1 Discovering Docker

This chapter covers

- What Docker is
- The uses of Docker and how it can save you time and money
- The differences between containers and images
- Docker's layering feature
- Building and running a to-do application using Docker

Docker is a platform that allows you to "build, ship, and run any app, anywhere." It has come a long way in an incredibly short time and is now considered a standard way of solving one of the costliest aspects of software: deployment.

Before Docker came along, the development pipeline typically consisted of combinations of various technologies for managing the movement of software, such as virtual machines, configuration management tools, different package management systems, and complex webs of library dependencies. All these tools needed to be managed and maintained by specialist engineers, and most had their own unique ways of being configured.

Docker has changed all of this, allowing different engineers involved in this process to effectively speak one language, making working together a breeze. Everything goes through a common pipeline to a single output that can be used on any target—there's no need to continue maintaining a bewildering array of tool configurations, as shown in figure 1.1.

At the same time, there's no need to throw away your existing software stack if it works for you—you can package it up in a Docker container as-is for others to consume. As a bonus, you can see how these containers were built, so if you need to dig into the details, you can.

This book is aimed at intermediate developers with some knowledge of Docker. If you're OK with the basics, feel free to skip to the later chapters. The goal of this book is to expose the real-world challenges that Docker brings and show how they can be overcome. But first we're going to provide a quick refresher on Docker itself. If you want a more thorough treatment of Docker's basics, take a look at *Docker in Action* by Jeff Nickoloff (Manning Publications, 2016).

In chapter 2 you'll be introduced to Docker's architecture more deeply with the aid of some techniques that demonstrate its power. In this chapter you're going to learn what Docker is, see why it's important, and start using it.

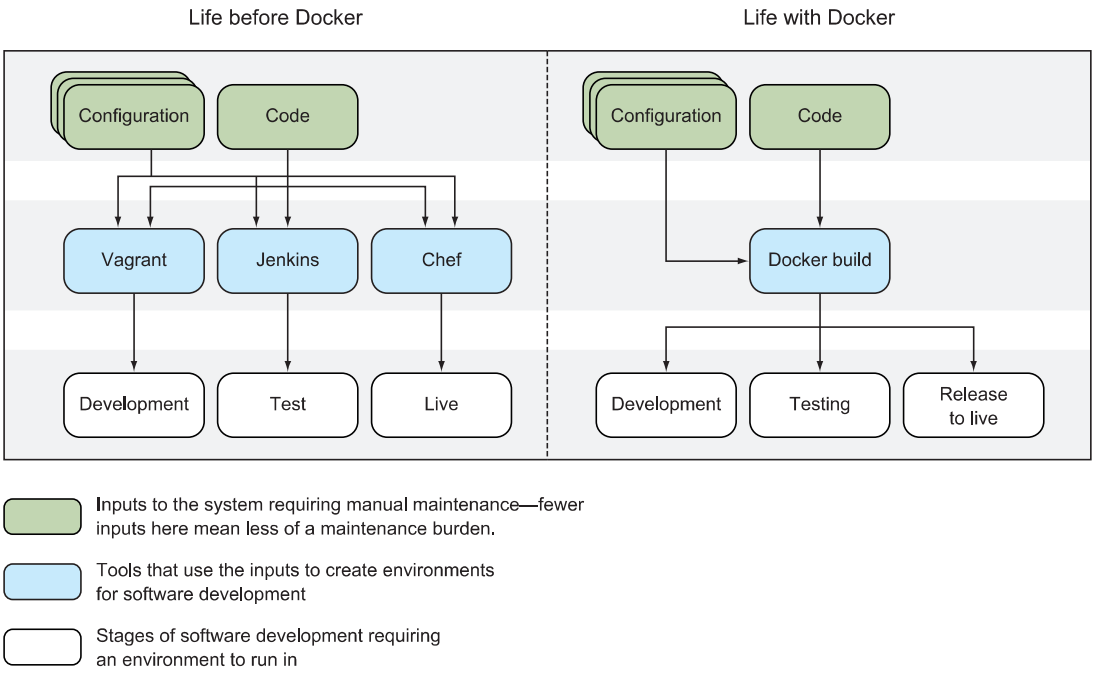


Figure 1.1 How Docker has eased the tool maintenance burden

1.1 The what and why of Docker

Before we get our hands dirty, we're going to discuss Docker a little so that you understand its context, where the name "Docker" came from, and why we're using it at all!

1.1.1 What is Docker?

To understand what Docker is, it's easier to start with a metaphor than a technical explanation, and the Docker metaphor is a powerful one. A docker was a labourer who moved commercial goods into and out of ships when they docked at ports. There were boxes and items of differing sizes and shapes, and experienced dockers were prized for their ability to fit goods into ships by hand in cost-effective ways (see figure 1.2). Hiring people to move stuff around wasn't cheap, but there was no alternative.

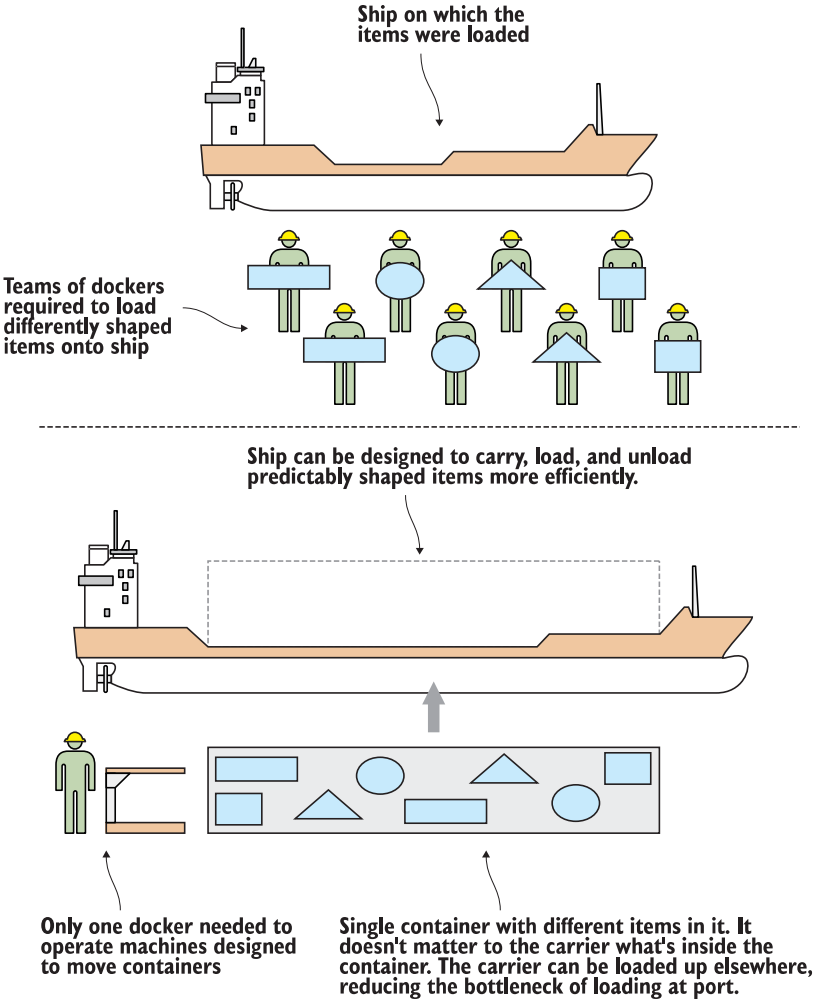


Figure 1.2 Shipping before and after standardized containers

This should sound familiar to anyone working in software. Much time and intellectual energy is spent getting metaphorically odd-shaped software into different sized metaphorical ships full of other odd-shaped software, so they can be sold to users or businesses elsewhere.

Figure 1.3 shows how time and money can be saved with the Docker concept.

Before Docker, deploying software to different environments required significant effort. Even if you weren't hand-running scripts to provision software on different machines (and plenty of people still do exactly that), you'd still have to wrestle with configuration management tools that manage state on what are increasingly fast-moving environments starved of resources. Even when these efforts were encapsulated in VMs, a lot of time was spent managing the deployment of these VMs, waiting for them to boot, and managing the overhead of resource use they created.

With Docker, the configuration effort is separated from the resource management, and the deployment effort is trivial: run `docker run`, and the environment's image is pulled down and ready to run, consuming fewer resources and contained so that it doesn't interfere with other environments.

You don't need to worry about whether your container is going to be shipped to a RedHat machine, an Ubuntu machine, or a CentOS VM image; as long as it has Docker on it, it'll be good to go.

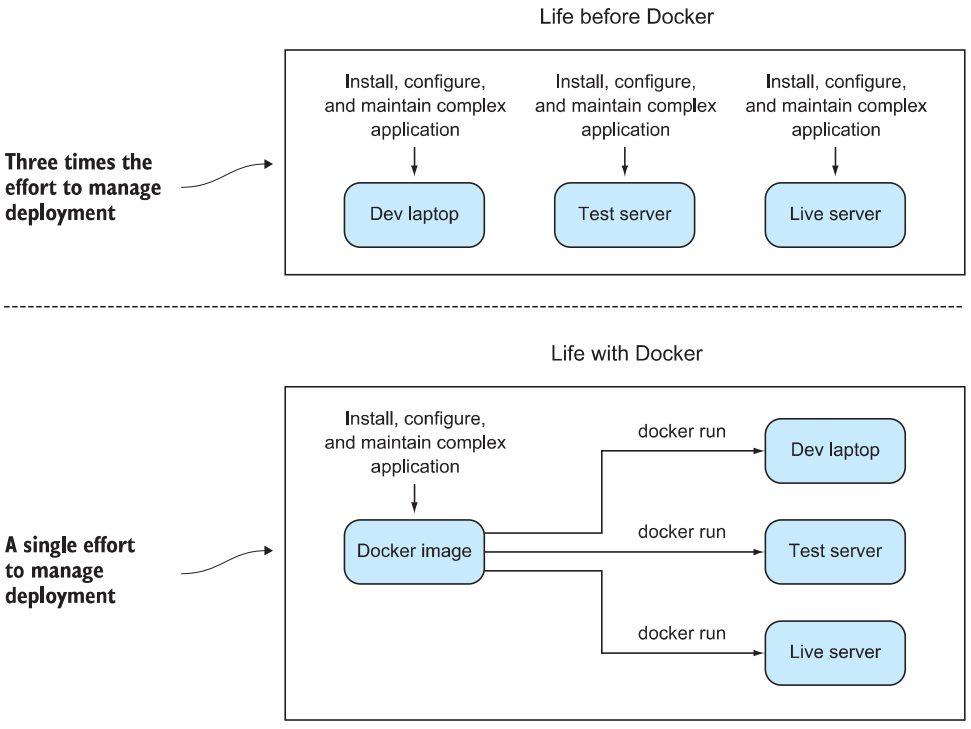


Figure 1.3 Software delivery before and after Docker

1.1.2 What is Docker good for?

Some crucial practical questions arise: why would you use Docker, and for what? The short answer to the "why" is that for a modicum of effort, Docker can save your business a lot of money quickly. Some of these ways (and by no means all) are discussed in the following subsections. We've seen all of these benefits first-hand in real working contexts.

REPLACES VIRTUAL MACHINES (VMS)

Docker can be used to replace VMs in many situations. If you only care about the application, not the operating system, Docker can replace the VM, and you can leave worrying about the OS to someone else. Not only is Docker quicker than a VM to spin up, it's more lightweight to move around, and due to its layered filesystem, it's much easier and quicker to share changes with others. It's also firmly rooted in the command line and is eminently scriptable.

PROTOTYPING SOFTWARE

If you want to quickly experiment with software without either disrupting your existing setup or going through the hassle of provisioning a VM, Docker can give you a sandbox environment in milliseconds. The liberating effect of this is difficult to grasp until you experience it for yourself.

PACKAGING SOFTWARE

Because a Docker image has effectively no dependencies for a Linux user, it's a great way to package software. You can build your image and be sure that it can run on any modern Linux machine—think Java, without the need for a JVM.

ENABLING A MICROSERVICES ARCHITECTURE

Docker facilitates the decomposition of a complex system to a series of composable parts, which allows you to reason about your services in a more discrete way. This can allow you to restructure your software to make its parts more manageable and pluggable without affecting the whole.

MODELLING NETWORKS

Because you can spin up hundreds (even thousands) of isolated containers on one machine, modelling a network is a breeze. This can be great for testing real-world scenarios without breaking the bank.

ENABLING FULL-STACK PRODUCTIVITY WHEN OFFLINE

Because you can bundle all the parts of your system into Docker containers, you can orchestrate these to run on your laptop and work on the move, even when offline.

REDUCING DEBUGGING OVERHEAD

Complex negotiations between different teams about software delivered is commonplace within the industry. We've personally experienced countless discussions about broken libraries; problematic dependencies; updates applied wrongly, or in the wrong order, or even not performed at all; unreproducible bugs, and so on. It's likely you have too. Docker allows you to state clearly (even in script form) the steps for debugging a problem on a system with known properties, making bug and environment reproduction a much simpler affair, and one normally separated from the host environment provided.

DOCUMENTING SOFTWARE DEPENDENCIES AND TOUCHPOINTS

By building your images in a structured way, ready to be moved to different environments, Docker forces you to document your software dependencies explicitly from a base starting point. Even if you decide not to use Docker everywhere, this need to document can help you install your software in other places.

ENABLING CONTINUOUS DELIVERY

Continuous delivery (CD) is a paradigm for software delivery based on a pipeline that rebuilds the system on every change and then delivers to production (or "live") through an automated (or partly automated) process.

Because you can control the build environment's state more exactly, Docker builds are more reproducible and replicable than traditional software building methods. This makes implementing CD much easier. Standard CD techniques such as Blue/Green deployment (where "live" and "last" deployments are maintained on live) and Phoenix Deployment (where whole systems are rebuilt on each release) are made trivial by implementing a reproducible Docker-centric build process.

Now you know a bit about how Docker can help you. Before we dive into a real example, let's go over a couple of core concepts.

1.1.3 Key concepts

In this section we're going to cover some key Docker concepts, which are illustrated in figure 1.4.

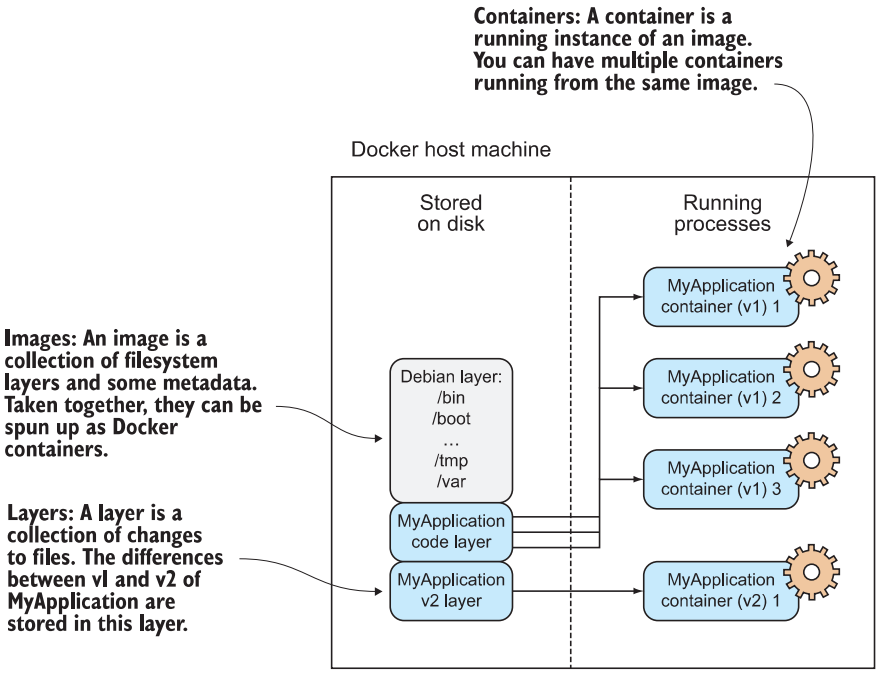


Figure 1.4 Core Docker concepts

It's most useful to get the concepts of images, containers, and layers clear in your mind before you start running Docker commands. In short, *containers* are running systems defined by *images*. These images are made up of one or more *layers* (or sets of diffs) plus some metadata for Docker.

Let's look at some of the core Docker commands. We'll turn images into containers, change them, and add layers to new images that we'll commit. Don't worry if all of this sounds confusing. By the end of the chapter it will all be much clearer!

KEY DOCKER COMMANDS

Docker's central function is to build, ship, and run software in any location that has Docker.

To the end user, Docker is a command-line program that you run. Like git (or any source control tool), this program has subcommands that perform different operations.

The principal Docker subcommands you'll use on your host are listed in table 1.1.

Table 1.1 Docker subcommands

Command	Purpose
`docker build`	Build a Docker image.
`docker run`	Run a Docker image as a container.
`docker commit`	Commit a Docker container as an image.
`docker tag`	Tag a Docker image.

IMAGES AND CONTAINERS

If you're unfamiliar with Docker, this may be the first time you've come across the words "container" and "image" in this context. They're probably the most important concepts in Docker, so it's worth spending a bit of time to make sure the difference is clear.

In figure 1.5 you'll see an illustration of these concepts, with three containers started up from one base image.

One way to look at images and containers is to see them as analogous to programs and processes. In the same way a process can be seen as an application being executed, a Docker container can be viewed as a Docker image in execution.

If you're familiar with object-oriented principles, another way to look at images and containers is to view images as classes and containers as objects. In the same way that objects are concrete instantiations of classes, containers are instantiations of images. You can create multiple containers from a single image, and they are all isolated from one another in the same way objects are. Whatever you change in the object, it won't affect the class definition—they're fundamentally different things.

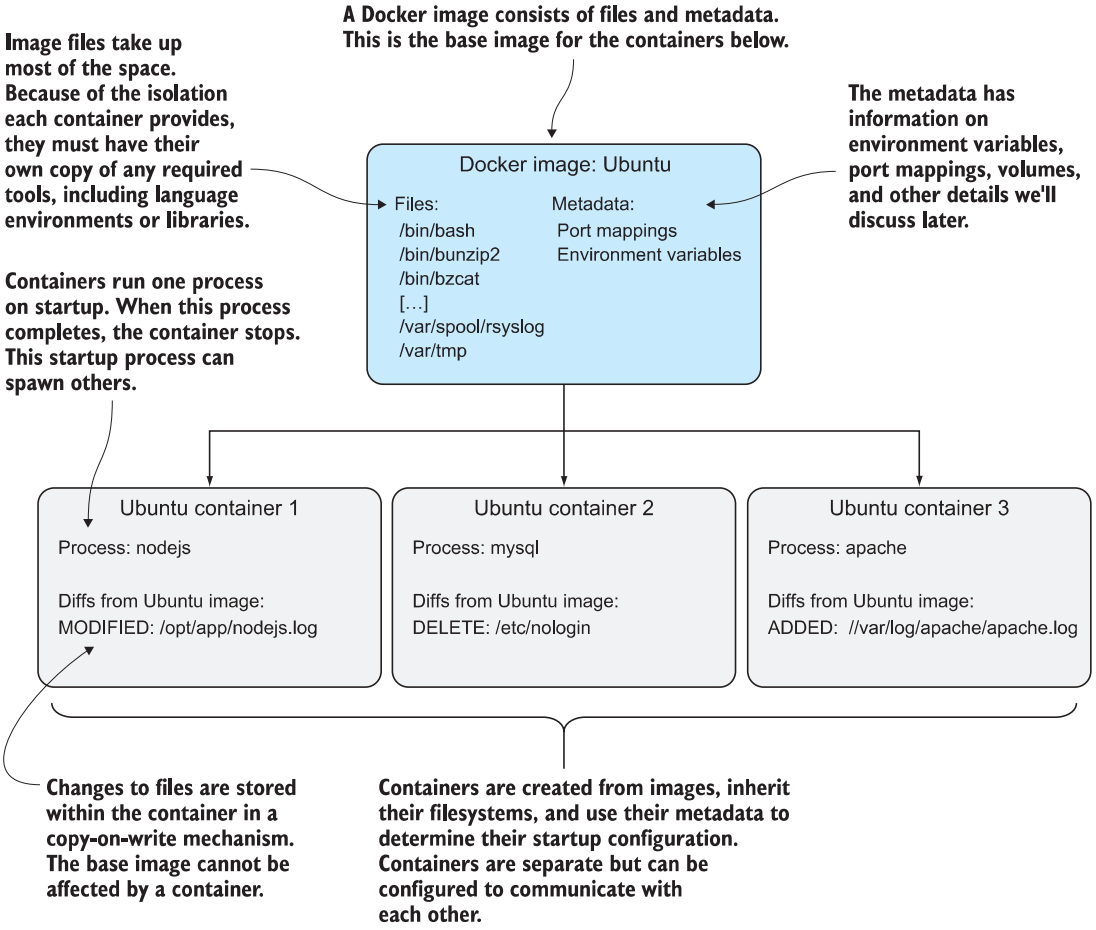


Figure 1.5 **Docker images and containers**

1.2 Building a Docker application

We're going to get our hands dirty now by building a simple "to-do" application (todo-app) image with Docker. In the process, you'll see some key Docker features like Dockerfiles, image re-use, port exposure, and build automation. Here's what you'll learn in the next 10 minutes:

- How to create a Docker image using a Dockerfile
- How to tag a Docker image for easy reference
- How to run your new Docker image

A to-do app is one that helps you keep track of things you want to get done. The app we'll build will store and display short strings of information that can be marked as done, presented in a simple web interface.

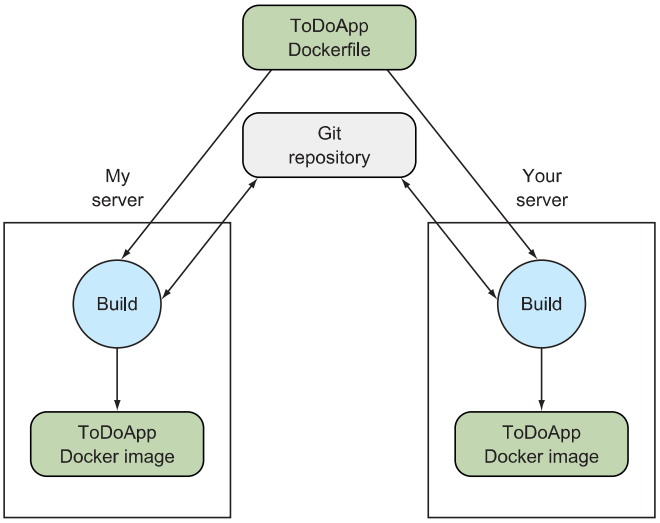


Figure 1.6 Building a Docker application

Figure 1.6 shows what we'll achieve by doing this.

The details of the application are unimportant. We're going to demonstrate that from the single short Dockerfile we're about to give you, you can reliably build, run, stop, and start an application in the same way on both your host and ours without needing to worry about application installations or dependencies. This is a key part of what Docker gives us—reliably reproduced and easily managed and shared development environments. This means no more complex or ambiguous installation instructions to follow and potentially get lost in.

THE TO-DO APPLICATION This to-do application will be used a few times throughout the book, and it's quite a useful one to play with and demonstrate, so it's worth familiarizing yourself with it.

1.2.1 Ways to create a new Docker image

There are four standard ways to create Docker images. Table 1.2 itemizes these methods.

Table 1.2 Options for creating Docker images

Method	Description	See technique
Docker commands / "By hand"	Fire up a container with `docker run` and input the commands to create your image on the command line. Create a new image with `docker commit`.	See technique 14.
Dockerfile	Build from a known base image, and specify build with a limited set of simple commands.	Discussed shortly.

Table 1.2 Options for creating Docker images *(continued)*

Method	Description	See technique
Dockerfile and configuration management (CM) tool	Same as Dockerfile, but hand over control of the build to a more sophisticated CM tool.	See technique 47.
Scratch image and import a set of files	From an empty image, import a TAR file with the required files.	See technique 10.

The first "by hand" option is fine if you're doing proofs of concept to see whether your installation process works. At the same time, you should be keeping notes about the steps you're taking so that you can return to the same point if you need to.

At some point you're going to want to define the steps for creating your image. This is the second option (and the one we'll use here).

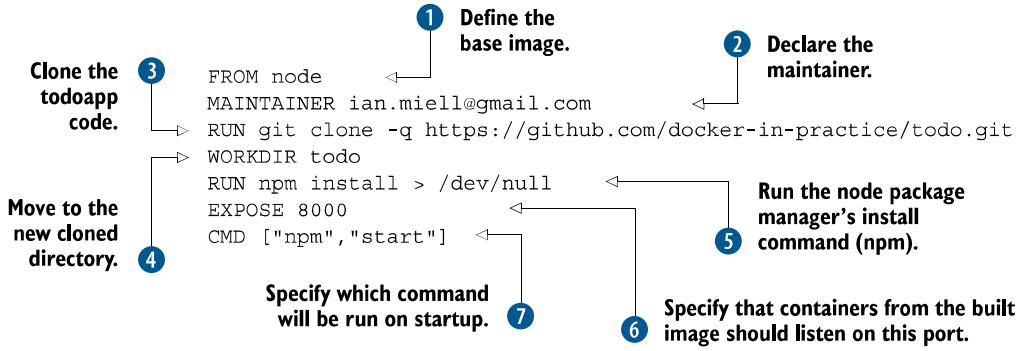
For more complex builds, you may want to go for the third option, particularly when the Dockerfile features aren't sophisticated enough for your image's needs.

The final option builds from a null image by overlaying the set of files required to run the image. This is useful if you want to import a set of self-contained files created elsewhere, but it's rarely seen in mainstream use.

We'll look at the Dockerfile method now; the other methods will be covered later in the book.

1.2.2 Writing a Dockerfile

A Dockerfile is a text file with a series of commands in it. Here's the Dockerfile we're going to use for this example:



You begin the Dockerfile by defining the base image with the `FROM` command 1. This example uses a Node.js image so you have access to the Node.js binaries. The official Node.js image is called `node`.

Next, you declare the maintainer with the `MAINTAINER` command 2. In this case, we're using one of our email addresses, but you can replace this with your own

reference because it's your Dockerfile now. This line isn't required to make a working Docker image, but it's good practice to include one. At this point, the build has inherited the state of the node container, and you're ready to work on top of it.

Next, you clone the todoapp code with a `RUN` command (3). This uses the specified command to retrieve the code for the application, running `git` within the container. Git is installed inside the base node image in this case, but you can't take this kind of thing for granted.

Now you move to the new cloned directory with a `WORKDIR` command (4). Not only does this change directory within the build context, but the last `WORKDIR` command determines which directory you're in by default when you start up your container from your built image.

Next, you run the node package manager's install command (`npm`) (5). This will set up the dependencies for your application. You aren't interested in the output here, so you redirect it to /dev/null.

Because port 8000 is used by the application, you use the `EXPOSE` command to tell Docker that containers from the built image should listen on this port (6).

Finally, you use the `CMD` command to tell Docker which command will be run on startup of the container (7).

This simple example illustrates several key features of Docker and Dockerfiles. A Dockerfile is a simple sequence of a limited set of commands run in strict order. They affect the files and metadata of the resulting image. Here the `RUN` command affects the filesystem by checking out and installing applications, and the `EXPOSE`, `CMD`, and `WORKDIR` commands affect the metadata of the image.

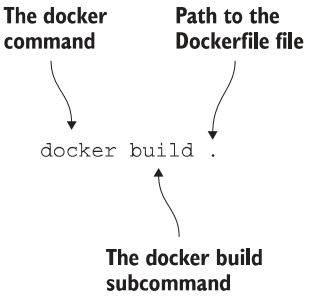


Figure 1.7 Docker `build` command

1.2.3 Building a Docker image

You've defined your Dockerfile's build steps. Now you're going to build the Docker image from it by typing the command in figure 1.7.

The output you'll see will be similar to this:

```
Sending build context to Docker daemon 178.7 kB
Sending build context to Docker daemon
Step 0 : FROM node
 ---> fc81e574af43
Step 1 : MAINTAINER ian.miell@gmail.com
 ---> Running in 21af1aad6950
 ---> 8f32669fe435
Removing intermediate container 21af1aad6950
Step 2 : RUN git clone https://github.com/ianmiell/todo.git
 ---> Running in 0a030ee746ea
Cloning into 'todo'...
```

Docker uploads the files and directories under the path supplied to the docker build command.

Each build step is numbered sequentially from 0 and output with the command.

Each command results in a new image being created, and the image ID is output.

To save space, each intermediate container is removed before continuing.

```
 ---> 783c68b2e3fc
Removing intermediate container 0a030ee746ea
Step 3 : WORKDIR todo
 ---> Running in 2e59f5df7152
 ---> 8686b344b124
Removing intermediate container 2e59f5df7152
Step 4 : RUN npm install
 ---> Running in bdf07a308fca
npm info it worked if it ends with ok
[...]
npm info ok
 ---> 6cf8f3633306
Removing intermediate container bdf07a308fca
Step 5 : RUN chmod -R 777 /todo
 ---> Running in c03f27789768
 ---> 2c0ededd3a5e
Removing intermediate container c03f27789768
Step 6 : EXPOSE 8000
 ---> Running in 46685ea97b8f
 ---> f1c29feca036
Removing intermediate container 46685ea97b8f
Step 7 : CMD npm start
 ---> Running in 7b4c1a9ed6af
 ---> 439b172f994e
Removing intermediate container 7b4c1a9ed6af
Successfully built 439b172f994e
```

Debug of the build is output here (and edited out of this listing).

Final image ID for this build, ready to tag

You now have a Docker image with an image ID ("66c76cea05bb" in the preceding example, but your ID will be different). It can be cumbersome to keep referring to this ID, so you can tag it for easier reference.

Type the preceding command, replacing the 66c76cea05bb with whatever image ID was generated for you.

You can now build your own copy of a Docker image from a Dockerfile, reproducing an environment defined by someone else!

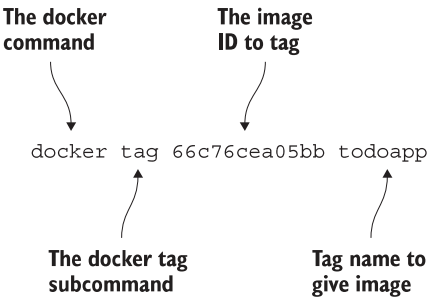


Figure 1.8 Docker `tag` command

1.2.4 Running a Docker container

You've built and tagged your Docker image. Now you can run it as a container:

```
docker run -p 8000:8000 --name example1 todoapp
npm install
npm info it worked if it ends with ok
npm info using npm@2.14.4
npm info using node@v4.1.1
npm info prestart todomvc-swarm@0.0.1

> todomvc-swarm@0.0.1 prestart /todo
> make all
```

The output of the container's starting process is sent to the terminal.

The docker run subcommand starts the container, -p maps the container's port 8000 to the port 8000 on the host machine, --name gives the container a unique name, and the last argument is the image.

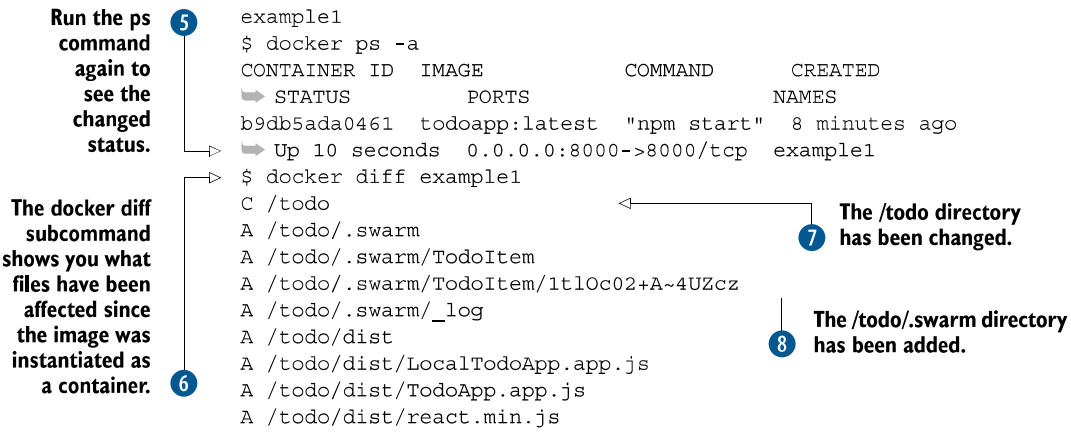
1

```
npm install
npm info it worked if it ends with ok
npm info using npm@2.14.4
npm info using node@v4.1.1
npm WARN package.json todomvc-swarm@0.0.1 No repository field.
npm WARN package.json todomvc-swarm@0.0.1 license should be a
➥ valid SPDX license expression
npm info preinstall todomvc-swarm@0.0.1
npm info package.json statics@0.1.0 license should be a valid
➥ SPDX license expression
npm info package.json react-tools@0.11.2 No license field.
npm info package.json react@0.11.2 No license field.
npm info package.json node-jsx@0.11.0 license should be a valid
➥ SPDX license expression
npm info package.json ws@0.4.32 No license field.
npm info build /todo
npm info linkStuff todomvc-swarm@0.0.1
npm info install todomvc-swarm@0.0.1
npm info postinstall todomvc-swarm@0.0.1
npm info prepublish todomvc-swarm@0.0.1
npm info ok
if [ ! -e dist/ ]; then mkdir dist; fi
cp node_modules/react/dist/react.min.js dist/react.min.js

LocalTodoApp.js:9:    // TODO: default english version
LocalTodoApp.js:84:            fwdList =
➥ this.host.get('/TodoList#'+listId); // TODO fn+id sig
TodoApp.js:117:        // TODO scroll into view
TodoApp.js:176:        if (i>=list.length()) { i=list.length()-1; }
➥ // TODO .length
local.html:30:    <!-- TODO 2-split, 3-split -->
model/TodoList.js:29:
➥ // TODO one op - repeated spec? long spec?
view/Footer.jsx:61:        // TODO: show the entry's metadata
view/Footer.jsx:80:            todoList.addObject(new TodoItem());
➥ // TODO create default
view/Header.jsx:25:
➥ // TODO list some meaningful header (apart from the id)

npm info start todomvc-swarm@0.0.1

> todomvc-swarm@0.0.1 start /todo
> node TodoAppServer.js

Swarm server started port 8000
^C
$ docker ps -a
CONTAINER ID  IMAGE           COMMAND      CREATED
➥ STATUS                     PORTS  NAMES
b9db5ada0461  todoapp:latest  "npm start"  2 minutes ago
➥ Exited (130) 2 minutes ago  example1
$ docker start example1
```

Hit Ctrl-C here to terminate the process and the container. (2)

(3) **Run this command to see containers that have been started and removed, along with an ID and status (like a process).**

(4) **Restart the container, this time in the background.**



The `docker run` subcommand starts up the container (1). The -p flag maps the container's port 8000 to the port 8000 on the host machine, so you should now be able to navigate with your browser to http://localhost:8000 to view the application. The --name flag gives the container a unique name you can refer to later for convenience. The last argument is the image name.

Once the container was started, we hit CTRL-C to terminate the process and the container (2). You can run the `ps` command to see the containers that have been started but not removed (3). Note that each container has its own container ID and status, analogous to a process. Its status is `Exited`, but you can restart it (4). After you do, notice how the status has changed to `Up` and the port mapping from container to host machine is now displayed (5).

The `docker diff` subcommand shows you which files have been affected since the image was instantiated as a container (6). In this case, the todo directory has been changed (7) and the other listed files have been added (8). No files have been deleted, which is the other possibility.

As you can see, the fact that Docker "contains" your environment means that you can treat it as an entity on which actions can be predictably performed. This gives Docker its breadth of power—you can affect the software lifecycle from development to production and maintenance. These changes are what this book will cover, showing you in practical terms what can be done with Docker.

Next you're going to learn about layering, another key concept in Docker.

1.2.5 Docker layering

Docker layering helps you manage a big problem that arises when you use containers at scale. Imagine what would happen if you started up hundreds—or even thousands—of the to-do app, and each of those required a copy of the files to be stored somewhere.

As you can imagine, disk space would run out pretty quickly! By default, Docker internally uses a copy-on-write mechanism to reduce the amount of disk space required

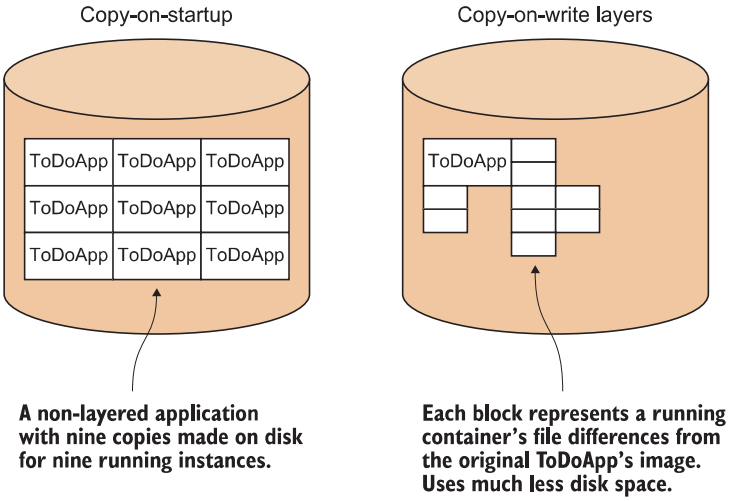


Figure 1.9 Copy-on-startup vs copy-on-write

(see figure 1.9). Whenever a running container needs to write to a file, it records the change by copying the item to a new area of disk. When a Docker commit is performed, this new area of disk is frozen and recorded as a layer with its own identifier.

This partly explains how Docker containers can start up so quickly—they have nothing to copy because all the data has already been stored as the image.

COPY-ON-WRITE Copy-on-write is a standard optimization strategy used in computing. When you create a new object (of any type) from a template, rather than copying the entire set of data required, you only copy data over when it's changed. Depending on the use case, this can save considerable resources.

Figure 1.10 illustrates that the to-do app you've built has three layers you're interested in.

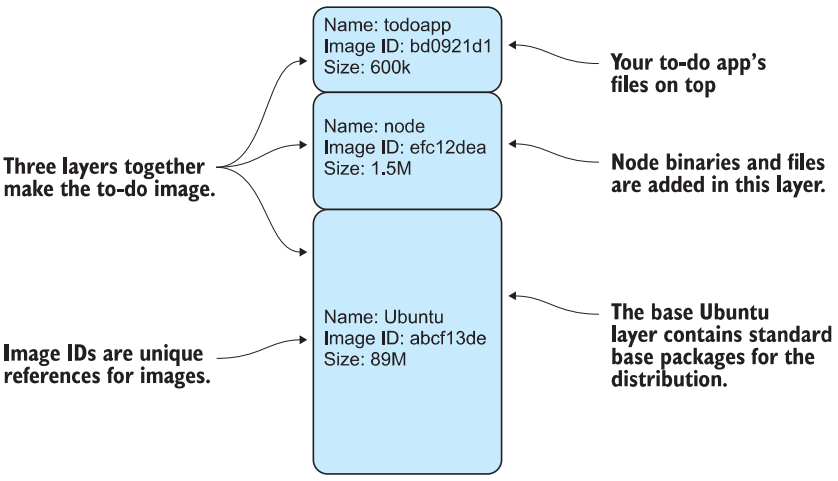


Figure 1.10 The to-do app's filesystem layering in Docker

Because the layers are static, you only need build on top of the image you wish to take as a reference, should you need anything to change in a higher layer. In the to-do app, you built from the publicly available node image and layered changes on top.

All three layers can be shared across multiple running containers, much as a shared library can be shared in memory across multiple running processes. This is a vital feature for operations, allowing the running of numerous containers based on different images on host machines without running out of disk space.

Imagine that you're running the to-do app as a live service for paying customers. You can scale up your offering to a large number of users. If you're developing, you can spin up many different environments on your local machine at once. If you're moving through tests, you can run many more tests simultaneously, and far more quickly than before. All these things are made possible by layering.

By building and running an application with Docker, you've begun to see the power that Docker can bring to your workflow. Reproducing and sharing specific environments and being able to land these in various places gives you both flexibility and control over development.

1.3 Summary

Depending on your previous experience with Docker, this chapter might have been a steep learning curve. We've covered a lot of ground in a short time.

You should now

- Understand what a Docker image is
- Know what Docker layering is, and why it's useful
- Be able to commit a new Docker image from a base image
- Know what a Dockerfile is

We've used this knowledge to

- Create a useful application
- Reproduce state in an application with minimal effort

Next we're going to introduce techniques that will help you understand how Docker works and, from there, discuss some of the broader technical debate around Docker's usage. These first two introductory chapters form the basis for the remainder of the book, which will take you from development to production, showing you how Docker can be used to improve your workflow.