume you are registered to the stores (or have a web hosting solution ready), and you have a viable business plan to make some money – it's now time to release your app.

Releasing your app on Android

In Android, **appbundle** is the format expected to be published in the Google Play Store. When we run the `flutter build appbundle` command, we generate the file ready for deployment.

You may have previously heard of the Android **APK** (short for **Android application package**) option instead of appbundle. Releasing your app as an APK is no longer allowed by Google as an option on the Play Store. Under the covers, an appbundle effectively generates device-specific APKs but hides that complexity away.

Before we generate the file for deployment and publishing in any store, we need to make sure all of the information is correct (that is, the name and package), all needed assets are provided, and all platform-specific adjustments are made.

Let's start by preparing our Hello World app for release on Google Play so that we can review all of the final steps to publishing a Flutter app.

AndroidManifest and build.gradle

For each platform, Flutter has a folder that holds all of the files needed to configure the build processes for that platform. You will see `ios`, `android`, and `web` folders in your project. Generally, you should ignore these folders unless you need to make configuration changes required for plugins.

In Android, the meta-information about the app is provided in the `android` folder in both the `app/src/main/AndroidManifest.xml` and `app/build.gradle` files, so we may need to review and make some adjustments in these ready for the app release build.

Permissions

One important step we need to do is review the permissions requested in the `app/src/main/AndroidManifest.xml` file. Asking only for the permissions that your app will actually need is a good and recommended practice, as your app may be analyzed and your publication may be revoked if you request more than the required permissions.

In our Hello World app, our initial `app/src/main/AndroidManifest.xml` file didn't have any permissions required. If you have added plugins to it, then you may have needed to add permissions. Here is an example file with some permissions requested:

```
<manifest xmlns:android="http://schemas.android.com/apk/res/android"
package="com.example.hello_world">

  <uses-permission
        android:name="android.permission.INTERNET"/>
  <uses-permission
        android:name="android.permission.READ_CONTACTS" />
  <uses-permission
        android:name="android.permission.WRITE_CONTACTS"/>
  <uses-permission
        android:name="android.permission.CAMERA" />
  <uses-feature
        android:name="android.hardware.camera"
        android:required="false" />
  ...
</manifest>
```

The permissions your app is requesting are listed within the `uses-permission` tags. The names of the permissions are defined by Android, and the plugins will guide you to add the correct permissions as required.

Besides permissions, there is also the `uses-feature` tag, which can limit installation to devices with a specific feature available. The use of `android:required` here is critical if the camera is not required, allowing devices that do not have a camera to still install and use the app. When you go through the publishing process on the Play Store, there are warnings if one of your permissions is likely to restrict the devices the app can be installed on. You should review this because a slight change to your `AndroidManifest.xml` file may make a huge change to your available market.

Some of the permissions are *normal permissions*, which means they are granted on the installation of the app, and some permissions are requested at runtime, so the user needs to choose to grant the permission to your app. You may have seen other apps requesting permission to view your photo album or access your camera. Your app will need to cope with users choosing not to enable permission.

Meta tags

Another very important step is to review the meta tags added to the app for working with services such as **AdMob** or **Google Maps**. You may have set up the app to use test configurations, so now is the time to review your settings and make sure they are set up for production use. Here is an example of the setting for AdMob:

```
<manifest xmlns:android="http://schemas.android.com/apk/res/android"
package="com.example.handson">
  ...
  <application>
    ...
    <meta-data
      android:name="com.google.android.gms.ads.APP_ID"
      android:value="ADMOB-KEY"/>
  </application>
</manifest>
```

Again, the plugin documentation will guide you to add the correct metadata tag within the `AndroidManifest.xml` file.

Application icon and name

Until now, when we launch the application in our tests, you can see the app icon is a Flutter logo. For release, you need to create a unique icon to make sure your users can distinguish your app from the millions of other apps available. Also, you need to come up with an awesome name for your app. Now is the time to do both.

When setting your icon, there are two options available to you – an easy automated way, and a harder manual way. For completeness, let's first look at the harder manual way while also setting the app name.

Manually setting the icon and name

The icon and name are defined in the `AndroidManifest.xml` `application` tag. By default, the icon refers to the default Flutter icon, as you can see:

```
<manifest ...>
    <application
        android:label="hello_world"
        android:icon="@mipmap/ic_launcher">
     ...
    </application>
</manifest>
```

So, we need to make two changes:

- Change the `label` value to the final name of your app – that is, the name by which your users will recognize your app
- Update the icon that is pointed to by the `icon` value

In Android, image resources such as the icon are located in the `android/app/src/main/res/` directory. Under this directory, there are many folders with variants of a resource, tailored to specific regions, screen sizes, system versions, and so on.

We need to replace the `ic_launcher.png` file in each of the `mipmap-xxxdpi` folders to make a full replacement of the app icon.

Check the **Material Design** guidelines on icons to make sure you create an awesome icon for your app:

`https://material.io/design/iconography/`

Setting icons using a plugin

You have a lovely icon for your app and you don't want to spend ages resizing it for all the different device types and different platforms. This is where the awesome **flutter_launcher_icons** plugin comes in handy.

To use the plugin, first, modify your `pubspec.yaml` file to add the plugin to the `dev_dependencies` section:

```
dev_dependencies:
  flutter_launcher_icons: "^0.13.1"
```

And then further down, add details of the icon you want to use in the app:

```
flutter_icons:
  android: true
  ios: true
  image_path: "assets/icon/icon.png"
```

The `true` value beside the `android` and `ios` properties specifies that the plugin can override the existing launcher icon for those platforms.

`image_path` tells the plugin where the icon image file is. Note that this is placed in your `assets` folder within your app.

Make sure you get this dependency downloaded and ready to go by running the following command:

```
flutter pub get
```

Then, run the plugin itself to generate all the icons:

```
flutter pub run flutter_launcher_icons
```

Magically, all of your icons are generated in the right sizes for each platform. You can also use the plugin to generate icons for the web.

After changing the name and replacing the icon, we need to review the `app/build.gradle` file to make the final adjustments for the deployment.

Application ID and versions

The `applicationID` value is what makes an app unique in the Play Store and the Android system. A good practice is to use the organization domain as the package and have the app name following it:

```
com.companyname.appname
```

In our Hello World app, we are using `com.example.hello_world` as the application ID. Make sure to review your application ID because it cannot be changed after you upload the app to the store.

You can find this code in the `app/build.gradle` file, inside the `defaultConfig` section:

```
    defaultConfig {
        applicationId "com.example.hello_world"
        minSdkVersion flutter.minSdkVersion
        targetSdkVersion flutter.targetSdkVersion
        versionCode flutterVersionCode.toInteger()
        versionName flutterVersionName
    }
```

As you can see, we can change more settings than just `applicationId`.

The `minSdkVersion` setting denotes the minimum version of the Android API level that our app will be supported on. In Flutter, the `minSdkVersion` setting is typically changed in two cases:

- If the Flutter framework requirements change
- If we use a plugin that requires a higher minimum **Software Development Kit** (**SDK**) version

The `targetSdkVersion` setting denotes the Android API level that our app is designed to run on. This is used to manage what manifest elements and behaviors are available. Generally, this can simply be set to the latest Android API level.

Both of these use a setting from our `local.properties` file. If you need to make a change that diverges from the default values, then add the following lines to your `android/local.properties` file:

```
flutter.minSdkVersion=21
flutter.targetSdkVersion=30
```

The `versionCode` and `versionName` settings are automatically drawn from our `pubspec.yaml` file. So, suppose our `pubspec.yaml` file contains the following:

```
version: 1.0.0+1
```

This value will be split into a `versionCode` of `1` and a `versionName` of `1.0.0`. The beauty of deriving this from the `pubspec.yaml` file is that it ensures our versioning is consistent across platforms.

Signing the app

The signing step is the final but most important step before releasing an app to the public, even if you do not want to publish it in the Google Play Store. It is the signing that confirms the ownership of the application – in short, whoever has the signature owns the app. You need this so you can manage your app by doing activities such as publishing updates to your app.

Start by taking a look at the `buildTypes` section of the `app/build.gradle` file:

```
    buildTypes {
        release {
            signingConfig signingConfigs.debug
        }
    }
```

It contains the `signingConfig` property, pointing to a default signing configuration. We need to change this to our own signing configuration, which we do by performing the following steps.

1. Generating a keystore file

We generate our developer **keystore file** (you can use the same keystore for multiple apps). This is done with the following command:

```
keytool -genkey -v -keystore DESTINATION_FILEPATH -keyalg RSA -
keysize 2048 -validity 10000 -alias key
```

Follow the prompts and this will generate a keystore in the `DESTINATION_FILEPATH` path.

2. The key.properties file

Create a `key.properties` file in the `android` folder with the following content:

```
storePassword=<password used when generating key>
keyPassword=<password used when generating key>
keyAlias=key
storeFile=<key store file path>
```

3. Loading the key.properties file

In `app/build.gradle`, we load this new `key.properties` file and create a new `signingConfig` class for it. Just before the `android {` line, add this configuration:

```
def keystoreProperties = new Properties()
def keystorePropertiesFile = rootProject.file('key.properties')
if (keystorePropertiesFile.exists()) {
    keystoreProperties.load(new
    FileInputStream(keystorePropertiesFile))
}

android{
  ...
```

This configuration defines a new `keystoreProperties` variable of type `Properties` and then defines a variable of type `File`, which points to our new `key.properties` file, and finally, if the file exists, we load the contents of the file into our `keystoreProperties` variable.

4. Using keystoreProperties

We now need to use `keystoreProperties`, which we read in from the `key.properties` file, to create a new signing configuration named `release` that we can refer to later in the build process:

```
    signingConfigs {
      release {
        keyAlias keystoreProperties['keyAlias']
        keyPassword keystoreProperties['keyPassword']
        storeFile keystoreProperties['storeFile'] ?
        file(keystoreProperties['storeFile']) : null
        storePassword keystoreProperties['storePassword']
      }
    }
```

This configuration simply links the build variables of `keyAlias`, `keyPassword`, `storeFile`, and `storePassword` to the properties we read in from `key.properties`.

5. Using the new signing configuration

Finally, replace the `signingConfig` property in the `release` option in the previous `buildTypes` section with the new one:

```
buildTypes {
  release {
    signingConfig signingConfigs.release
  }
}
```

Now, when we build the release appbundle, the app will be signed with our own key. These steps may have seemed intimidating and confusing, but you only need to do this once, and if you follow the steps accurately, you will have no problems. Get it sorted and then forget about it (until you build your next app anyway!)

Building and uploading your appbundle

With all the configuration ready, it's time to build the appbundle. You do this by running the following command:

```
flutter build appbundle
```

This will generate an `appbundle` file at the following location:

```
<project location>/build/app/outputs/bundle/release/app.aab
```

In the **Google Play Console**, you will be able to create a new release and upload your `appbundle` as part of that.

There are several types of releases available in the Google Play Console:

- **Internal testing**: The app is only available to a small subset of specified testers. New versions are made available to testers within a few minutes.
- **Closed testing**: Similar to internal testing, but with a slightly larger audience, and there may be a review delay for the release.
- **Open testing**: A wider audience again, and anyone can join an open test and then submit private feedback.
- **Production**: Your release to the world (or specific geographies if you so choose). This may have a lengthy review before being available on the Play Store.

As soon as you upload to the Play Store, you should aim to do an internal test so that you can check there are no surprise gotchas before you share the app more widely. For all types of testing or production, testers simply need to go to the Play Store and the correct version of the app will be available for them to install.

You will also need to set up your store presence with images, screenshots, descriptions, links to your privacy and terms-of-service documents, and contact details, among other things such as content ratings. It can take a long time to set up the store presence, so don't leave this to the last moment assuming it will only take a few minutes.

And there you have it – you are good to go on Android. Let's now look at the Apple iOS release process.

Releasing your app on iOS

Releasing on Apple iOS is more complex when compared to Android. Although you can test on your own device when developing, making an app public requires you to have a valid **Apple Developer** account with the ability to publish on the App Store, as it's the only supported app publishing channel.

Like Android and the configuration changes we had to make in `AndroidManifest.xml`, iOS has a similar configuration file that is used by the iOS build tool, **Xcode**.

> **What is Xcode?**
>
> Xcode is an IDE that is only available on macOS and is used for the development of native iOS apps. You can download it from the Apple App Store for free. It is used by Flutter to package your app code ready for release on the App Store.

iOS apps can only be built on a Mac computer, so if you are a Windows or Linux user, you will either need to invest in a Mac or get a virtual machine you can use.

App Store Connect

In Android, we did not need to configure anything in the Play Store Console before we created an `appbundle` ready for publishing. In iOS, the process is different. The upload and publishing are managed inside Xcode, and to upload the app, we first create a record on **App Store Connect**. Then, on Xcode, we build and upload our iOS app using the App Store Connect bundle identifier. To register the app, perform these steps:

1. Registering the bundle ID

All iOS applications are associated with a **bundle ID**. This is a unique identifier that is registered with Apple.

To register your app bundle ID, head over to your developer account web page at `https://developer.apple.com/account/resources/certificates/list`:

1. Select the **Identifiers** section.
2. Click **+** and select **App Ids**.
3. Select the type as **App** (not **App clip**, which is like a very lightweight app).

4. Enter your new bundle ID under **Explicit Bundle ID**. This ID can be (and, for simplicity, should be) the same as the one you set in your `applicationId` for the Android build – so something such as the following:

   ```
   com.companyname.appname
   ```

5. To finish setting up your bundle ID, complete the registration, including adding any required capabilities.

2. Creating your app entry

Next, create an app in the App Store Connect portal at `https://appstoreconnect.apple.com/`:

1. Open the **My Apps** section.
2. Click **+** and create a **New app** offering.
3. Enter your app details, ensuring that the iOS platform is selected, and click **Create**.
4. Open the App Store tab for your app, and then the **App Information** option from the side menu.
5. Select the bundle ID we registered in the previous step.

After completing these steps in App Store Connect, let's look at configuring the app in Xcode.

Xcode

In Xcode, we need to make a few changes to get the app ready for release. We need to change the application icon, public name, and bundle ID. This is very similar to what we did in Android.

So, open Xcode on your Mac (or virtual machine), and you will get a popup asking for the project location. Flutter has already created a workspace file in your project, so point Xcode to the location:

```
<project location>/ios/Runner.xcworkspace
```

Note that there is also a file in that folder called `Runner.xcodeproj`. Do not use that file, as it will not set up Xcode correctly for your project.

Xcode will then pop open and show you your app details:

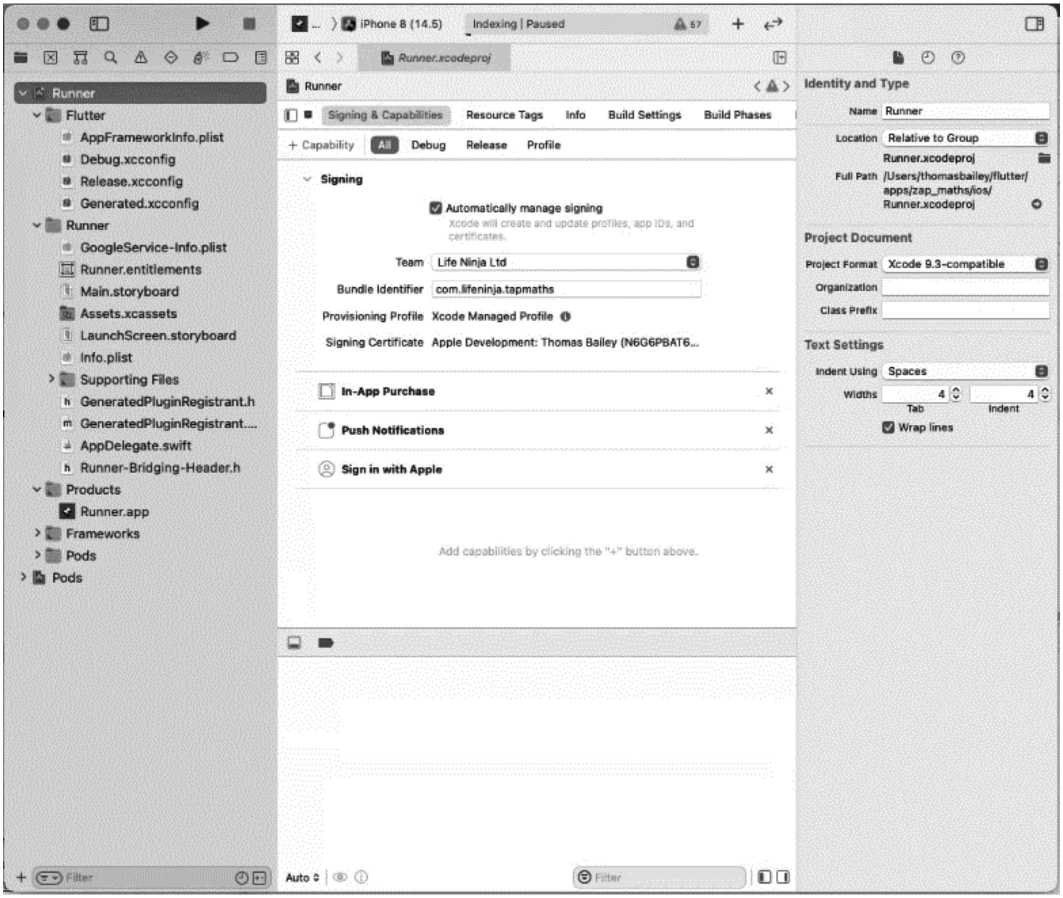


Figure 13.1 – The Xcode tool

Ensure you have the *Project Navigator* view open and the top-level `Runner` folder is selected.

Application details and bundle ID

In the **General** tab of the Runner project, you can edit the application *display name*, which is the name of your app.

Set **Bundle Identifier** to the same value as you specified in the *Application ID and versions* section earlier in this chapter. Keeping the application ID consistent across platforms will make it much easier to maintain your app in the future, and will reduce the chance of configuration issues as you add new plugins and services to your app.

Under **Deployment Target**, you can set the minimum required iOS version, which is *8.0* by default (the minimum version Flutter supports). As discussed in the Android section, this minimum version will likely be modified based on the plugins that are being used by your app. For example, the **flutter_stripe** plugin requires a minimum iOS level of *13*.

If you do need to change the **Deployment Target** setting, then you will also need to update the `ios/Flutter/AppframeworkInfo.plist` file and set the `MinimumOSVersion` value to match the value you set in Xcode.

Note also the *Version* and *Build* values – they are similar to the version name and version code in Android respectively. Each time you upload a new version of your app to the App Store, you need to ensure you have increased the version value in the `pubspec.yaml` file; otherwise, the build will be rejected by App Store Connect.

App icon

We saw in the Android section how we can use a plugin to generate the app icon. I would strongly recommend following that approach, but for completeness, here is the process for manually updating the iOS app icon.

Firstly, it is useful to review the iOS app icon guidelines to ensure your icon adheres to its constraints. One gotcha is that icons with any transparency are rejected, so ensure your icon is fully opaque. The guidelines can be viewed here:

`https://developer.apple.com/design/human-interface-guidelines/app-icons`

Once you have an icon you are happy with, in Xcode, select **Assets.xcassets** in the `Runner` folder and add your icons in all the various sizes and resolutions.

Signing the app

Like on Android, we need a way to assert the ownership of the application. In this case, Xcode manages it for us, and we do not need to touch any file directly. When we register as an **Apple Developer** and enroll in the **Apple Developer Program**, we have all of this prepared for us automatically.

If you move to the **Signing & Capabilities** tab, you will see that **Automatically manage signing** is selected. If you decide to have complex functionality, such as **Apple Pay**, then you will probably need to manage signing more closely. Nevertheless, generally, this setting is sufficient.

Ensure that your **Team** setting has correctly been set. If you cannot select it from the drop-down menu, then select **Add Account…** and update the values.

After these settings have been configured, we can build an iOS version of the app.

Building and uploading

Much like the Android process, there is a *build* step and then an *upload* step. To build the code, run the following command:

```
flutter build ipa
```

This will build an `ipa` file, which, a bit like `appbundle`, contains the iOS app bundles within it, as well as some other configuration files.

The first step of this build process is where the **CocoaPods** are installed and, as discussed in *Chapter 9*, *Flutter Plugins – Get Great Functionality for Free!*, you may want to review the *Common issues* section of that chapter if you have any issues at this stage.

When you have successfully built the `ipa` file, you will need to open Xcode and choose to open it at the following location:

```
build/ios/archive/MyApp.xcarchive
```

This will pop up a window showing all of your uploads of the app. Select **Distribute App** to start the upload. You will need to review some build settings before the upload commences, but the default selections should be fine.

Once the upload has been completed, there are some automated reviews that Apple runs on its servers to ensure the app is configured correctly. If there are any issues, then you will receive emails from their review system detailing the suggested corrections.

After about 30 minutes, the automated reviews should be complete, and you are free to use your app for testing or put it forward for production review. Testing on iOS is a little different from Android. There is only one testing stage, but you can choose whether testing has an internal and/or external audience. If you choose an external audience, then a short review is needed before the app is made available.

Testers have to install the **TestFlight** app to be able to install pre-release versions of your app. This is relatively painless, and in many ways preferable to the Android approach, because it is very easy to switch between test and production versions of an app.

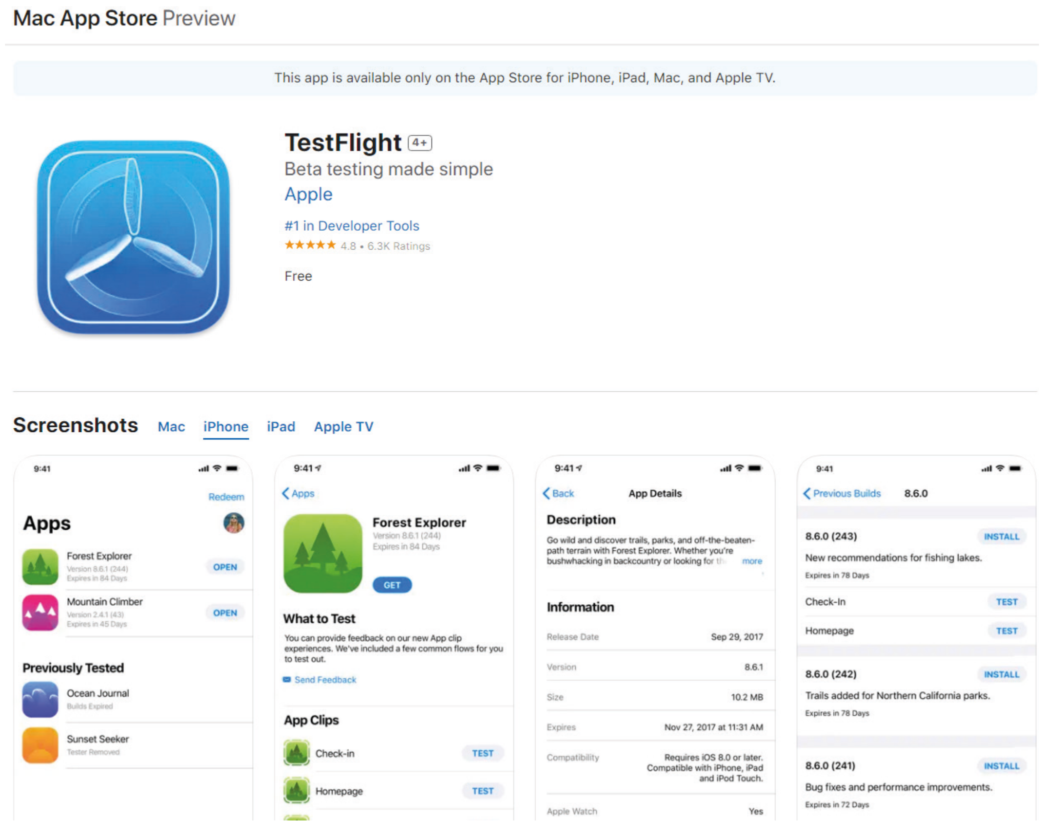


Figure 13.2 – TestFlight app App Store page

Again, like Android, before the production release, you will also need to set up your store presence with images, screenshots, descriptions, links to your privacy and terms-of-service documents, and contact details, among other things such as content ratings. It can take a long time to set up the store presence, so don't leave this until the end, assuming it will only take a few minutes.

Once you put an app version forward for production review, you will have to wait a couple of days for your app to be reviewed before it is released. There are some great controls on iOS to manage the release process after review completion. In addition to automatically releasing on review completion, you can choose to manually release or schedule the release at a specific date and time. On Android, the same control is not available, and you are not even alerted when the review and release are completed!

Make sure you install the **App Connect** app on your phone so that you can get push alerts as your app moves through the review stages. If you notice your app is stuck in the *In review* state for a long time, there are a few possible reasons for this which I've experienced during our app releases:

- The app is failing to install on the reviewer's device.
- The reviewer is having issues logging into your app, or following your specific guidance if you have supplied some.
- There is something that the reviewer thinks may contravene an app guideline, and has asked for assistance from another reviewer. This one sometimes happens if the review is happening outside of US working hours and the reviewer wants guidance from a US team member.

Ultimately, there are many reasons why your app may get stuck in the review state, but getting stuck there suggests something isn't quite right, and it is worth starting to investigate possible issues early so that you can diagnose the problem quickly and restart the review.

I'll be honest with you – releasing on iOS is definitely the hardest platform to release on. The App Store review process is infamously difficult to traverse. However, I've generally found that any review violations are clearly explained and, on the odd occasion we feel the need to appeal a decision, our appeal has been upheld. In contrast, the web release process has literally no review to go through. Let's now look at the web release process.

Releasing your app on the web

Compared to the configuration headaches of Android and iOS, the web release process can be much simpler. You only need to run the following command:

```
flutter build web
```

This will generate the app and all required assets and place them into the following folder:

```
/build/web
```

The trickiest part is to decide how to host your web app. As mentioned previously, Firebase hosting is a great choice for this. Not only is the setup very easy but it's also cheap until you start to really scale up.

Firebase hosting

To set up Firebase hosting, set up a Firebase account (as discussed in *Chapter 9*, *Flutter Plugins – Get Great Functionality for Free!*). Then, on your local machine, install the **Firebase CLI** (explained at the following link):

`https://firebase.google.com/docs/cli`

This will give you the ability to run `firebase` commands from your command line.

Next, run the Firebase initialization command on your project:

```
firebase init
```

This will connect your Flutter project to your Firebase project.

Finally, deploy your app to the hosting by running this:

```
firebase deploy
```

And your web app will be uploaded and made available publicly.

However, as discussed in the Android and iOS instructions, it is useful to have a testing option before you go live. In Firebase hosting, there is also a way to run testing in advance of the production release. To do this, run the following command:

```
firebase hosting:channel:deploy <test_name>
```

This will create a temporary deployment channel with an obscure URL that you can share with testers and get feedback. If you use the same `test_name` value on future deployments when you act on the feedback from testers, then you will have to update the same test version at the same URL, and testers will automatically see your updates.

PWA support

Flutter web apps include support for the core features of an installable, offline-capable **progressive web app** (**PWA**). This is currently a work in progress, but quite well advanced, so if this is an area that is important to you, then take a look and engage with the Flutter development team, which is keen for feedback.

Now your app is on its way to production, let's see how we can keep track of it out in the wild.

Tracking app usage and crashes

When your app is in production use, it can be very hard to know how the app is being used and whether your users are encountering issues. Knowing when there are issues with app usage or crashes at the earliest opportunity is especially important when your app is released on mobile stores because the update cycle can take days.

There are two Firebase tools that are great for tracking this information, **Crashlytics** and **Google Analytics**, and we looked at how to set them up in *Chapter 10*, *Popular Third-Party Plugins*. In this chapter, let's take a look at some of the output that is generated and how that can help us as we improve our app.

Crashlytics

Every time your app has an unexpected crash, or you specifically send a crash report from within your code, Crashlytics will receive that information and display it on the dashboard.

This can be especially useful if you have an asynchronous operation that doesn't directly impact the running of the app but stops some underlying service from functioning within your app. For example, a database listener may fail and Crashlytics will report this. The user of the app may not actually know that the failure has occurred, so wouldn't report it to you, but you can see from the dashboard that the issue has occurred, and you are able to start investigating a fix.

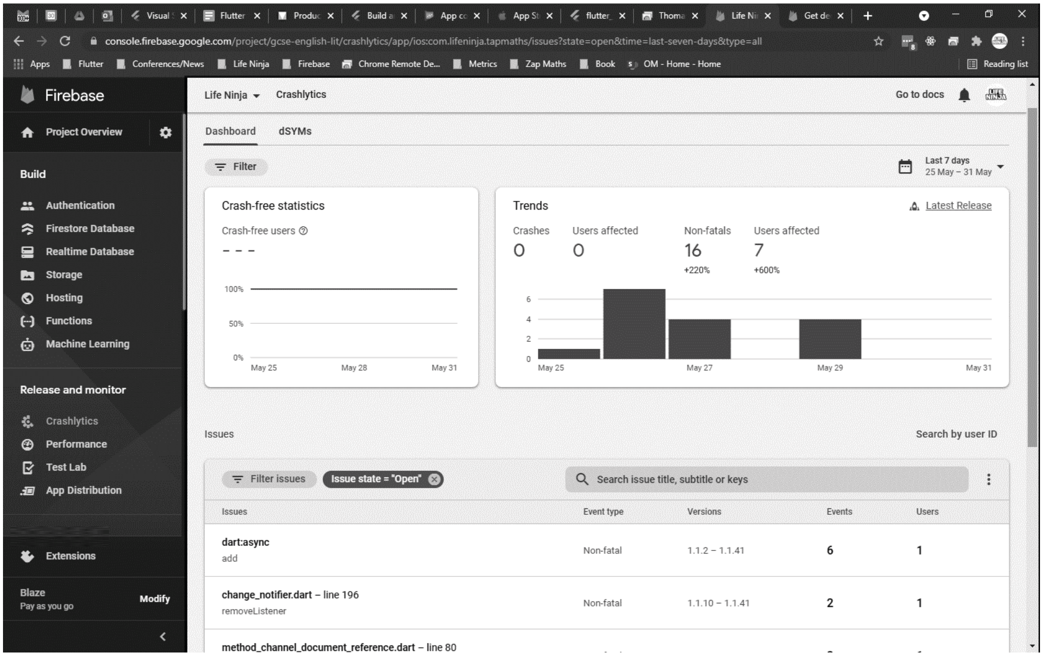


Figure 13.3 – Crashlytics dashboard

The Crashlytics dashboard is relatively easy to navigate. It shows the number of issues impacting users, the versions of the app the crash was on, whether the crash was fatal (that is, the app closed and had to be restarted), details about the device the crash was recorded on (such as the operating system version and manufacturer/model), and, most usefully, the stack trace when the crash occurred.

When you build your app for release, if you have Crashlytics configured, then the Android mapping file or iOS debug symbol (`dSYM`) file is uploaded to the Crashlytics server. This means that when a stack trace is created by the app, this can be mapped to your code and specifically the files and line numbers, allowing you to find the failing code quickly and easily.

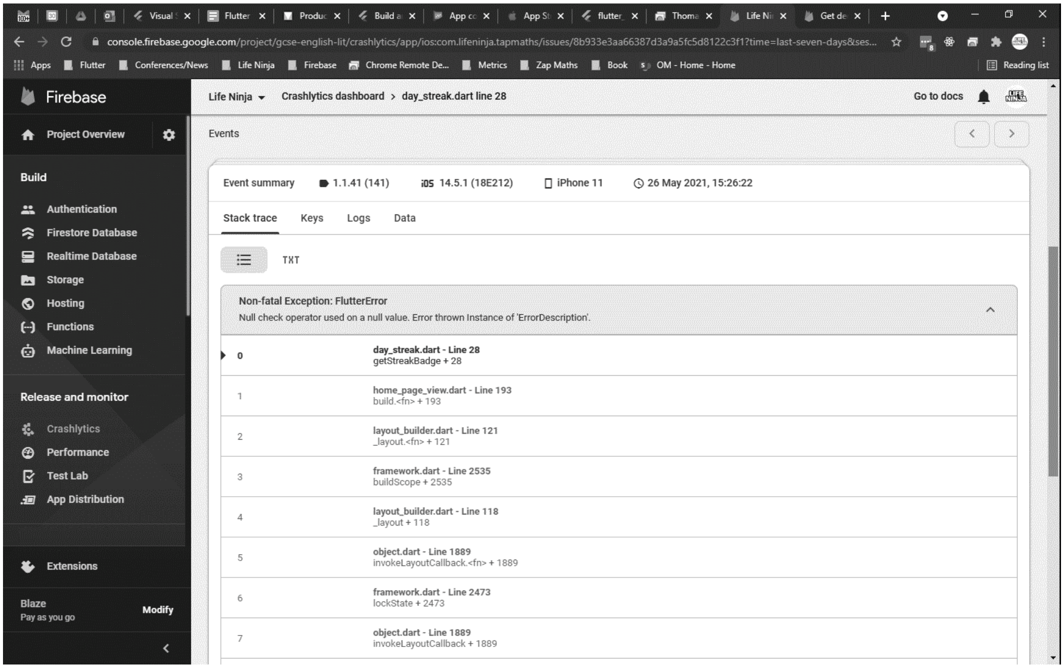


Figure 13.4 – Example of a crash report

Crashlytics will group issues where they are similar, allow you to manage whether an issue is resolved, and alert you when a resolved issue reappears.

Google Analytics

If you want to track how your app is used, there are few tools as well known as Google Analytics. Initially used by many people to track traffic through a website, it is now also available for mobile apps.

Google Analytics is especially useful if you are trying to convert users. Perhaps there is a page to unlock features or to make an in-app purchase, and you want to see how many users you are converting.

To do this, within your app, you will record *events* that denote either an action or a navigation by the user. These are reported back to Google Analytics, allowing you to get a view of how users are traversing your app.

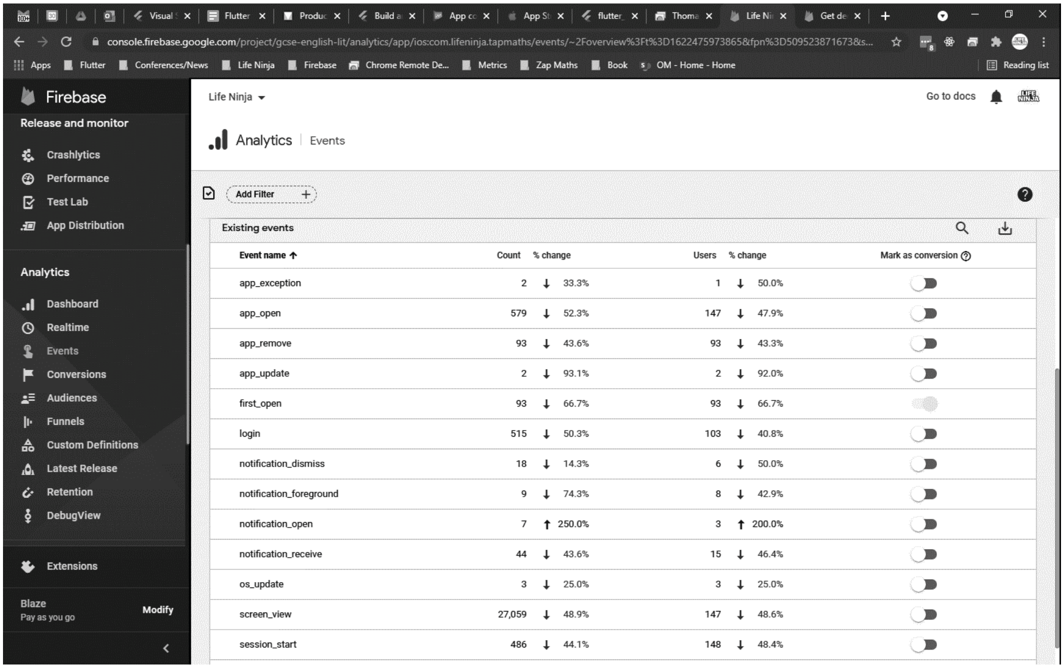


Figure 13.5 – Google Analytics events

Additionally, Google Analytics adds useful data such as demographics and user location, allowing you to see what your audience is like.

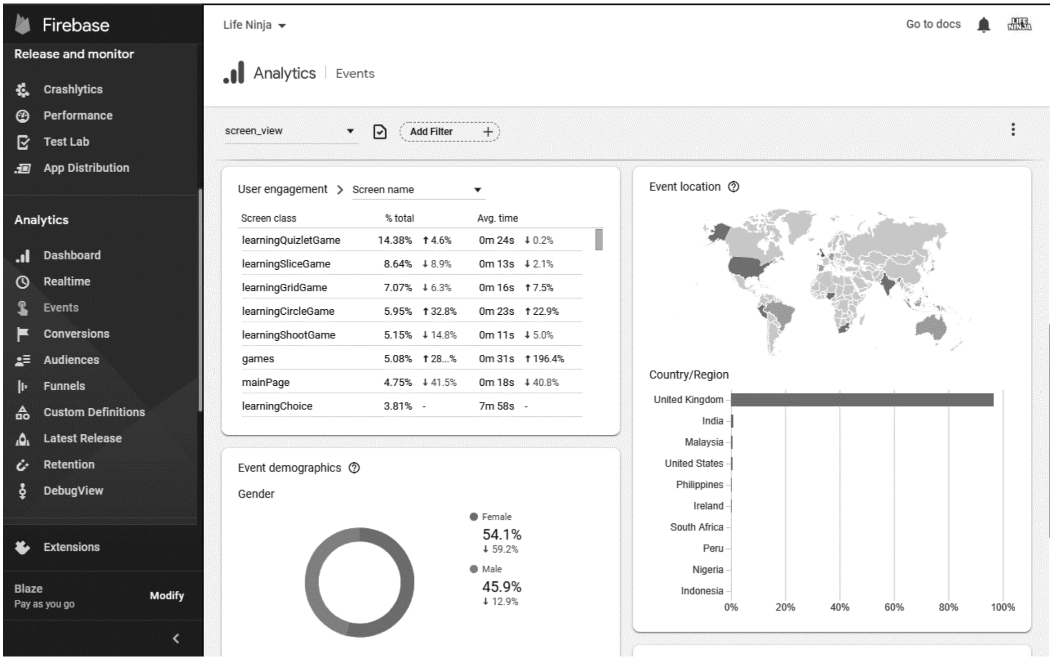


Figure 13.6 – Diving into further details on Google Analytics

In this example, we've dived into one event type, `screen_view`, and can see the breakdown of the pages within the app that users are accessing, where those users are located, and demographic data.

Summary

In this chapter, we explored the steps required to make our app ready for deployment.

Firstly, we looked at some admin to get an app ready for the production build, including registering for a developer account and preparing your hosting provider for the web.

We then looked at releasing an app on the Google Play Store, including configuring the `AndroidManifest.xml` and `build.gradle` files; investigated the build process; and explored the testing options on Google Play.

Next, we did the same for the App Store, including registering our app bundle ID, using Xcode, looking at the build process, and exploring the different test processes.

Finally, we dug into the release process of our app on the web and finally covered how to use Crashlytics and Google Analytics to track app usage and crashes.

Questions

There was a lot of content in this chapter that you won't get to explore until you release your app. However, testing a release process early is important, so why not use these questions to prompt you to get an early internal testing release out now, even if there isn't much to test other than the release process?

1. Have you registered as a developer for the App Store and Play Store?
2. Have you defined a business model for your app that takes into account the fees and rules around an app release?
3. Have you created your app icon and ensured it aligns with the iOS app icon rules?
4. Have you generated your Android key store and set up your signing configuration?
5. Have you registered your iOS bundle ID?
6. Have you tried uploading an `appBundle` or an `ipa` to their respective stores?
7. Have you created your app entries in the stores, including privacy and terms-of-service documents?
8. Have you purchased a web domain for your app (if you are setting up a web version)?
9. Have you decided on web hosting and tried to upload a web build to the hosting?
10. Have you embedded Crashlytics and Google Analytics into your app?

Further reading

If you have the stomach for it, the App Store review guidelines are a worthwhile read. Generally, I've found the App Store to be much more restrictive than the Play Store, so if you can manage to release an app on the App Store, then you are likely to succeed on the Play Store:

`https://developer.apple.com/app-store/review/guidelines/`

Now is a great time to start thinking more generally about your app and how you can turn it into a business. It may be that your business solely revolves around your app, or it may be that your app is just a part of a bigger business. Either way, you need to start thinking about how you will market your app to your users, so taking a look at your marketing strategy would make sense at this point. There are many books, including the excellent *Cracking the Product Marketing Code: Unlocking product marketers' potential to craft outstanding GTM strategies and win the market* by Iman Bayatra.

Additionally, you will want a way to contact your users, perhaps to help them become power users of the app or re-engage them with your offering. Again, there are many books available to guide you on this, including *Marketing Automation with Mailchimp: Expert tips, techniques, and best practices for scaling marketing strategies and ROI for your business* by Margarita Caraballo.

And that's all folks. In this book, I tried to show you the basic but fundamental concepts of this incredible framework. I hope you enjoyed the book, learned something new, and are excited about using Flutter in the future!

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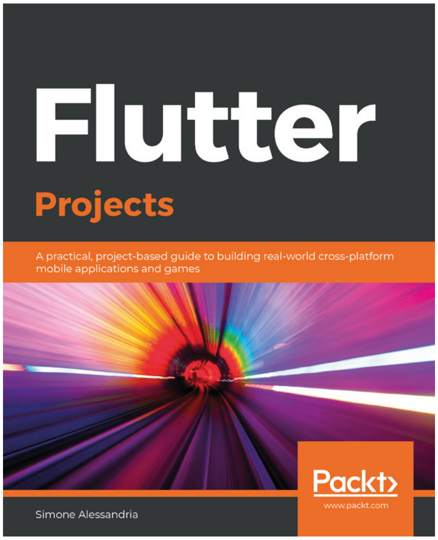

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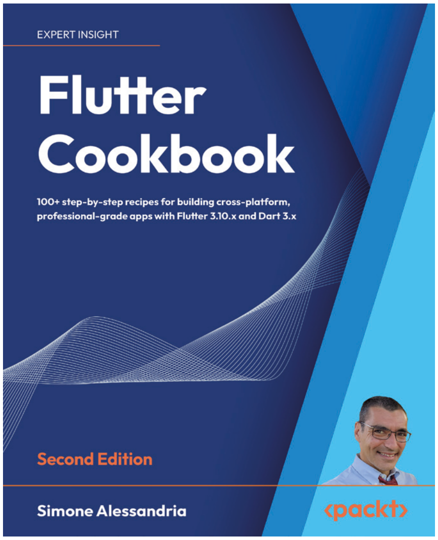

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