



Practical Docker with Python

Build, Release and Distribute your
Python App with Docker

Sathyajith Bhat

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Bangalore, Karnataka, India

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Printed on acid-free paper

*To my parents, Jayakar and Jyothika Bhat,
who have unconditionally supported me
throughout my entire life.*

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Introduction

Docker has exploded in popularity and has become the de facto target as a containerization image format as well as a containerization runtime. With modern applications getting more and more complicated, the increased focus on microservices has led to adoption of Docker, as it allows for applications along with their dependencies to be packaged into a file as a container that can run on any system. This allows for faster turnaround times in application deployment and less complexity and it negates the chances of the “it-works-on-my-server-but-not-on-yours” problem.

Practical Docker with Python covers the fundamentals of containerization, gets you acquainted with Docker, breaks down terminology like Dockerfile and Docker Volumes, and takes you on a guided tour of building a chatbot using Python. You’ll learn how to package a traditional application as a Docker Image.

Book Structure

This book is divided into seven chapters—we start the first chapter with a brief introduction to Docker and containerization. We then take a 101 class of Docker, including installing, configuring, and understanding some Docker jargon. In Chapter 3, we take a look at our project and look at how to configure our chatbot.

In Chapters 4 to 6, we dive into the meat of Docker, focusing on Dockerfiles, Docker Networks, and Docker Volumes. These chapters include practical exercises on how to incorporate each of these into the project. Finally, we take a look at Docker Compose and see how we can run multi-container applications.

CHAPTER 1

Introduction to Containerization

In this chapter, we look at what Docker is, as well as what containerization is and how it is different from virtualization.

What Is Docker?

When we answer this question, we need to clarify the word “docker,” because Docker has become synonymous with containers.

Docker the Company

Docker Inc. is the company behind Docker. Docker Inc. was founded as dotCloud Inc. in 2010 by Solomon Hykes. dotCloud engineers built abstraction and tooling for Linux Containers and used the Linux Kernel features cgroups and namespaces with the intention of reducing complexity around using Linux containers. dotCloud made their tooling open source and changed the focus from the PaaS business to focus on containerization. Docker Inc. sold dotCloud to cloudControl, which eventually filed for bankruptcy.

Docker the Software Technology

Docker is the technology that provides for operating system level virtualization known as *containers*. It is important to note that this is not the same as hardware virtualization. We will explore this later in the chapter. Docker uses the resource isolation features of the Linux kernel such as cgroups, kernel namespaces, and OverlayFS, all within the same physical or virtual machine. OverlayFS is a union-capable filesystem that combines several files and directories into one in order to run multiple applications that are isolated and contained from one other, all within the same physical or virtual machine.

Understanding Problems that Docker Solves

For the longest period, setting up a developer's workstation was a highly troublesome task for sysadmins. Even with complete automation of the installation of developer tools, when you have a mix of different operating systems, different versions of operating systems, and different versions of libraries and programming languages, setting up a workspace that is consistent and provides a uniform experience is nearly impossible. Docker solves much of this problem by reducing the moving parts. Instead of targeting operating systems and programming versions, the target is now the Docker engine and the runtime. The Docker engine provides a uniform abstraction from the underlying system, making it very easy for developers to test their code

Things get even more complicated on the production landscape. Assume that we have a Python web application that is running on Python 2.7 on Amazon Web Services EC2 instance. In an effort to modernize the codebase, the application had some major upgrades, including a change in Python version from 2.7 to version 3.5. Assume that this version of Python is not available in the packages offered by the Linux

distribution currently running the existing codebases. Now to deploy this new application, we have the choice of either of the following:

- Replace the existing instance
- Set up the Python Interpreter by
 - Changing the Linux distribution version to one that includes the newer Python packages
 - Adding a third-party channel that offers a packaged version of the newer Python version
 - Doing an in-place upgrade, keeping the existing version of the Linux distribution
 - Compiling Python 3.5 from sources, which brings in additional dependencies
 - Or using something like `virtualenv`, which has its own set of tradeoffs

Whichever way you look at it, a new version deployment for application code brings about lots of uncertainty. As an operations engineer, limiting the changes to the configuration is critical. Factoring in an operating system change, a Python version change, and a change in application code results in a lot of uncertainty.

Docker solves this issue by dramatically reducing the surface area of the uncertainty. Your application is being modernized? No problem. Build a new container with the new application code and dependencies and ship it. The existing infrastructure remains the same. If the application doesn't behave as expected, then rolling back is as simple as redeploying the older container—it is not uncommon to have all the generated Docker images stored in a Docker registry. Having an easy way to roll back without messing with the current infrastructure dramatically reduces the time required to respond to failures.

Containerization Through the Years

While containerization has picked up in pace and has exploded in popularity over the past couple of years, the concept of containerization goes back to the 1970s.

1979: chroot

The chroot system call was introduced in Version 7 UNIX in 1979. The premise of chroot was that it changed the apparent root directory for the current running process and its children. A process initiated within a chroot cannot access files outside the assigned directory tree. This environment was known as the *chroot jail*.

2000: FreeBSD Jails

Expanding on the chroot concept, FreeBSD added support for a feature that allowed for partitioning of the FreeBSD system into several independent, isolated systems called *jails*. Each jail is a virtual environment on the host system with its own set of files, processes, and user accounts. While chroot only restricted processes to a view of the filesystem, FreeBSD jails restricted activities of the jailed process to the whole system, including the IP addresses that were bound to it. This made FreeBSD jails the ideal way to test out new configurations of Internet-connected software, making it easy to experiment with different configurations while not allowing for changes from the jail to affect the main system outside.

2005: OpenVZ

OpenVZ was quite popular in providing operating system virtualization for low-end *Virtual Private Server (VPS)* providers. OpenVZ allowed for a physical server to run multiple isolated operating system instances, known

as *containers*. OpenVZ uses a patched Linux kernel, sharing it with all the containers. Each container acts as a separate entity and has its own virtualized set of files, users, groups, process trees, and virtual network devices.

2006: cgroups

Originally known as *process containers*, cgroups (short for control groups) was started by Google engineers. cgroups is a Linux kernel feature that limits and isolates resource usage (such as CPU, memory, disk I/O, and network) to a collection of processes. cgroups have been redesigned multiple times, each redesign accounting for its growing number of use cases and required features.

2008: LXC

LXC provides operating-system level virtualization by combining Linux kernel's cgroups and support for isolated namespaces to provide an isolated environment for applications. Docker initially used LXC for providing the isolation features, but then switched to its own library.

Knowing the Difference Between Containers and Virtual Machines

Many people assume that since containers isolate the applications, they are the same as virtual machines. At first glance it looks like it, but the fundamental difference is that containers share the same kernel as the host.

Docker only isolates a single process (or a group of processes, depending on how the image is built) and all the containers run on the same host system. Since the isolation is applied at the kernel level, running containers does not impose a heavy overhead on the host as compared to virtual machines. When a container is spun up, the selected process

or group of processes still runs on the same host, without the need to virtualize or emulate anything. Figure 1-1 shows the three apps running on three different containers on a single physical host.

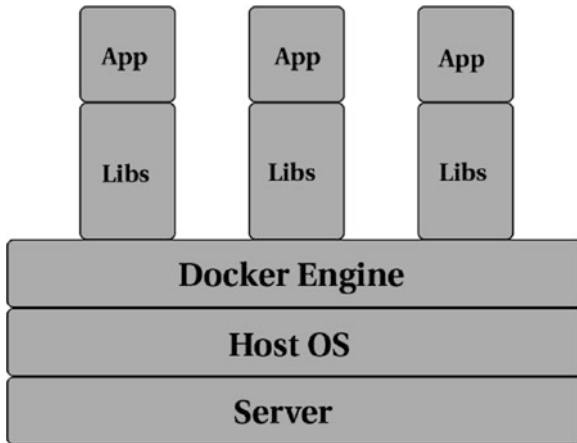


Figure 1-1. Representation of three apps running on three different containers

In contrast, when a virtual machine is spun up, the hypervisor virtualizes an entire system—from the CPU to RAM to storage. To support this virtualized system, an entire operating system needs to be installed. For all practical purposes, the virtualized system is an entire computer running in a computer. Now if you can imagine how much overhead it takes to run a single operating system, imagine how it'd be if you ran a nested operating system! Figure 1-2 shows a representation of the three apps running on three different virtual machines on a single physical host.

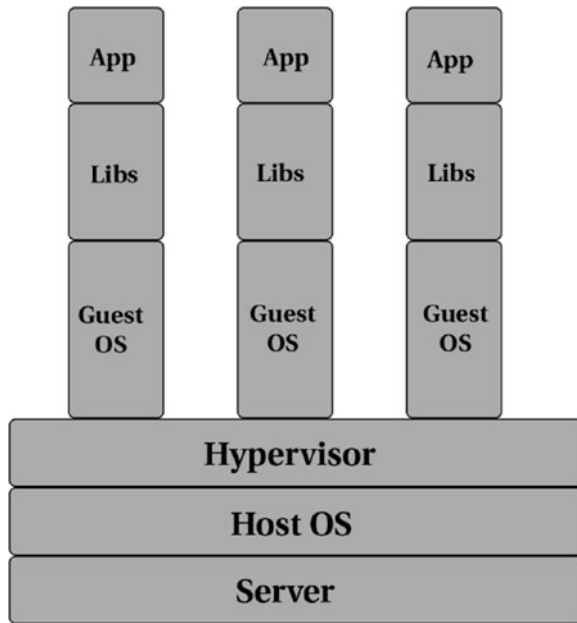


Figure 1-2. Representation of three apps running on three different virtual machines

Figures 1-1 and 1-2 give an indication of three different applications running on a single host. In the case of a VM, not only do we need the application's dependent libraries, we also need an operating system to run the application. In comparison, with containers, the sharing of the host OS's kernel with the application means that the overhead of an additional OS is removed. Not only does this greatly improve the performance, it also lets us improve the resource utilization and minimize wasted compute power.

Summary

In this chapter, you learned a bit about Docker the company, Docker Containers, and containers compared to virtual machines. You also learned a bit about the real-world problems that containers are trying to solve. In the upcoming chapter, you take an introductory tour of Docker and run a couple of hands-on sessions on building and running containers.

CHAPTER 2

Docker 101

Now that you understand what Docker is and why its popularity has exploded, this chapter covers some basics about the different terminology associated with Docker. In this chapter, you will learn how to install Docker and learn Docker terms such as images, containers, Dockerfiles, and Docker Compose. You will also work with some simple Docker commands for creating, running, and stopping Docker containers.

Installing Docker

Docker supports Linux, MacOS, and Windows platforms. It's straightforward to install Docker on most platforms and we'll get to that in a bit. Docker Inc. provides Community and Enterprise editions of the Docker platform. The Enterprise edition has the same features as the Community edition, but it provides additional support and certified containers, plugins, and infrastructure. For the purpose of this book and for most general development and production use, the Community edition is suitable, thus we will be using that in this book.

Installing Docker on Windows

You need to meet certain prerequisites before you can install Docker on Windows. These include the following:

- Hyper-V support
- Hardware virtualization support, typically be enabled from your system BIOS
- Only 64-bit editions of Windows 10 (Pro/Education/Enterprise editions having the Anniversary Update v1607) are supported at the moment

Notice that this looks like what a virtualization setup would require, and you learned in the previous chapter that Docker is not virtualization. So why does Docker for Windows require features required for virtualization?

The short answer is that Docker relies on numerous features, such as namespaces and cgroups, and these are not available on Windows. To get around this limitation, Docker for Windows creates a lightweight Hyper-V container running a Linux kernel.

At the time of writing, Docker includes experimental support for Native containers that allow for creation of containers without the need for Hyper-V.

Let's focus on installing Docker CE for Windows. This section assumes that all prerequisites have been met and that Hyper-V is enabled. Head over to <https://store.docker.com/editions/community/docker-ce-desktop-windows> to download Docker CE.

Note Make sure you select the Stable channel and click on the Get Docker CE button.

You may be prompted to enable Hyper-V and container support as part of the install, as shown in Figure 2-1.

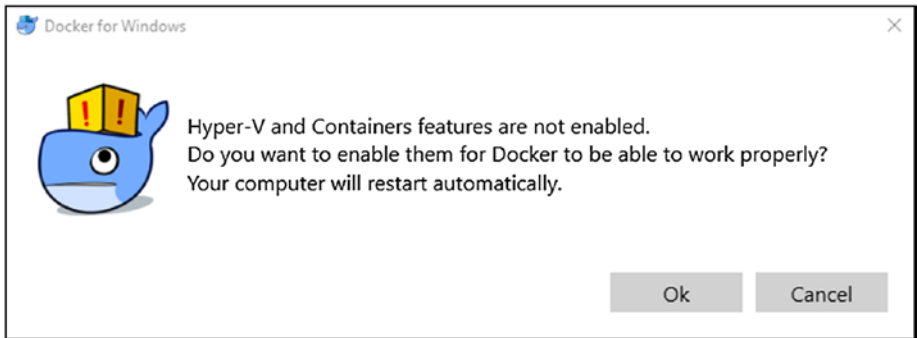


Figure 2-1. Enable Hyper-V and the Containers feature

Click OK and finish the installation. You may be required to restart your system, as enabling Hyper-V is a Windows system feature. If it's not installed, this feature will be installed and that requires a restart to enable the feature.

Once the install is complete, open a command prompt window (or PowerShell, if that is your preference) and type the command shown in Listing 2-1 to check that Docker is installed and is working correctly.

Listing 2-1. Check That Docker Is Working

```
docker run --rm hello-world
```

If the install went fine, you should see the response shown in Listing 2-2.

Listing 2-2. Response from the Docker Run Command

```
docker run --rm hello-world
Unable to find image 'hello-world:latest' locally
latest: Pulling from library/hello-world
ca4f61b1923c: Pull complete
Digest: sha256:66ef312bbac49c39a89aa9bcc3cb4f3c9e7de3788c944158
df3ee0176d32b751
Status: Downloaded newer image for hello-world:latest
```

Hello from Docker!

This message shows that your installation appears to be working correctly.

...

We will take a deeper look later into what the commands mean, so do not worry about understanding them. If we see the message "Installation appears to be working correctly", you should be good for now.

Installing on MacOS

Installing Docker for Mac is much like installing any other application.

Go to <https://store.docker.com/editions/community/docker-ce-desktop-mac>, click the Get Docker for CE Mac (stable) link, and double-click the file to run the installer that is downloaded. Drag the Docker whale to the Applications folder to install it, as shown in Figure 2-2.

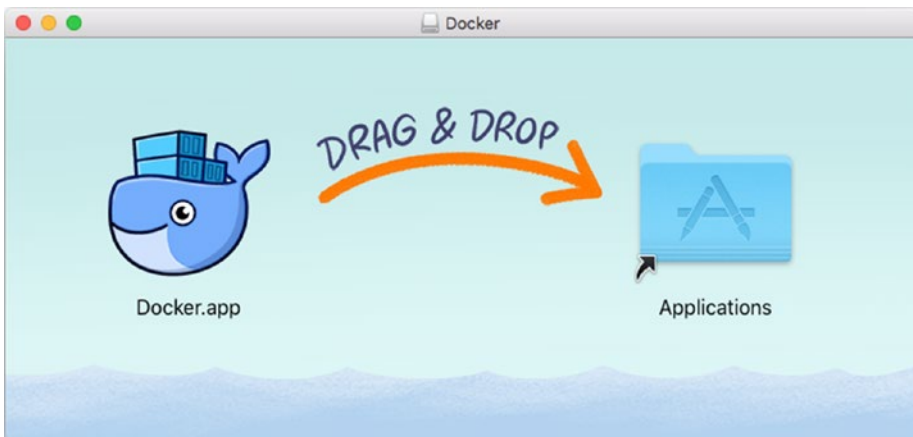


Figure 2-2. *Installing Docker for Mac*

Once Docker is installed, open the Terminal app and run the command listed in Listing 2-3 to confirm the install was successful.

Listing 2-3. Check That Docker for Mac Is Working

```
docker run --rm hello-world
```

If the install went fine, you should see the response shown in Listing 2-4.

Listing 2-4. Response from the Docker Run Command

```
docker run --rm hello-world
Unable to find image 'hello-world:latest' locally
latest: Pulling from library/hello-world
ca4f61b1923c: Pull complete
Digest: sha256:66ef312bbac49c39a89aa9bcc3cb4f3c9e7de3788c944158
df3ee0176d32b751
Status: Downloaded newer image for hello-world:latest

Hello from Docker!
This message shows that your installation appears to be working
correctly.
...
```

The "Hello from Docker!" message indicates that Docker is installed and is working correctly.

Installing on Linux

To install Docker on Linux, visit <https://www.docker.com/community-edition>. Select the distro you're using and follow the commands to install Docker.

The following section outlines the steps needed to install Docker on Ubuntu.

1. Update the apt index:

```
sudo apt-get update
```


2. Install the necessary packages required to use a repository over HTTPS:

```
sudo apt-get install \
    apt-transport-https \
    ca-certificates \
    curl \
    software-properties-common
```

3. Install Docker's official GPG key:

```
curl -fsSL https://download.docker.com/linux/ubuntu/gpg
| sudo apt-key add -
```

4. Add Docker's stable repository:

```
sudo add-apt-repository \
    "deb [arch=amd64] https://download.docker.com/linux/
ubuntu \
    $(lsb_release -cs) \
    stable"
```

5. Update the apt package index:

```
sudo apt-get update
```

6. Install Docker:

```
sudo apt-get install docker-ce
```

Additional Steps

Docker communicates via a UNIX socket that is owned by the root user. We can avoid having to type `sudo` by following these steps:

Warning The Docker group rights are still equivalent to the root user.

1. Create the docker group:

```
sudo groupadd docker
```

2. Add your user to the docker group:

```
sudo usermod -aG docker $USER
```

3. Log out and log back in. Run the command shown in Listing 2-5 to confirm the Docker has been installed correctly.

Listing 2-5. Check That Docker for Linux Is Working

```
docker run --rm hello-world
```

If the install went fine, you should see the response shown in Listing 2-6.

Listing 2-6. Response from the Docker Run Command

```
docker run --rm hello-world
Unable to find image 'hello-world:latest' locally
latest: Pulling from library/hello-world
ca4f61b1923c: Pull complete
Digest: sha256:66ef312bbac49c39a89aa9bcc3cb4f3c9e7de3788c944158
df3ee0176d32b751
Status: Downloaded newer image for hello-world:latest

Hello from Docker!
This message shows that your installation appears to be working
correctly.
...
```

Understanding Jargon Around Docker

Now that we have Docker installed and running, let's understand the different terminologies that are associated with Docker.

Layers

A *layer* is a modification applied to a Docker image as represented by an instruction in a Dockerfile. Typically, a layer is created when a base image is changed—for example, consider a Dockerfile that looks like this:

```
FROM ubuntu
Run mkdir /tmp/logs
RUN apt-get install vim
RUN apt-get install htop
```

Now in this case, Docker will consider Ubuntu image as the base image and add three layers:

- One layer for creating /tmp/logs
- One other layer that installs vim
- A third layer that installs htop

When Docker builds the image, each layer is stacked on the next and merged into a single layer using the union filesystem. Layers are uniquely identified using sha256 hashes. This makes it easy to reuse and cache them. When Docker scans a base image, it scans for the IDs of all the layers that constitute the image and begins to download the layers. If a layer exists in the local cache, it skips downloading the cached image.

Docker Image

Docker image is a read-only template that forms the foundation of your application. It is very much similar to, say, a shell script that prepares a system with the desired state. In simpler terms, it's the equivalent of a cooking recipe that has step-by-step instructions for making the final dish.

A Docker image starts with a base image—typically the one selected is that of an operating system are most familiar with, such as Ubuntu. On top of this image, we can add build our application stack adding the packages as and when required.

There are many pre-built images for some of the most common application stacks, such as Ruby on Rails, Django, PHP-FPM with nginx, and so on. On the advanced scale, to keep the image size as low as possible, we can also start with slim packages, such as Alpine or even Scratch, which is Docker's reserved, minimal starting image for building other images.

Docker images are created using a series of commands, known as instructions, in the Dockerfile. The presence of a Dockerfile in the root of a project repository is a good indicator that the program is container-friendly. We can build our own images from the associated Dockerfile and the built image is then published to a registry. We will take a deeper look at Dockerfile in later chapters. For now, consider the Docker image as the final executable package that contains everything to run an application. This includes the source code, the required libraries, and any dependencies.

Docker Container

A Docker image, when it's run in a host computer, spawns a process with its own namespace, known as a *Docker container*. The main difference between a Docker image and a container is the presence of a thin read/write layer known as the container layer. Any changes to the filesystem of a container, such as writing new files or modifying existing files, are done to this writable container layer than the lower layers.

An important aspect to grasp is that when a container is running, the changes are applied to the container layer and when the container is stopped/killed, the container layer is not saved. Hence, all changes are lost. This aspect of containers is not understood very well and for this reason, stateful applications and those requiring persistent data were initially not recommended as containerized applications. However, with Docker Volumes, there are ways to get around this limitation. We discuss Docker Volumes more in Chapter 5, “Understanding Docker Volumes”.

Bind Mounts and Volumes

We mentioned previously that when a container is running, any changes to the container are present in the container layer of the filesystem. When a container is killed, the changes are lost and the data is no longer accessible. Even when a container is running, getting data out of it is not very straightforward. In addition, writing into the container’s writable layer requires a storage driver to manage the filesystem. The storage driver provides an abstraction on the filesystem available to persist the changes and this abstraction often reduces performance.

For these reasons, Docker provides different ways to mount data into a container from the Docker host: volumes, bind mounts, and tmpfs volumes. While tmpfs volumes are stored in the host system’s memory only, bind mounts and volumes are stored in the host filesystem.

We explore Docker Volumes in detail in Chapter 5, “Understanding Docker Volumes”.

Docker Registry

We mentioned earlier that you can leverage existing images of common application stacks—have you ever wondered where these are and how you can use them in building your application? A Docker Registry is a place where you can store Docker images so that they can be used as the basis

for an application stack. Some common examples of Docker registries include the following:

- Docker Hub
- Google Container Registry
- Amazon Elastic Container Registry
- JFrog Artifactory

Most of these registries also allow for the visibility level of the images that you have pushed to be set as public/private. Private registries will prevent your Docker images from being accessible to the public, allowing you to set up access control so that only authorized users can use your Docker image.

Dockerfile

A *Dockerfile* is a set of instructions that tells Docker how to build an image. A typical Dockerfile is made up of the following:

- A FROM instruction that tells Docker what the base image is
- An ENV instruction to pass an environment variable
- A RUN instruction to run some shell commands (for example, install-dependent programs not available in the base image)
- A CMD or an ENTRYPOINT instruction that tells Docker which executable to run when a container is started

As you can see, the Dockerfile instruction set has clear and simple syntax, which makes it easy to understand. We take a deeper look at Dockerfiles later in the book.

Docker Engine

Docker Engine is the core part of Docker. Docker Engine is a client-server application that provides the platform, the runtime, and the tooling for building and managing Docker images, Docker containers, and more.

Docker Engine provides the following:

- Docker daemon
- Docker CLI
- Docker API

Docker Daemon

- The Docker daemon is a service that runs in the background of the host computer and handles the heavy lifting of most of the Docker commands. The daemon listens for API requests for creating and managing Docker objects, such as containers, networks, and volumes. Docker daemon can also talk to other daemons for managing and monitoring Docker containers. Some examples of inter-daemon communication include communication Datadog for container metrics monitoring and Aqua for container security monitoring.

Docker CLI

Docker CLI is the primary way that you will interact with Docker. Docker CLI exposes a set of commands that you can provide. The Docker CLI forwards the request to Docker daemon, which then performs the necessary work.

While the Docker CLI includes a huge variety of commands and sub-commands, the most common commands that we will work with in this book are as mentioned:

```
docker build
docker pull
docker run
docker exec
```

Tip Docker maintains an extensive reference of all the Docker commands on its documentation page at <https://docs.docker.com/engine/reference/commandline/cli/>.

At any point in time, prepending help to a command will reveal the command's required documentation. For example, if you're not quite sure where to start with Docker CLI, you could type the following:

```
docker help
```

```
Usage:  docker COMMAND
```

```
A self-sufficient runtime for containers
```

```
Options:
```

<code>--config string</code>	Location of client config files (default ".docker")
<code>-D, --debug</code>	Enable debug mode
<code>-H, --host list</code>	Daemon socket(s) to connect to
<code>-l, --log-level string</code>	Set the logging level ("debug" "info" "warn" "error" "fatal") (default "info")

```
[..]
```


If you'd like to know more about Docker pull, you would type the following:

```
docker help pull
```

```
Usage:  docker pull [OPTIONS] NAME[:TAG|@DIGEST]
```

Pull an image or a repository from a registry

Options:

<code>-a, --all-tags</code>	Download all tagged images in the repository
<code>--disable-content-trust</code>	Skip image verification (default true)
<code>--platform string</code>	Set platform if server is multi-platform capable

Docker API

Docker also provides an API for interacting with the Docker Engine. This is particularly useful if there's a need to create or manage containers from within applications. Almost every operation supported by the Docker CLI can be done via the API.

The simplest way to get started by Docker API is to use `curl` to send an API request. For Windows Docker hosts, we can reach the TCP endpoint:

```
curl http://localhost:2375/images/json
[{"Containers":-1,"Created":1511223798,"Id":"sha256:f2a91732366c0332ccd7afd2a5c4ff2b9af81f549370f7a19acd460f87686bc7","Labels":null,"ParentId":"","RepoDigests":["hello-world@sha256:66ef312bbac49c39a89aa9bcc3cb4f3c9e7de3788c944158df3ee0176d32b751"],"RepoTags":["hello-world:latest"],"SharedSize":-1,"Size":1848,"VirtualSize":1848}]
```

On Linux and Mac, the same effect can be achieved by using `curl` to send requests to the UNIX socket:

```
curl --unix-socket /var/run/docker.sock -X POST http://images/
json
```

```
[{"Containers":-1,"Created":1511223798,"Id":"sha256:f2a91732
366c0332ccd7afd2a5c4ff2b9af81f549370f7a19acd460f87686bc7","
Labels":null,"ParentId":"","RepoDigests":["hello-world@sha2
56:66ef312bbac49c39a89aa9bcc3cb4f3c9e7de3788c944158df3ee017
6d32b751"],"RepoTags":["hello-world:latest"],"SharedSize"
:-1,"Size":1848,"VirtualSize":1848}]
```

Docker Compose

Docker Compose is a tool for defining and running multi-container applications. Much like how Docker allows you to build an image for your application and run it in your container, Compose use the same images in combination with a definition file (known as the *compose file*) to build, launch, and run multi-container applications, including dependent and linked containers.

The most common use case for Docker Compose is to run applications and their dependent services (such as databases and caching providers) in the same simple, streamlined manner as running a single container application. We take a deeper look at Docker Compose in Chapter 7, “Understanding Docker Compose”.

Docker Machine

Docker Machine is a tool for installing Docker Engines on multiple virtual hosts and then managing the hosts. Docker Machine allows you to create Docker hosts on local as well remote systems, including on cloud platforms like Amazon Web Services, DigitalOcean, and Microsoft Azure.

Hands-On Docker

Let's try some of the things you've read about so far. Before we start exploring the various commands, it's time to ensure that your Docker install is correct and that it is working as expected.

Tip To make things easy to read and understand, we have used a tool called `jq` for processing Docker's JSON output. You can download and install `jq` from <https://stedolan.github.io/jq/>.

Open a terminal window and type the following command:

```
docker info
```

You should see a result like the following:

```
docker info
Containers: 0
  Running: 0
  Paused: 0
  Stopped: 0
Images: 1
Server Version: 17.12.0-ce
Storage Driver: overlay2
  Backing Filesystem: extfs
  Supports d_type: true
  Native Overlay Diff: true
Logging Driver: json-file
Cgroup Driver: cgroupfs
Plugins:
  Volume: local
  Network: bridge host ipvlan macvlan null overlay
```

```
Log: awslogs fluentd gcplogs gelf journald json-file
logentries splunk syslog
Swarm: inactive
Runtimes: runc
Default Runtime: runc
Init Binary: docker-init
containerd version: 89623f28b87a6004d4b785663257362d1658a729
runc version: b2567b37d7b75eb4cf325b77297b140ea686ce8f
init version: 949e6fa
Security Options:
    seccomp
    Profile: default
Kernel Version: 4.9.60-linuxkit-aufs
Operating System: Docker for Windows
OSType: linux
Architecture: x86_64
CPUs: 2
Total Memory: 1.934GiB
Name: linuxkit-00155d006303
ID: Y6MQ:YGY2:VSAR:WUPD:Z4DA:PJ6P:ZRWQ:C724:6RKP:YCCA:3NPJ:TRWO
Docker Root Dir: /var/lib/docker
Debug Mode (client): false
Debug Mode (server): true
    File Descriptors: 19
    Goroutines: 35
    System Time: 2018-02-11T15:56:36.2281139Z
    EventsListeners: 1
Registry: https://index.docker.io/v1/
Labels:
Experimental: true
Insecure Registries:
    127.0.0.0/8
Live Restore Enabled: false
```

If you do not see this message or something similar, refer to the previous sections to install and validate your Docker install.

Working with Docker Images

Let's look at the available Docker images. To do this, type the following command:

```
docker image ls
```

Here's a listing of the images available locally.

REPOSITORY	TAG	IMAGE ID	CREATED	SIZE
hello-world	latest	f2a91732366c	2 months ago	1.85kB

If you had pulled more images or run more containers, you'd have seen a bigger list. Let's look at the hello-world image now. To do this, type the following:

```
docker image inspect hello-world
```

```
[
  {
    "Id": "sha256:f2a91732366c0332ccd7afd2a5c4ff2b9af81f549
      370f7a19acd460f87686bc7",
    "RepoTags": [
      "hello-world:latest"
    ],
    "RepoDigests": [
      "hello-world@sha256:66ef312bbac49c39a89aa9bcc3cb4f3
        c9e7de3788c944158df3ee0176d32b751"
    ],
    "Parent": "",
    "Comment": "",
    "Created": "2017-11-21T00:23:18.797567713Z",
```

```

"Container": "fb0b4536aac3a96065e1bedb2b637a6019feec666
c7699592206956c9d3adf5f",
"ContainerConfig": {
  "Hostname": "fb0b4536aac3",
  "Domainname": "",
  "User": "",
  "AttachStdin": false,
  "AttachStdout": false,
  "AttachStderr": false,
  "Tty": false,
  "OpenStdin": false,
  "StdinOnce": false,
  "Env": [
    "PATH=/usr/local/sbin:/usr/local/bin:/usr/
    sbin:/usr/bin:/sbin:/bin"
  ],
  "Cmd": [
    "/bin/sh",
    "-c",
    "#(nop) ",
    "CMD [\"/hello\"]"
  ],
  "ArgsEscaped": true,
  "Image": "sha256:2243ee460b69c4c036bc0e42a48eaa59e8
2fc7737f7c9bd2714f669ef1f8370f",
  "Volumes": null,
  "WorkingDir": "",
  "Entrypoint": null,
  "OnBuild": null,
  "Labels": {}
},

```

```

"DockerVersion": "17.06.2-ce",
"Author": "",
"Config": {
  "Hostname": "",
  "Domainname": "",
  "User": "",
  "AttachStdin": false,
  "AttachStdout": false,
  "AttachStderr": false,
  "Tty": false,
  "OpenStdin": false,
  "StdinOnce": false,
  "Env": [
    "PATH=/usr/local/sbin:/usr/local/bin:/usr/
      sbin:/usr/bin:/sbin:/bin"
  ],
  "Cmd": [
    "/hello"
  ],
  "ArgsEscaped": true,
  "Image": "sha256:2243ee460b69c4c036bc0e42a48eaa59e8
    2fc7737f7c9bd2714f669ef1f8370f",
  "Volumes": null,
  "WorkingDir": "",
  "Entrypoint": null,
  "OnBuild": null,
  "Labels": null
},
"Architecture": "amd64",
"Os": "linux",
"Size": 1848,
"VirtualSize": 1848,

```

```

"GraphDriver": {
  "Data": {
    "MergedDir": "/var/lib/docker/overlay2/5855bd20
      ab2f521c39e1157f98f235b46d7c12c9d8
      f69e252f0ee8b04ac73d33/merged",
    "UpperDir": "/var/lib/docker/overlay2/5855bd20a
      b2f521c39e1157f98f235b46d7c12c9d8f6
      9e252f0ee8b04ac73d33/diff",
    "WorkDir": "/var/lib/docker/overlay2/5855bd20ab
      2f521c39e1157f98f235b46d7c12c9d8f69e
      252f0ee8b04ac73d33/work"
  },
  "Name": "overlay2"
},
"RootFS": {
  "Type": "layers",
  "Layers": [
    "sha256:f999ae22f308fea973e5a25b57699b5daf6b
      of1150ac2a5c2ea9d7fecee50fdf"
  ]
},
"Metadata": {
  "LastTagTime": "0001-01-01T00:00:00Z"
}
}
]

```

The **docker inspect** command provides a lot of information about the image. Of importance are the image properties **Env**, **Cmd**, and **Layers**, which tell us about these environment variables. They tell us which executable runs when the container is started and the layers associated with these environment variables.


```
docker image inspect hello-world | jq .[].Config.Env  
[  
  "PATH=/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin:/bin"  
]
```

Here's the startup command on the container:

```
docker image inspect hello-world | jq .[].Config.Cmd  
[  
  "/hello"  
]
```

Here are the layers associated with the image:

```
docker image inspect hello-world | jq .[].RootFS.Layers  
[  
  "sha256:f999ae22f308fea973e5a25b57699b5daf6b0f1150ac2a5c2ea9d7fecee50fdf"  
]
```

Working with a Real-World Docker Images

Let's look at a more complex image now. Nginx is a very popular reverse proxy server for HTTP/S (among others), as well as a load balancer and a webserver.

To pull down the nginx image, type the following:

```
docker pull nginx
```

```
Using default tag: latest  
latest: Pulling from library/nginx  
e7bb522d92ff: Pull complete  
6edc05228666: Pull complete  
cd866a17e81f: Pull complete
```

```
Digest: sha256:285b49d42c703fdf257d1e2422765c4ba9d3e37768d6ea83
d7fe2043dad6e63d
```

```
Status: Downloaded newer image for nginx:latest
```

Notice the first line:

Using default tag: latest

Every Docker image has an associated tag. Tags typically include names and version labels. While it is not mandatory to associate a version tag with a Docker image name, these tags make it easier to roll back to previous versions. Without a tag name, Docker must fetch the image with the latest tag. You can also provide a tag name to force-fetch a tagged image.

Docker Store lists the different tags associated with the image. If you're looking for a specific tag/version, it's best to check Docker Store. Figure 2-3 shows a typical tag listing of an image.

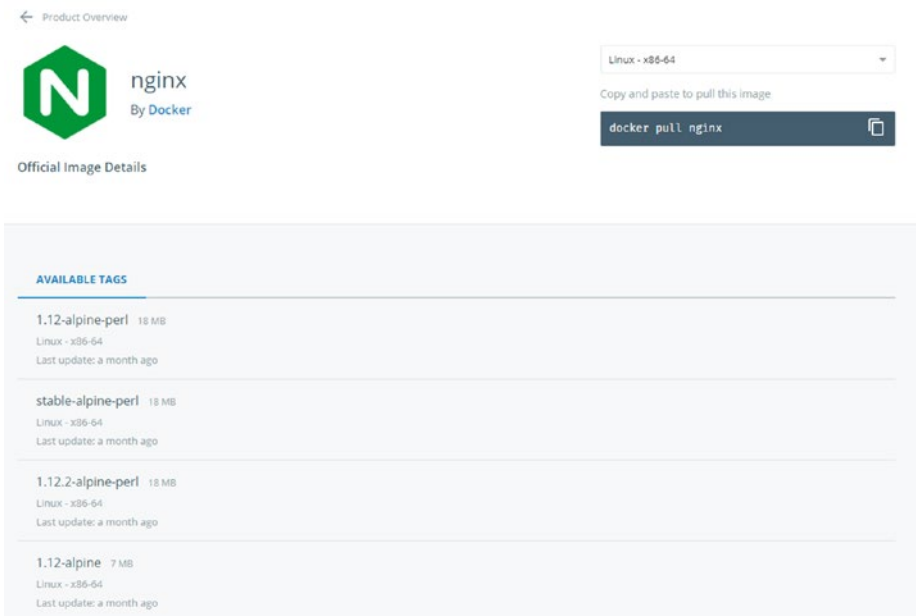


Figure 2-3. Docker Store listing of nginx and the available tags

Let's try to pull the `1.12-alpine-perl` version of `nginx`. This command is the same as before; you only have to append the tag with a colon to explicitly mention the tag:

```
docker pull nginx:1.12-alpine-perl
1.12-alpine-perl: Pulling from library/nginx
550fe1bea624: Pull complete
20a55c7b3b0e: Pull complete
552be5624b14: Pull complete
40fc04944e91: Pull complete
Digest: sha256:b7970b06de2b70acca1784ab92fb06d60f4f714e901a55b6
      b5211c22a446dbd2
Status: Downloaded newer image for nginx:1.12-alpine-perl
```

The different hex numbers that you see are the associated layers of the image. By default, Docker pulls the image from Docker Hub. You can manually specify a different registry, which is useful if the Docker images are not available on Docker Hub and are instead stored elsewhere, such as an on-premise hosted artifactory. To do this, you have to prepend the registry path to the image name. So, if the registry is hosted on `docker-private.registry` and is being served on 1337 port, the pull command will now be:

```
docker pull docker-private.registry:1337/nginx
```

If the registry needs authentication, you can log in to the registry by typing `docker login`:

```
docker login docker-private.registry:1337
```

Now that you have the image, try to start a container. To start a container and run the associated image, you have to type `docker run`.

```
docker run -p 80:80 nginx
```

Let's try making a curl request to see if the nginx webserver is running:

```
curl http://localhost:80
<!DOCTYPE html>
<html>
<head>
<title>Welcome to nginx!</title>
<style>
  body {
    width: 35em;
    margin: 0 auto;
    font-family: Tahoma, Verdana, Arial, sans-serif;
  }
</style>
</head>
<body>
<h1>Welcome to nginx!</h1>
<p>If you see this page, the nginx web server is successfully
installed and working. Further configuration is required.</p>
<p>For online documentation and support please refer to
<a href="http://nginx.org/">nginx.org</a>.<br/>
Commercial support is available at
<a href="http://nginx.com/">nginx.com</a>.</p>
<p><em>Thank you for using nginx.</em></p>
</body>
</html>
```

This confirms that our nginx container is indeed up and running. In this, we see an extra flag called `-p`. This flag tells Docker to publish the exposed port from the Docker container to the host.

The first parameter after the flag is the port on the Docker host that must be published and the second parameter refers to the port within the container. We can confirm that the image publishes the port using the `docker inspect` command:

```
docker image inspect nginx | jq .[].Config.ExposedPorts
{
  "80/tcp": {}
}
```

We can change the port on which the service is published on the Docker host by changing the first parameter after the `-p` flag:

```
docker run -p 8080:80 nginx
```

Now, try running a `curl` request to port 8080:

```
curl http://localhost:8080
```

You should see the same response. To list all the running containers, you can type `docker ps`:

```
docker ps
```

```
docker ps
CONTAINER ID   IMAGE     COMMAND                  CREATED
STATUS        PORTS     NAMES
fac5e92fdfac   nginx     "nginx -g 'daemon of..." 5 seconds ago
Up 3 seconds   0.0.0.0:80->80/tcp   elastic_hugle
3ed1222964de   nginx     "nginx -g 'daemon of..." 16 minutes ago
Up 16 minutes  0.0.0.0:8080->80/tcp  clever_thompson
```

The point to note is the `NAMES` column. Docker automatically assigns a random name when a container is started. Since you'd like more meaningful names, you can provide a name to the container by providing `-n required-name` as the parameter.

Tip Docker names are of the format `adjective_surname` and are randomly generated, with the exception that if the adjective selected is boring and the surname is Wozniak, Docker retries the name generation.

Another point to note is that when we created a second container with port publishing to port 8080, the other container continues to run. To stop the container, you have to type `docker stop`:

```
docker stop <container-id>
```

where **container-id** is available from the list. If the stop was successful, Docker will echo the container ID back. If the container refuses to stop, you can issue a `kill` command to force stop and kill the container:

```
docker stop <container-id>
```

Let's try stopping a container. Type the following:

```
docker stop fac5e92fdfac
fac5e92fdfac
```

Now, let's try killing the other container:

```
docker kill 3ed1222964de
3ed1222964de
```

Let's confirm that the containers are no longer running. For this, type the following:

```
docker ps
```

CONTAINER ID	IMAGE	COMMAND	CREATED	STATUS	PORTS	NAMES
--------------	-------	---------	---------	--------	-------	-------

So, what about the stopped containers—where are they? By default, **docker ps** only shows the active, running containers. To list all the containers, type the following:

```
docker ps -a
```

CONTAINER ID	IMAGE	COMMAND	CREATED
STATUS	PORTS	NAMES	
fac5e92fdfac	nginx	"nginx -g 'daemon of...'"	6 minutes ago
Exited (0)	4 minutes ago	elastic_hugle	
3ed1222964de	nginx	"nginx -g 'daemon of...'"	22 minutes ago
Exited (137)	3 minutes ago	clever_thompson	
febda50b0a80	nginx	"nginx -g 'daemon of...'"	28 minutes ago
Exited (137)	24 minutes ago	objective_franklin	
dc0c33a79fb7	nginx	"nginx -g 'daemon of...'"	33 minutes ago
Exited (137)	28 minutes ago	vigorous_mccarthy	
179f16d37403	nginx	"nginx -g 'daemon of...'"	34 minutes ago
Exited (137)	34 minutes ago	nginx-test	

Even though the containers have been stopped and/or killed, these containers continue to exist in the local filesystem. You can remove the containers by typing the following:

```
docker rm <container-id>
docker rm fac5e92fdfac
fac5e92fdfac
```

Now confirm that the container was indeed removed:

```
docker ps -a
```

CONTAINER ID	IMAGE	COMMAND	CREATED
STATUS	PORTS	NAMES	
3ed1222964de	nginx	"nginx -g 'daemon of...'"	28 minutes ago
Exited (137)	9 minutes ago	clever_thompson	

```

febda50b0a80  nginx  "nginx -g 'daemon of..." 34 minutes ago
Exited (137) 30 minutes ago      objective_franklin
dc0c33a79fb7  nginx  "nginx -g 'daemon of..." 39 minutes ago
Exited (137) 34 minutes ago      vigorous_mccarthy
179f16d37403  nginx  "nginx -g 'daemon of..." 40 minutes ago
Exited (137) 40 minutes ago      nginx-test

```

You can see from this table that that container with the ID `fac5e92fdfac` is no longer shown and hence has been removed.

Similarly, you can list all the images present in the system by typing the following:

```

docker image ls

```

REPOSITORY	TAG	IMAGE ID	CREATED	SIZE
nginx	1.12-alpine-perl	b6a456f1d7ae	4 weeks ago	57.7MB
nginx	latest	3f8a4339aadd	6 weeks ago	108MB
hello-world	latest	f2a91732366c	2 months ago	1.85kB
kitematic/	latest	03b4557ad7b9	2 years ago	7.91MB

```

hello-world
-nginx

```

Let's try to remove the nginx image:

```

docker rmi 3f8a4339aadd
Error response from daemon: conflict: unable to delete
3f8a4339aadd (must be forced) - image is being used by stopped
container dc0c33a79fb7

```

In this case, Docker refuses to remove the image because there is a reference to this image from another container. Until we remove all the containers that use a particular image, we will not be able to remove the image altogether.

Summary

In this chapter, you learned about how to install Docker on various operating systems. We also learned how to validate that Docker is installed and working correctly and learned about some commonly used terms associated with Docker. Finally, you run through few practical exercises using Docker, including how to pull an image, run a container, list the running containers, and stop and remove a container.

In the next chapter, we take a brief look at Telegram, including how to create and register a bot with Telegram and understand how to run a Python-based Telegram Messaging bot that will fetch posts from Reddit.

CHAPTER 3

Building the Python App

For many people getting into programming, one of their first problems is not understanding the language syntax, rather the problem starts with “what can I build?”. Programming is seldom learned by just reading. Many people will read couple of definitive guides and look at the syntax, while rarely diving into the actual practical aspects. This is a mistake.

For this reason, this book provides you with a sample Python project. The project is not very complicated for those getting started with Python, but at the same time it’s easy to continue working further on the project, extending and customizing it as required.

About the Project

Note This book assumes you have basic knowledge of Python and have Python 3.0 and above installed.

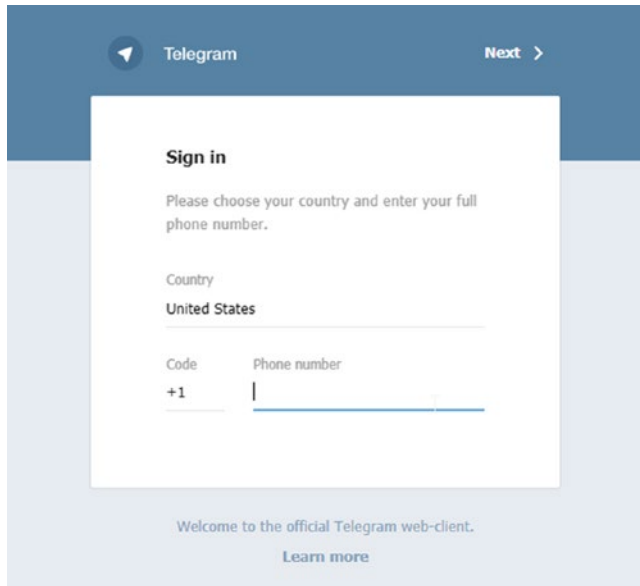
To help you get acquainted with Docker, the book will teach you how to take an existing Python app, run it using the Python command line, introduce different Docker components, and transition the app into a Dockerized image.

The Python app is a simple application with a bot interface using Telegram Messenger to fetch the latest 10 stories from Reddit. Using Telegram, we will be able to subscribe to a list of subreddits. The web application will check the subscribed subreddits for new posts and if it finds new topics, will publish the topics to the bot interface, which will then deliver the message to Telegram Messenger, when requested by the user.

Initially, we will not be saving the preferences (i.e., subreddit subscriptions) and will focus on getting the bot up and running. Once things are working fine, we will save the preferences to a text file, and eventually, to a database.

Setting Up Telegram Messenger

Before we can proceed, we will need a Telegram Messenger account. To sign up, go to <https://telegram.org>, download the application for the platform of your choice, and install it. Once it's running, you'll be asked to provide a cell phone number. Telegram uses this to validate your account. Enter the cell phone number as shown in Figure 3-1.



The image shows the Telegram Messenger signup page. At the top, there is a blue header with the Telegram logo on the left and the word "Next" followed by a right-pointing arrow on the right. Below the header is a white sign-in form. The form has a title "Sign in" and a subtitle "Please choose your country and enter your full phone number." Below the subtitle, there is a "Country" label and a dropdown menu showing "United States". Below the country, there are two input fields: "Code" with the value "+1" and "Phone number" which is empty. At the bottom of the form, there is a blue link that says "Learn more".

Figure 3-1. Telegram Messenger signup page

Once we've entered our number, we should be getting a one-time password to log in. Enter the one-time password and sign in, as shown in Figure 3-2.

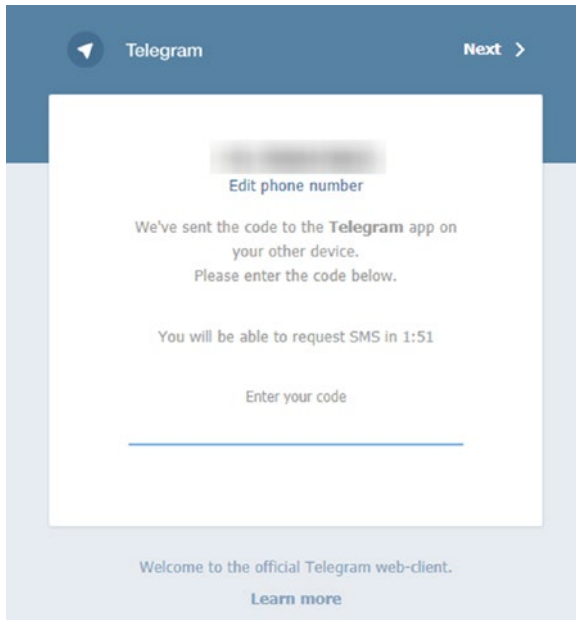


Figure 3-2. *Telegram one-time password*

BotFather: Telegram's Bot Creation Interface

Telegram uses a bot called “BotFather” as its interface for creating and updating bots. To get started with BotFather, in the search panel type BotFather. From the chat window, type /start.

This will trigger BotFather to provide an introductory set of messages, as shown in Figure 3-3.

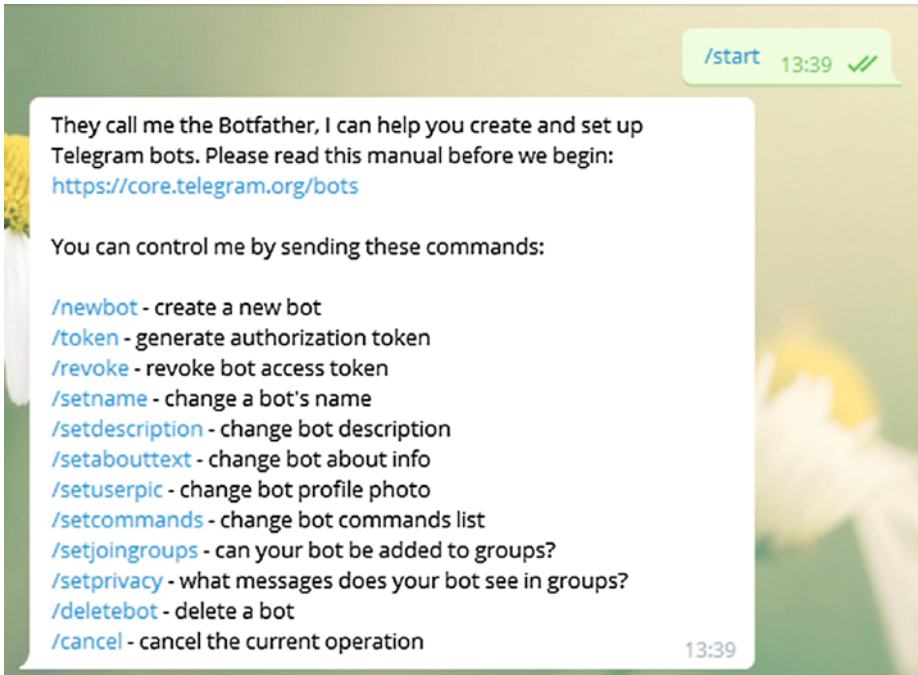


Figure 3-3. *BotFather options*

Creating the Bot with BotFather

We will be using BotFather to generate a new bot. Start by typing `/newbot` in Telegram Messenger. This will trigger a series of questions that you need to answer (most of them are straightforward). Due to Telegram's restrictions, the username for a bot must always end with `bot`. This means that you might not get your desired username—just keep this in mind. See Figure 3-4.

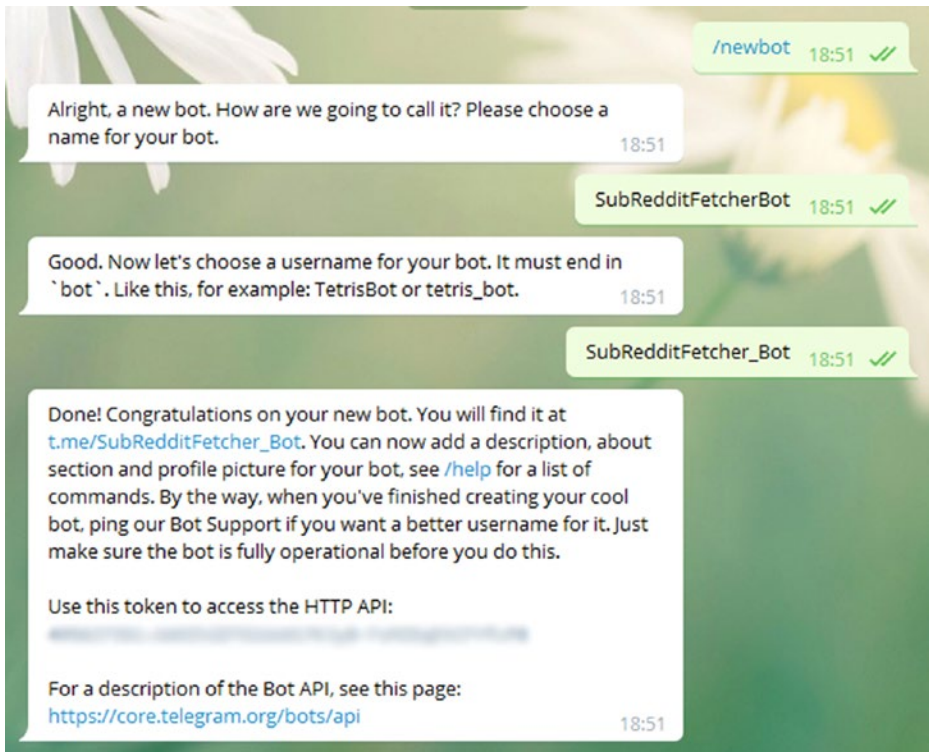


Figure 3-4. Telegram bot ready for action

Along with the link to the documentation, you will notice that Telegram has issued you a token. HTTP is a stateless protocol—the webserver does not know and does not keep track of who is requesting the resource, so the client needs to identify itself so the webserver can identify the client, authorize it, and serve the request. Telegram uses the API token (henceforth, referred to as <token>, including code samples) as way of identifying and authorizing bots.

Note The token is extremely sensitive and if it's leaked online, anyone can post messages as your bot. Do not check it in with your version control or publish it anywhere!

When you're working with APIs you are not familiar with, it's always a good idea to use a tool to test and explore the endpoints instead of typing the code right away. Some examples of REST API test tools include [Insomnia](#), [Postman](#), and [curl](#).

Telegram's Bot API documentation is available at <https://core.telegram.org/bots/api>. To make a request, you'll have to include the <token> as part of the request. The general URL is:

```
https://api.telegram.org/bot<token>/METHOD_NAME
```

Let's try a sample API request that confirms the token is working as expected. Telegram Bot API provides a /getMe endpoint for testing the auth token. Let's try it out, first without the token:

```
curl https://api.telegram.org/bot/getMe

{
  "ok": false,
  "error_code": 404,
  "description": "Not Found"
}
```

We can see that without the bot token, Telegram doesn't honor our request. Let's try it with the token:

```
curl https://api.telegram.org/bot<token>/getMe

{
  "ok": true,
  "result": {
    "id": 495637361,
    "is_bot": true,
    "first_name": "SubRedditFetcherBot",
    "username": "SubRedditFetcher_Bot"
  }
}
```


We can see with the proper token, Telegram identified and authorized our bot. This confirms that our bot token is proper and we can go ahead with the app.

Newsbot: The Python App

Newsbot is a Python script that interacts with our bot with the help of [Telegram Bot API](#). Newsbot does the following things:

- Continuously polls the Telegram API for new updates being posted to the bot.
- If the keyword for fetching new updates was detected, fetches the news from the selected subreddits.

Behind the scenes, Newsbot also handles these scenarios:

- If there's a new message starting with `/start` or `/help`, it shows a simple help text explaining what to do.
- If there's a message starting with `/sources` followed by a list of subreddits, it accepts them as the subreddits from where the Reddit posts must be fetched.

Newsbot depends on a couple of Python libraries:

- Praw or Python Reddit API Wrapper, for fetching posts from subreddits.
- Requests, one of the most popular Python libraries for providing a simpler, cleaner API for making HTTP requests.

Installing Dependencies of Newsbot

To get started with this bot, let's install the dependencies. To do this, type this:

```
pip3 install -r requirements.txt
```

Note *pip* (the acronym for *Pip installs packages*) is a package manager for installing Python libraries. Pip is included with Python 2.7.9 and later, and Python 3.4 and later. `pip3` indicates that we are installing libraries for Python 3. If `pip` is not installed, install it before proceeding.

The `-r` flag tells `pip` to install the required packages from `requirements.txt`.

`pip` will check, download, and install the dependencies. If all goes well, it should show the following output:

```
Collecting praw==3.6.0 (from -r requirements.txt (line 1))
  Downloading praw-3.6.0-py2.py3-none-any.whl (74kB)
Collecting requests==2.18.4 (from -r requirements.txt (line 2))
[...]
Installing collected packages: requests, update-checker,
decorator, six, praw
Successfully installed decorator-4.0.11 praw-3.6.0
requests-2.18.4 six-1.10.0 update-checker-0.16
```

If there were some packages already installed, then `pip` will not reinstall the package and will inform us that the dependency is installed with a "Requirement already satisfied" message.

Running Newsbot

Let's start the bot. The bot requires the `<token>` to be passed an environment variable to the script named `NBT_ACCESS_TOKEN`, so prepend this and run as follows:

```
NBT_ACCESS_TOKEN=<token> python newsbot.py
```

If all's well, you should be seeing periodic OK messages like shown here. This means that Newsbot is running and is actively listening for updates.

```
python newsbot.py
```

```
INFO: get_updates - received response: {'ok': True, 'result': []}
INFO: get_updates - received response: {'ok': True, 'result': []}
INFO: get_updates - received response: {'ok': True, 'result': []}
INFO: get_updates - received response: {'ok': True, 'result': []}
INFO: get_updates - received response: {'ok': True, 'result': []}
INFO: get_updates - received response: {'ok': True, 'result': []}
```

Sending Messages to Newsbot

Let's try sending a message to our bot to see if it responds. From the BotFather window, click on the link to the bot (alternatively, you can also search with the bot username). Click on the start button. This will trigger a /start command, which will be intercepted by the bot.

Notice that the log window shows the incoming request and the outgoing message being sent:

```
INFO: get_updates - received response: {'ok': True, 'result': []}
INFO: get_updates - received response: {'ok': True, 'result': []}
INFO: get_updates - received response: {'ok': True, 'result': []}
INFO: get_updates - received response: {'ok': True, 'result':
[{'update_id': 720594461, 'message': {'message_id': 5, 'from':
{'id': 7342383, 'is_bot': False, 'first_name': 'Sathya', 'last_
name': 'Bhat', 'username': 'sathyabhat', 'language_code': 'en-
US'}, 'chat': {'id': 7342383, 'first_name': 'Sathya', 'last_
name': 'Bhat', 'username': 'sathyabhat', 'type': 'private'},
'date': 1516558659, 'text': '/start', 'entities': [{'offset':
0, 'length': 6, 'type': 'bot_command'}]}]}}
```

```
INFO: handle_incoming_messages - Chat text received: /start
INFO: post_message - posting
Hi! This is a News Bot which fetches news
from subreddits. Use "/source" to select a
subreddit source.
```

Example `"/source programming, games"` fetches news from `r/programming`, `r/games`.

Use `"/fetch"` for the bot to go ahead and fetch the news. At the moment, bot will fetch total of 10 posts from all subreddits

to 7342383

```
INFO: get_updates - received response: {'ok': True, 'result':
[]}]
```

Figure 3-5 shows what you will see in the Telegram Messenger window.

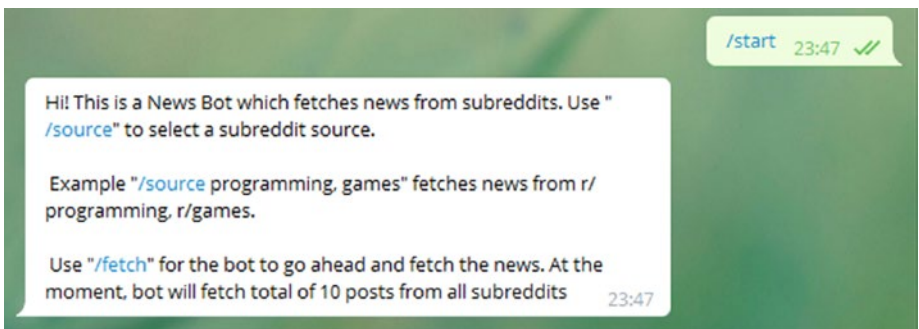


Figure 3-5. *The response from bot to our start message*

Let's try setting a source subreddit. From the Telegram Messenger window, type the following:

```
/source python
```

You should get a positive acknowledgement from the bot saying the source was selected, as shown in Figure 3-6.

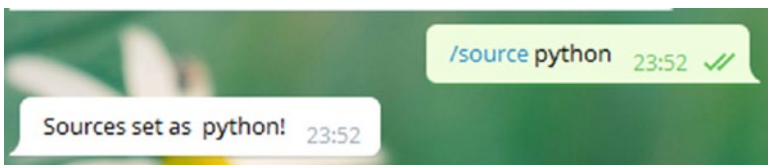


Figure 3-6. *Sources assigned*

Let's have the bot fetch us some news. To do this, type the following:

/fetch

The bot should send an acknowledgement message about fetching the posts and then publish the posts from Reddit. See Figure 3-7.

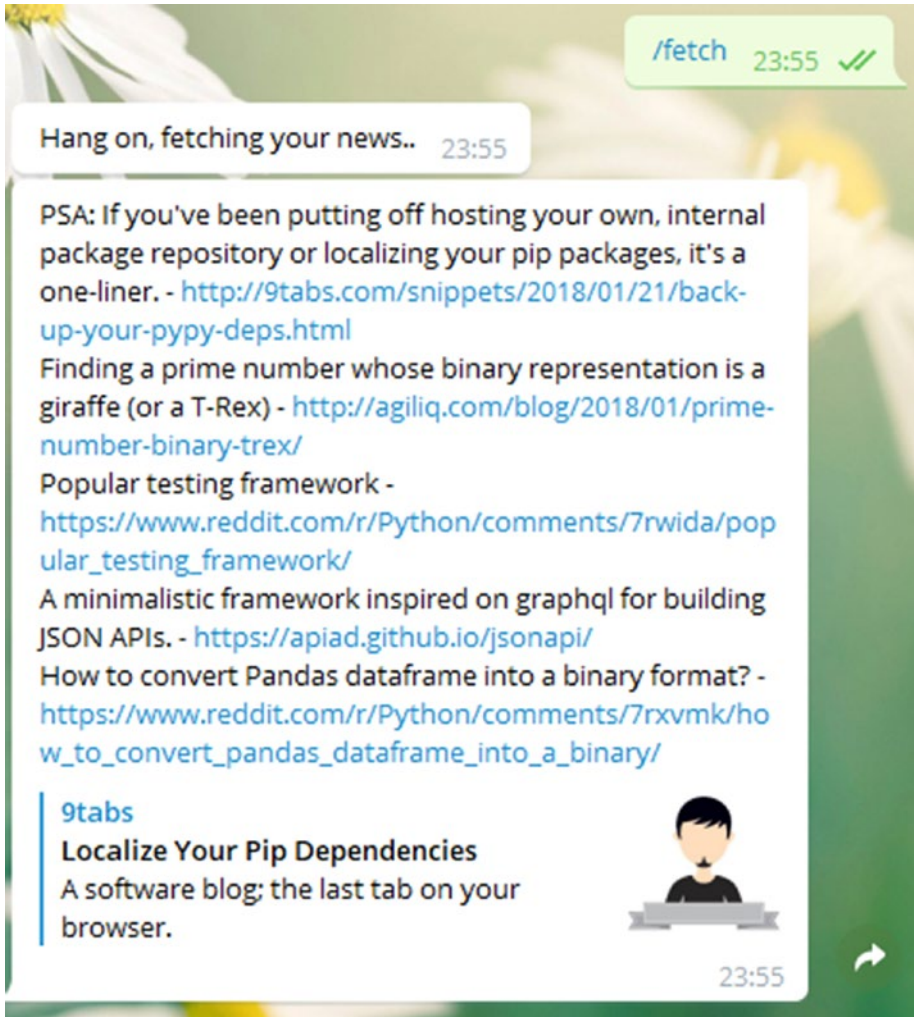


Figure 3-7. Posts are published

The bot works by fetching the top posts as expected. In the next series of chapters, you learn how to move the application to Docker.

Summary

In this chapter, you learned about the Python project, which is a chatbot. You also learned how to install and configure Telegram Messenger using Telegram's BotFather to create the bot, how to install the dependencies for the bot, and finally, how to run the bot and ensure that it works correctly. In the next chapter, we dive deep into Docker, learn more about the Dockerfile, and Dockerize our Newsbot by writing a Dockerfile for it.

CHAPTER 4

Understanding the Dockerfile

Now that you have a better understanding of Docker and its associated terminology, let's convert the project into a Dockerized application. In this chapter, you take a look at a Dockerfile, including its syntax, and learn how to write a sample Dockerfile.

By understanding the Dockerfile, you are working toward the first step in writing a Dockerfile for the project.

Dockerfile

For a traditionally deployed application, building and packaging an application was often quite tedious. With the aim to automate the building and packaging of the application, people turned to different utilities, such as GNU Make, maven, gradle, etc., to build the application package. Similarly, in the Docker world, a Dockerfile is an automated way to build your Docker images.

The Dockerfile contains special instructions, which tell the Docker Engine about the steps required to build an image. To invoke a build using Docker, you issue the Docker build command.

A typical Dockerfile looks like this:

```
FROM ubuntu:latest
LABEL author="sathyabhat"
LABEL description="An example Dockerfile"
RUN apt-get install python
COPY hello-world.py
CMD python hello-world.py
```

Looking at the Dockerfile, it's easy to comprehend what we're telling the Docker Engine to build. However, don't let the simplicity fool you—the Dockerfile lets you build complex conditions when generating your Docker image. When a Docker build command is issued, it builds the Docker images from the Dockerfile within context.

Build Context

A build context is a file or set of files available at a specific path or URL. To understand this better, we might have some supporting files that we need during a Docker image build—for instance, an application specific config file that was been generated earlier and needs to be part of the container.

The build context can be local or remote—we can even set the build context to the URL of a Git repository, which can come in handy if the source files are not located on the same host as the Docker daemon or if we'd like to test out feature branches. We simply set the context to the branch. The build command looks like this:

```
docker build https://github.com/sathyabhat/sample-repo.  
git#mybranch
```

Similarly, to build images based on your Git tags, the build command would look like this:

```
docker build https://github.com/sathyabhat/sample-repo.  
git#mytag
```


Working on a feature via a pull request? Want to try out that pull request? Not a problem; you can even set the context to a pull request as follows:

```
docker build https://github.com/sathyabhat/sample-repo.  
git#pull/1337/head
```

The build command sets the context to the path or URL provided, uploading the files to the Docker daemon and allowing it to build the image. You are not limited to the build context of the URL or path. If you pass an URL to a remote tarball, the tarball at the URL is downloaded onto the Docker daemon and the build command is issued with that as the build context.

Caution If you provide the Dockerfile on the root (/) directory and set that as the context, this will transfer your hard disk contents to the Docker daemon.

Dockerignore

You should now understand that the build context transfers the contents of the current directory to the Docker daemon during the build. Consider the case where the context directory has a lot of files/directories that are not relevant to the build process. Uploading these files can cause a significant increase in traffic. Dockerignore, much like gitignore, allows you to define files which are exempt from being transferred during the build process.

The ignore list is provided by a file known as `.dockerignore` and when the Docker CLI finds this file, it modifies the context to exclude the files/patterns provided in the file. Anything starting with a hash (#) is considered a comment and ignored. Here's a sample `.dockerignore` file that excludes a `temp` directory, a `.git` directory, and the `.DS_Store` directory:

.dockerignore Listing

```
*/temp*  
.DS_Store  
.git
```

Building Using Docker Build

We'll return to the sample Dockerfile a bit later. Let's try a simple Dockerfile first. Copy the following contents to a file and save it as a Dockerfile:

Dockerfile Listing

```
FROM ubuntu:latest  
CMD echo Hello World!
```

Now build this image:

```
docker build .
```

You should see a response like this:

```
Sending build context to Docker daemon  2.048kB  
Step 1/2 : FROM ubuntu:latest  
latest: Pulling from library/ubuntu  
22dc81ace0ea: Pull complete  
1a8b3c87dba3: Pull complete  
91390a1c435a: Pull complete  
07844b14977e: Pull complete  
b78396653dae: Pull complete  
Digest: sha256:e348fbbea0e0a0e73ab0370de151e7800684445c509d4619  
5aef73e090a49bd6  
Status: Downloaded newer image for ubuntu:latest  
---> f975c5035748  
Step 2/2 : CMD echo Hello World!
```

```

---> Running in 26723ca45a12
Removing intermediate container 26723ca45a12
---> 7ae54947f6a4
Successfully built 7ae54947f6a4

```

We can see that the Docker build works in steps, each step corresponding to one instruction of the Dockerfile. Try the build process again.

Dockerfile Listing

```

docker build .
Sending build context to Docker daemon 2.048kB
Step 1/2 : FROM ubuntu:latest
---> f975c5035748
Step 2/2 : CMD echo Hello World!
---> Using cache
---> 7ae54947f6a4
Successfully built 7ae54947f6a4

```

In this case, the build process is much faster since Docker has already cached the layers and doesn't have to pull them again. To run this image, use the `docker run` command followed by the image ID `7ae54947f6a4`:

```

docker run 7ae54947f6a4
Hello World!

```

The Docker runtime was able to start a container and run the command defined by the `CMD` instruction. Hence, we get the output. Now, starting a container from an image by typing the image ID gets tedious fast. You can make this easier by tagging the image with an easy-to-remember name. You can do this by using the `docker tag` command, as follows:

```

docker tag image_id tag_name
docker tag 7ae54947f6a4 sathya:hello-world

```

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You can also do this as part of the build process itself:

```
docker build -t sathya:hello-world .
```

```
Sending build context to Docker daemon 2.048kB
```

```
Step 1/2 : FROM ubuntu:latest
```

```
---> f975c5035748
```

```
Step 2/2 : CMD echo Hello World!
```

```
---> Using cache
```

```
---> 7ae54947f6a4
```

```
Successfully built 7ae54947f6a4
```

```
Successfully tagged sathya:hello-world
```

The last line tells you that the image was tagged successfully. You can verify this by searching for docker images as follows:

```
docker images sathya:hello-world
```

REPOSITORY	TAG	IMAGE ID
CREATED	SIZE	
sathya	hello-world	7ae54947f6a4
24 minutes ago	112MB	

Docker also validates that the Dockerfile's instructions are valid and in the proper syntax. Consider the earlier Dockerfile, shown here.

Dockerfile Listing

```
FROM ubuntu:latest
LABEL author="sathyabhat"
LABEL description="An example Dockerfile"
RUN apt-get install python
COPY hello-world.py
CMD python hello-world.py
```

If you try to build this Dockerfile, Docker will complain with an error:

```
docker build -t sathyabhat:python-hello-world .  
Sending build context to Docker daemon 2.048kB  
Error response from daemon: Dockerfile parse error line 5: COPY  
requires at least two arguments, but only one was provided.  
Destination could not be determined.
```

We'll get back to fixing this problem a little later in the chapter. For now, let's look at some of the commonly used Dockerfile instructions.

Dockerfile Instructions

When looking at a Dockerfile, you're mostly likely to run into the following instructions:

- FROM
- ADD
- COPY
- RUN
- CMD
- ENTRYPOINT
- ENV
- VOLUME
- LABEL
- EXPOSE

Let's see what they do.

FROM

As you learned earlier, every image needs to start from a base image. The FROM instruction tells the Docker Engine which base image to use for subsequent instructions. Every valid Dockerfile must start with a FROM instruction. The syntax is as follows:

```
FROM <image> [AS <name>]
```

OR

```
FROM <image>[:<tag>] [AS <name>]
```

OR

```
FROM <image>[@<digest>] [AS <name>]
```

Where <image> is the name of a valid Docker image from any public/private repository. If the tag is skipped, Docker will fetch the image tagged as the latest. This is verified by this simple step. Create a Dockerfile with contents as shown here:

Dockerfile Listing

```
FROM ubuntu
CMD echo Hello World!
Build the image
docker build .
Sending build context to Docker daemon 2.048kB
Step 1/2 : FROM ubuntu:latest
--> f975c5035748
Step 2/2 : CMD echo Hello World!
--> 7ae54947f6a4
Successfully built 7ae54947f6a4
```

Now modify the Dockerfile to include the latest tag, as shown.

Dockerfile Listing

```
FROM ubuntu:latest
CMD echo Hello World!
```

Build the image:

```
docker build .
Sending build context to Docker daemon 2.048kB
Step 1/2 : FROM ubuntu:latest
---> f975c5035748
Step 2/2 : CMD echo Hello World!
---> 7ae54947f6a4
Successfully built 7ae54947f6a4
```

You can see in the first step that the image hash remains the same, confirming that skipping the image tag will result in Docker fetching the image with the latest tag.

Note We recommend always providing a tag to avoid unexpected changes that might not have been tested when a latest tagged image was built.

WORKDIR

WORKDIR instruction sets the current working directory for RUN, CMD, ENTRYPOINT, COPY, and ADD instructions. The syntax is as follows:

```
WORKDIR /path/to/directory
```

WORKDIR can be set multiple times in a Dockerfile and, if a relative directory succeeds a previous WORKDIR instruction, it will be relative to the previously set working directory. The following example demonstrates this.

Dockerfile Listing

```
FROM ubuntu:latest
WORKDIR /usr
CMD pwd
```

This Dockerfile fetches the latest tagged image from Ubuntu as the base image, sets the current working directory to `/usr`, and prints the current working directory when the image is run.

Let's try building and running this and then examining the output:

```
docker build -t sathyabhat:workdir .
Sending build context to Docker daemon 2.048kB
Step 1/3 : FROM ubuntu:latest
---> f975c5035748
Step 2/3 : WORKDIR /usr
---> Using cache
---> 8b0b5742b476
Step 3/3 : CMD pwd
---> Using cache
---> 4a827ca4a571
Successfully built 4a827ca4a571
Successfully tagged sathyabhat:workdir

docker run sathyabhat:workdir
/usr
```

The result of `pwd` makes it clear that the current working directory is set as `/usr` by way of the `WORKDIR` instruction.

Now we'll modify the Dockerfile to add couple of `WORKDIR` instructions.

Dockerfile Listing

```
FROM ubuntu:latest
```

```
WORKDIR /usr
```

```
WORKDIR src
```

```
WORKDIR app
```

```
CMD pwd
```

Now build and run the new image:

```
docker build -t sathyabhat:workdir .
Sending build context to Docker daemon 2.048kB
Step 1/5 : FROM ubuntu:latest
---> f975c5035748
Step 2/5 : WORKDIR /usr
---> Using cache
---> 8b0b5742b476
Step 3/5 : WORKDIR src
Removing intermediate container 5b1b88e4da20
---> 5ac5d4d4fe05
Step 4/5 : WORKDIR app
Removing intermediate container b9679196e934
---> b94f50750702
Step 5/5 : CMD pwd
---> Running in f78c97738bed
Removing intermediate container f78c97738bed
---> 90ebd71d1794
Successfully built 90ebd71d1794
Successfully tagged sathyabhat:workdir
```

Note that the image ID has changed, so that's a new image being built with the same tag:

```
docker run sathyabhat:workdir
/usr/src/app
```

As expected, the WORKDIR instructions of the relative directory has appended to the initial absolute directory set. By default, the WORKDIR is set as / so any WORKDIR instructions featuring a relative directory will be appended to /. Here's an example demonstrating this. Let's modify the Dockerfile as follows.

Dockerfile Listing

```
FROM ubuntu:latest
WORKDIR var
WORKDIR log/nginx
CMD pwd
```

Build the image:

```
docker build -t sathyabhat:workdir .
Sending build context to Docker daemon 2.048kB
Step 1/4 : FROM ubuntu:latest
---> f975c5035748
Step 2/4 : WORKDIR var
Removing intermediate container 793a97be060e
---> ae4b53721bab
Step 3/4 : WORKDIR log/nginx
Removing intermediate container b557dfe11cf3
---> 04fb3808cb35
Step 4/4 : CMD pwd
---> Running in 6ce9f7854160
Removing intermediate container 6ce9f7854160
---> bfd10d1dfd4a
Successfully built bfd10d1dfd4a
Successfully tagged sathyabhat:workdir
```

And let's run it:

```
docker run sathyabhat:workdir
/var/log/nginx
```

Notice that we did not set any absolute working directory in the Dockerfile. The relative directories were appended to the default.

ADD and COPY

At first glance, the ADD and COPY instructions seem to do the same—they allow you to transfer files from the host to the container’s filesystem. COPY supports basic copying of files to the container, while ADD has support for features like tarball auto extraction and remote URL support.

Syntax for both is quite similar:

```
ADD <source> <destination>
COPY <source> <destination>
```

For Dockerfiles used to build Linux containers, both of these instructions let you change the owner/group of the files being added to the container. This is done with the `--chown` flag, as follows:

```
ADD --chown=<user>:<group> <source> <destination>
COPY --chown=<user>:<group> <source> <destination>
```

For example, if you want to move the `requirements.txt` file from the current working directory to the `/usr/share/app` directory, the instruction would be as follows:

```
ADD requirements.txt /usr/share/app
COPY requirements.txt /usr/share/app
```

Both ADD and COPY support wildcards while specifying patterns. For example, having the following instructions in your Dockerfile will copy all files with the `.py` extension to the `/apps/` directory of the image.

```
ADD *.py /apps/
COPY *.py /apps/
```

Docker recommends using COPY over ADD, especially when it's a local file that's being copied. There are a few gotchas to be considered when using COPY versus ADD and the behavior of COPY/ADD instructions:

- If the `<destination>` does not exist in the image, it will be created.
- All new files/directories are created with UID and GID as 0, i.e., as the root user. To change this, use the `--chown` flag.
- If the files/directories contain special characters, they will need to be escaped.
- The `<destination>` can be an absolute or relative path. In case of relative paths, the relativeness will be inferred from the path set by the `WORKDIR` instruction.
- If the `<destination>` doesn't end with a trailing slash, it will be considered a file and the contents of the `<source>` will be written into `<destination>`.
- If the `<source>` is specified as a wildcard pattern, the `<destination>` must be a directory and must end with a trailing slash; otherwise, the build process will fail.
- The `<source>` must be within the build context—it cannot be a file/directory outside of the build context because the first step of a Docker build process involves sending the context directory to the Docker daemon.
- In case of the ADD instruction:
 - If the `<source>` is a URL and the `<destination>` is not a directory and doesn't end with a trailing slash, the file is downloaded from the URL and copied into `<destination>`.

- If the `<source>` is a URL and the `<destination>` is a directory and ends with a trailing slash, the filename is inferred from the URL and the file is downloaded and copied to `<destination>/<filename>`.
- If the `<source>` is a local tarball of a known compression format, the tarball is unpacked as a directory. Remote tarballs, however, are not uncompressed.

RUN

The `RUN` instruction will execute any commands in a new layer on top of the current image and create a new layer that is available for the next steps in the Dockerfile.

`RUN` has two forms:

`RUN <command>` (known as the shell form)

`RUN ["executable", "parameter 1", "parameter 2"]` (known as the exec form)

In *shell form*, the command is run in a shell with the command as a parameter. This form provides for a shell where shell variables, subcommands, and commanding piping and chaining is possible.

Consider a scenario where you'd like to embed the kernel release version into the home directory of the Docker image. With the shell form, it's easy enough:

```
RUN echo `uname -rv` > $HOME/kernel-info
```

This wouldn't be possible with the exec form. `RUN` is a build-time command and, as such, is run when a Docker image is built, rather than when it's run. The resultant layer is then cached. It's important to note that Docker uses the command string of a `RUN` instruction to build the cache, rather than the actual contents of the `RUN` instruction.

Consider the following Dockerfile.

Dockerfile Listing

```
FROM ubuntu:16.04
RUN apt-get update
```

When the image is built, Docker will cache all the layers of this command. However, consider when we build another Dockerfile, shown here.

Dockerfile Listing

```
FROM ubuntu:18.04
RUN apt-get update
```

In this case, Docker reuses the cache of the previous image and, as a result, the image build can contain outdated packages. The cache for the RUN instructions can be invalidated by using the `--no-cache` flag. Every RUN instruction creates a new layer. This can be a good or a bad thing—it's good because the resulting cache means that future builds can reuse the cache layer.

It can be bad because the cached layer might not be compatible with future builds and increases the size of the Docker image. Docker recommends chaining multiple RUN commands into a single command. For example, installing or using multiple RUN commands to install the required packages:

```
RUN apt-get update
RUN apt-get install foo
RUN apt-get install bar
RUN apt-get install baz
```

It's better to wrap them in a single RUN command:

```
RUN apt-get update && apt-get install -y \
    foo \
    bar \
    baz
```

This reduces the number of layers and makes for a leaner Docker image.

CMD and ENTRYPOINT

CMD and ENTRYPOINT instructions define which command is executed when running a container. The syntax for both are as follows:

```
CMD ["executable","param1","param2"] (exec form)
CMD ["param1","param2"] (as default parameters to ENTRYPOINT)
CMD command param1 param2 (shell form)
ENTRYPOINT ["executable", "param1", "param2"] (exec form)
ENTRYPOINT command param1 param2 (shell form)
```

The CMD instruction provides the defaults for an executing container. We can skip providing the executable for a CMD instruction, in which case the executable should be provided via the ENTRYPOINT instruction.

Consider the following Dockerfile.

Dockerfile Listing

```
FROM ubuntu:latest
RUN apt-get update && \
    apt-get install -y curl && \
    rm -rf /var/lib/apt/lists/*
CMD curl
```

In this Docker image, we select Ubuntu as the base image, install curl on it, and choose curl as the CMD instruction. This means that when the container is created and run, it will run curl without any parameters. Let's see the result when we run the container:

```
docker run sathyabhat:curl
curl: try 'curl --help' or 'curl --manual' for more information
```

This is because curl expects a parameter to be passed. We can override the CMD instruction by passing arguments to the docker run command. As an example, let's try to curl wttr.in, which fetches the current weather.

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```
docker run sathyabhat:curl wttr.in
docker: Error response from daemon: OCI runtime create failed:
container_linux.go:296: starting container process caused
"exec: \"wttr.in\": executable file not found in $PATH":
unknown.
```

Uh oh, an error. As mentioned, the parameters after `docker run` are used to override the `CMD` instruction. However, we have passed only `wttr.in` as the argument, not the executable itself. So, for the override to work properly, we need to pass in the executable, i.e. `curl`, as well:

```
docker run sathyabhat:curl curl -s wttr.in
Weather report: Gurgaon, India
```

```

                Haze
_ - _ - _ - 24-25 °C
_ - _ - _ - ↗ 13 km/h
_ - _ - _ - 3 km
                0.0 mm
```

Passing an executable every time to override a parameter can be quite tedious. This is where the combination of `ENTRYPOINT` and `CMD` shines—we can set `ENTRYPOINT` to the executable while the parameter can be passed from the command line and will be overridden. Modify the Dockerfile as shown:

```
FROM ubuntu:latest
RUN apt-get update && \
    apt-get install -y curl && \
    rm -rf /var/lib/apt/lists/*
ENTRYPOINT ["curl", "-s"]
```


Now we can `curl` any URL by just passing the URL as a parameter, instead of having to add the executable as well:

```
docker run sathyabhat:curl wttr.in
Weather report: Gurgaon, India
```

```

                Haze
_ - _ - _ - 24-25 °C
_ - _ - _ - ↗ 13 km/h
_ - _ - _ - 3 km
                0.0 mm
```

Of course, `curl` is just an example here—you can replace `curl` with any other program that accepts parameters (such as load testing utilities, benchmarking utilities, etc.) and the combination of CMD and ENTRYPOINT makes it easy to distribute the image.

We must note that the ENTRYPOINT must be provided in exec form. Writing it in shell form means that the parameters are not passed properly and will not work as expected. Table 4-1 is from *Docker's Reference Guide* and explains which commands are executed for various ENTRYPOINT/CMD combinations.

Table 4-1. *Commands for ENTRYPOINT/CMD Combinations*

	No ENTRYPOINT	ENTRYPOINT exec_ entry p1_entry	ENTRYPOINT ["exec_ entry", "p1_entry"]
No CMD	error, not allowed	/bin/sh -c exec_ entry p1_entry	exec_entry p1_ entry
CMD ["exec_ cmd", "p1_ cmd"]	exec_cmd p1_ cmd	/bin/sh -c exec_ entry p1_entry	exec_entry p1_ entry exec_cmd p1_cmd
CMD ["p1_ cmd", "p2_ cmd"]	p1_cmd p2_cmd	/bin/sh -c exec_ entry p1_entry	exec_entry p1_entry p1_cmd p2_cmd
CMD exec_ cmd p1_cmd	/bin/sh -c exec_cmd p1_ cmd	/bin/sh -c exec_ entry p1_entry	exec_entry p1_ entry /bin/sh -c exec_cmd p1_cmd

Gotchas About Shell and Exec Form

As mentioned earlier, you can specify RUN, CMD, and ENTRYPOINT in shell form and exec form. What should be used will entirely depend on what the requirements are. But as a general guide:

- In shell form, the command is run in a shell with the command as a parameter. This form provides for a shell where shell variables, subcommands, commanding piping, and chaining is possible.
- In exec form, the command does not invoke a command shell. This means that normal shell processing (such as \$VARIABLE substitution, piping, etc.) will not work.

- A program started in shell form will run as subcommand of `/bin/sh -c`. This means the executable will not be running as PID and will not receive UNIX signals.

As a consequence, a Ctrl+C to send a SIGTERM will not be forwarded to the container and the application might not exit correctly.

ENV

The ENV instruction sets the environment variables to the image. The ENV instruction has two forms:

```
ENV <key> <value>
ENV <key>=<value> ...
```

In the first form, the entire string after the `<key>` will be considered the value, including whitespace characters. Only one variable can be set per line in this form.

In the second form, multiple variables can be set at one time, with the equals character assigning value to the key.

The environment variables set are persisted through the container runtime. They can be viewed using `docker inspect`.

Consider the following Dockerfile.

Dockerfile Listing

```
FROM ubuntu:latest
ENV LOGS_DIR="/var/log"
ENV APPS_DIR /apps/
```

Let's build the Docker image:

```
docker build -t sathyabhat:env-example .
Sending build context to Docker daemon 2.048kB
Step 1/3 : FROM ubuntu:latest
```

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```
---> f975c5035748
Step 2/3 : ENV LOGS_DIR="/var/log"
---> Running in 2e564f4d1905
Removing intermediate container 2e564f4d1905
---> c5a8627690d1
Step 3/3 : ENV APPS_DIR /apps/
---> Running in 3978aeb419d6
Removing intermediate container 3978aeb419d6
---> 8d2a35d35b86
Successfully built 8d2a35d35b86
```

You can inspect the environment variables by using the following:

```
docker inspect sathyabhat:env-example | jq .[0].Config.Env
[
  "PATH=/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/
  sbin:/bin",
  "LOGS_DIR=/var/log",
  "APPS_DIR=/apps/"
]
```

The environment variables defined for a container can be changed when running a container by the `-e` flag. In this example, let's change the `LOGS_DIR` value to `/logs` for a container. This is achieved by:

```
docker run -it -e LOGS_DIR="/logs" sathyabhat:env-example
```

We can confirm the changed value as follows:

```
printenv | grep LOGS
LOGS_DIR=/logs
```

VOLUME

The `VOLUME` instruction tells Docker to create a directory on the host and mount it to a path specified in the instruction.

For instance, an instruction like this:

```
VOLUME /var/logs/nginx
```

Tells Docker to create a directory on the Docker host (typically within the Docker root path) and point to the named directory, within the container to the host directory. We look at volumes in a later chapter in the book.

EXPOSE

The `EXPOSE` instruction tells Docker that the container listens for the specified network ports at runtime. The syntax follows:

```
EXPOSE <port> [<port>/<protocol>...]
```

For example, if you want to expose port 80, the `EXPOSE` instruction will be:

```
EXPOSE 80
```

If you want to expose port 53 on TCP and UDP, the Dockerfile instruction would be:

```
EXPOSE 53/tcp
```

```
EXPOSE 53/udp
```

We can also mention the port number and whether the port listens on TCP/UDP or both. If it's not specified, Docker assumes the protocol to be TCP.

Note An `EXPOSE` instruction doesn't publish the port. For the port to be published to the host, you need to use the `-p` flag when you do a `docker run` to publish and map the ports.

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Here's a sample Dockerfile that uses the nginx Docker image and exposes port 80 on the container.

Dockerfile Listing

```
FROM nginx:alpine
```

```
EXPOSE 80
```

Build the container:

```
docker build -t sathyabhat:web .
Sending build context to Docker daemon 2.048kB
Step 1/2 : FROM nginx:alpine
alpine: Pulling from library/nginx
ff3a5c916c92: Pull complete
e42d0afb8d8c: Pull complete
27afbdoeb904: Pull complete
5a306d33279c: Pull complete
Digest: sha256:8cbbbf68ef2d22852dfcccbe371aaa2d34b3bccb49c34cc0
c2b18434a01e8cb3
Status: Downloaded newer image for nginx:alpine
---> 91ce6206f9d8
Step 2/2 : EXPOSE 80
---> Running in ca68af23085a
Removing intermediate container ca68af23085a
---> 99d0d61cbd38
Successfully built 99d0d61cbd38
Successfully tagged sathyabhat:web
```

To run this container, you have to provide the host port to which it is to be mapped. Let's map port 8080 on the host to port 80 of the container. To do that, type this command:

```
docker run -d -p 8080:80 sathyabhat:web
```

The `-d` flag makes the `nginx` container run in the background; the `-p` flag does the port mapping. Let's confirm that the container is running:

```
curl http://localhost:8080
<!DOCTYPE html>
<html>
<head>
<title>Welcome to nginx!</title>
<style>
  body {
    width: 35em;
    margin: 0 auto;
    font-family: Tahoma, Verdana, Arial, sans-serif;
  }
</style>
</head>
<body>
<h1>Welcome to nginx!</h1>
<p>If you see this page, the nginx web server is successfully
installed and
working. Further configuration is required.</p>

<p>For online documentation and support please refer to
<a href="http://nginx.org/">nginx.org</a>.<br/>
Commercial support is available at
<a href="http://nginx.com/">nginx.com</a>.</p>

<p><em>Thank you for using nginx.</em></p>
</body>
</html>
```

LABEL

The LABEL instruction adds metadata to an image as a key/value pair.

```
LABEL <key>=<value> <key>=<value> <key>=<value> ...
```

An image can have multiple labels, which is typically used to add metadata to assist in searching and organizing images and other Docker objects.

Docker recommends the following guidelines:

- *For Keys*
 - Authors of third-party tools should prefix each key with reverse DNS notation of a domain owned by them. For example, `com.sathyasays.my-image`.
 - The `com.docker.*`, `io.docker.*`, and `org.dockerproject.*` are reserved by Docker for internal use.
 - Label keys should begin and end with lowercase letters and should contain only lowercase alphanumeric characters, as well as the period (.) and hyphen (-) characters. Consecutive hyphens or periods are not allowed.
 - The period (.) separates namespace fields.
- *For Values*
 - Label values can contain any data type that can be represented as string, including JSON, XML, YAML, and CSV.

Guidelines and Recommendations for Writing Dockerfiles

Following are some of the guidelines and best practices for writing Dockerfiles as recommended by Docker.

- *Containers should be ephemeral*

Docker recommends that the image generated by Dockerfile should be as ephemeral as possible. By this, we should be able stop, destroy, and restart the container at any point with minimal setup and configuration to the container.

- *Keep the build context minimal*

We discussed build context earlier in this chapter. It's important to keep the build context as minimal as possible to reduce the build times and image size. This can be done by using the `.dockerignore` file effectively.

- *Use multi-stage builds*

Multi-stage builds help drastically reduce the size of the image without having to write complicated scripts to transfer/keep the required artifacts. Multi-stage builds are described in the next section.

- *Skip unwanted packages*

Having unwanted or nice-to-have packages increases the size of the image, introduces unwanted dependent packages, and increases the surface area for attacks.

- *Minimize the number of layers*

While not as big of a concern as they used to be, it's still important to reduce the number of layers in the image. As of Docker 1.10 and above, only RUN, COPY, and ADD instructions create layers. With these in mind, having minimal instruction or combining many lines of the respective instructions will reduce the number of layers, ultimately reducing the size of the image.

Multi-Stage Builds

As of version 17.05 and above, Docker added support for multi-stage builds, allowing for complex image builds to be performed without the Docker image being unnecessarily bloated. Multi-stage builds are especially useful for building images of applications that require some additional build-time dependencies but are not needed during runtime. Most common examples are applications written using programming languages such as Go or Java, where prior to multi-stage builds, it was common to have two different Dockerfiles, one for build and the other for release. The orchestration of the artifacts from the build time image to the runtime image could be done via shell scripts.

With multi-stage builds, a single Dockerfile can be leveraged for build and deploy images—the build images can contain the build tools required for generating the binary or the artifact and in the second stage, the artifact can be copied to the runtime image, thereby reducing considerably the size of the runtime image. For a typical multi-stage build, a build stage has several layers—each layer for installing tools required to build the application, generating the dependencies, and generating the application. In the final layer, the application built from the build stages would be copied over to the final layer and only that layer is considered for building the image—the build layers are discarded, drastically reducing the size of the final image.

While this book doesn't focus on multi-stage builds in detail, we do include an exercise on how to create a multi-stage build. We demonstrate the difference that using a slim image with a multi-stage build makes to the final image.

Note More details about multi-stage builds are available on Docker's website at <https://docs.docker.com/develop/develop-images/multistage-build/>.

Dockerfile Exercises

You have learned a fair bit about Dockerfiles, so it's time to try some exercises to better understand them.

BUILDING A SIMPLE HELLO WORLD DOCKER IMAGE

At the start of the chapter, we introduced a simple Dockerfile that did not build due to syntax errors. Here, you'll fix the Dockerfile and add some of the instructions that you learned about in this chapter.

Tip The source code and Dockerfile associated with this are available as `docker-hello-world.zip`.

The original Dockerfile is shown here.

Dockerfile Listing

```
FROM ubuntu:latest
LABEL author="sathyabhat"
LABEL description="An example Dockerfile"
RUN apt-get install python
```

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```
COPY hello-world.py
CMD python hello-world.py
```

Trying to build this will result in an error since `hello-world.py` is missing. Let's fix the build error. To do this, you will add a `hello-world.py` file, which reads an environment variable, `NAME`, and prints "Hello, \$NAME!". If the environment variable is not defined, then it will print "Hello, World!". The contents of `hello-world.py` are as follows:

```
#!/usr/bin/env python3

from os import getenv

if getenv('NAME') is None:
    name = 'World!'
else:
    name = getenv('NAME')

print("Hello {}".format(name))
```

The corrected Dockerfile follows.

Corrected Dockerfile Listing

```
FROM python:3-alpine

LABEL author="sathyabhat"
LABEL description="Dockerfile for Python script which prints
Hello, Name"

COPY hello-world.py /app/
ENV NAME=Sathya
CMD python3 /app/hello-world.py
```

Build the Dockerfile:

```
docker build -t sathyabhat:hello-python .
Sending build context to Docker daemon 3.072kB
Step 1/6 : FROM python:3-alpine
```

```

---> 4fcaf5fb5f2b
Step 2/6 : LABEL author="sathyabhat"
---> 29e08fa6b4c2
Step 3/6 : LABEL description="Dockerfile for Python script which
           prints Hello, Name"
---> Running in bbabe9d8322a
Removing intermediate container bbabe9d8322a
---> abf1d06444ca
Step 4/6 : COPY hello-world.py /app/
---> 19454b206b46
Step 5/6 : ENV NAME=Sathya
---> Running in 83b5ff92f771
Removing intermediate container 83b5ff92f771
---> 839197bb6542
Step 6/6 : CMD python3 /app/hello-world.py
---> Running in 6dbdd98d868b
Removing intermediate container 6dbdd98d868b
---> 2410783edf5d
Successfully built 2410783edf5d
Successfully tagged sathyabhat:hello-python

```

Confirm the image name and the size:

```

docker images sathyabhat:hello-python

```

REPOSITORY	TAG	IMAGE ID	CREATED	SIZE
sathyabhat	hello-python	2410783edf5d	Less than a second ago	90MB

Run the Docker image:

```

docker run sathyabhat:hello-python
Hello, Sathya!

```

Try overriding the environment variable at runtime. You can do this by providing the `-e` parameter to the `docker run` command:

```
docker run -e NAME=John sathyabhat:hello-python
Hello, John!
```

Congrats! You have successfully written your first Dockerfile and built your first Docker image.

A LOOK AT SLIM DOCKER RELEASE IMAGE (USING MULTI-STAGE BUILDS)

In this exercise, you will build two Docker images, the first one using a standard build process using `python:3` as the base image.

Tip The source code and Dockerfiles associated with both builds are available as `docker-multi-stage.zip`.

Building the Docker Image Using a Standard Build

Create a `requirements.txt` file with the following content:

```
praw
```

Now create a Dockerfile with the following content.

Dockerfile Listing

```
FROM python:3
COPY requirements.txt .
RUN pip install -r requirements.txt
```

Now build the Docker image:

```
docker build -t sathyabhat:base-build .
Sending build context to Docker daemon 3.072kB
```

```

Step 1/3 : FROM python:3
3: Pulling from library/python
f2b6b4884fc8: Pull complete
4fb899b4df21: Pull complete
74eaa8be7221: Pull complete
2d6e98fe4040: Pull complete
414666f7554d: Pull complete
135a494fed80: Pull complete
6ca3f38fdd4d: Pull complete
4de6fcaa1241: Pull complete
Digest: sha256:e5a05b8979f5cd1d43433a75663ed9a9d04227a3473c89abf
e60b027ca334256
Status: Downloaded newer image for python:3
---> 07d72c0beb99
Step 2/3 : COPY requirements.txt .
---> 237dd8b9b17c
Step 3/3 : RUN pip install -r requirements.txt
---> Running in c69bebd9dc91
Collecting praw (from -r requirements.txt (line 1))
  Downloading praw-5.4.0-py2.py3-none-any.whl (94kB)
Collecting update-checker>=0.16 (from praw->-r requirements.txt
(line 1))
  Downloading update_checker-0.16-py2.py3-none-any.whl
Collecting prawcore<0.15,>=0.14.0 (from praw->-r requirements.
txt (line 1))
  Downloading prawcore-0.14.0-py2.py3-none-any.whl
Collecting requests>=2.3.0 (from update-checker>=0.16->praw->-r
requirements.txt (line 1))
  Downloading requests-2.18.4-py2.py3-none-any.whl (88kB)
Collecting urllib3<1.23,>=1.21.1 (from requests>=2.3.0->update-
checker>=0.16->praw->-r requirements.txt (line 1))
  Downloading urllib3-1.22-py2.py3-none-any.whl (132kB)
Collecting idna<2.7,>=2.5 (from requests>=2.3.0->update-
checker>=0.16->praw->-r requirements.txt (line 1))

```

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```
Downloading idna-2.6-py2.py3-none-any.whl (56kB)
Collecting chardet<3.1.0,>=3.0.2 (from requests>=2.3.0->update-
checker>=0.16->praw->-r requirements.txt (line 1))
Downloading chardet-3.0.4-py2.py3-none-any.whl (133kB)
Collecting certifi>=2017.4.17 (from requests>=2.3.0->update-
checker>=0.16->praw->-r requirements.txt (line 1))
Downloading certifi-2018.1.18-py2.py3-none-any.whl (151kB)
Installing collected packages: urllib3, idna, chardet, certifi,
requests, update-checker, prawcore, praw
Successfully installed certifi-2018.1.18 chardet-3.0.4 idna-2.6
praw-5.4.0 prawcore-0.14.0 requests-2.18.4 update-checker-0.16
urllib3-1.22
Removing intermediate container c69bebd9dc91
---> ed26b55221f4
Successfully built ed26b55221f4
Successfully tagged sathyabhat:base-build
```

The image was built successfully. Let's see the size of the image:

```
docker images sathyabhat:base-build
REPOSITORY TAG          IMAGE ID      CREATED      SIZE
sathyabhat base-build  ed26b55221f4 32 minutes ago 698MB
```

The Docker image sits at a fairly hefty 698MB even though you didn't add any of the application code, just a dependency. Let's rewrite it to a multi-stage build.

Building the Docker Image Using Multi-Stage Build

Dockerfile Listing

```
FROM python:3 as python-base
COPY requirements.txt .
RUN pip install -r requirements.txt

FROM python:3-alpine
COPY --from=python-base /root/.cache /root/.cache
```



```
COPY --from=python-base requirements.txt .
RUN pip install -r requirements.txt && rm -rf /root/.cache
```

The Dockerfile is different in that there are multiple FROM statements, signifying the different stages. In the first stage, we build the required packages using the `python:3` image, which has the necessary build tools.

In the second stage, we copy the files installed from the first stage, reinstall them (notice this time, pip fetches the cached files and doesn't build them again), and then delete the cached install files.

```
docker images sathyabhat:multistage-build
```

REPOSITORY	TAG	IMAGE ID	CREATED	SIZE
sathyabhat	multistage	4e2ad2b6e221	Less than	99MB
	-build		a second ago	

If we look at the size of the second image, the difference is significant.

WRITING DOCKERFILE FOR THE PROJECT

Now you'll try writing the Dockerfile for this project. Before you start writing a Dockerfile, here are some guidelines on Dockerizing an application.

Tip The source code and Dockerfile associated with this are available as `docker-subreddit-fetcher.zip`.

Let's review what you need for this project:

- A Docker image based on Python 3
- The project dependencies listed in `requirements.txt`
- An environment variable named `NBT_ACCESS_TOKEN`

Now that you have what you need, let's write the Dockerfile for the project.

The steps are as follows:

1. Start with a proper base image.
2. Make a list of files required for the application.
3. Make a list of environment variables required for the application.
4. Copy the application files to the image using a COPY instruction.
5. Specify the environment variable with the ENV instruction.

Combining these steps, you will arrive at the following Dockerfile.

Dockerfile Listing

```
FROM python:3-alpine
COPY * /apps/subredditfetcher/
WORKDIR /apps/subredditfetcher/
RUN ["pip", "install", "-r", "requirements.txt"]

ENV NBT_ACCESS_TOKEN="<token>"

CMD ["python", "newsbot.py"]
```

Take care to replace <token> with the token generated from the earlier chapter. Let's build the image:

```
docker build -t sathyabhat:subreddit_fetcher .
Sending build context to Docker daemon 17.41kB
Step 1/6 : FROM python:3-alpine
--> 4fcaf5fb5f2b
Step 2/6 : COPY * /apps/subredditfetcher/
--> 3fe719598159
Step 3/6 : WORKDIR /apps/subredditfetcher/
--> ab997e6e51b5
Step 4/6 : RUN ["pip", "install", "-r", "requirements.txt"]
--> 7d7ced5dcc8c
```

```
Step 5/6 : ENV NBT_ACCESS_TOKEN="495637361:AAHIhiDTX1UeX17KJy0-
FsMZEqEtCFYfcP8"
```

```
---> c6db29f52053
```

```
Step 6/6 : CMD ["python", "newsbot.py"]
```

```
---> 8aa4ff615bac
```

```
Successfully built 8aa4ff615bac
```

```
Successfully tagged sathyabhat:subreddit_fetcher
```

And run the container:

```
docker run --name subreddit_fetcher_bot sathyabhat:subreddit_
fetcher
```

You should be seeing logs from the bot to ensure it's running:

```
INFO: get_updates - received response: {'ok': True, 'result': []}
INFO: get_updates - received response: {'ok': True, 'result': []}
INFO: get_updates - received response: {'ok': True, 'result': []}
INFO: get_updates - received response: {'ok': True, 'result': []}
INFO: get_updates - received response: {'ok': True, 'result': []}
INFO: get_updates - received response: {'ok': True, 'result': []}
```

Congrats! You have successfully Dockerized the project.

Summary

In this chapter, you learned about Dockerfiles, the significance of the build context, and about `dockerignore`. You also took a deep dive into some commonly used Dockerfile instructions, a brief glimpse of multi-stage builds, and learned about some guidelines on writing Dockerfiles. You completed the chapter with some exercises on writing Dockerfiles, including how to write Dockerfiles for multi-stage builds. You also proceeded to Dockerize the Newsbot project. In the next chapter, we look at how you can persist data generated by containers using Docker Volumes.

CHAPTER 5

Understanding Docker Volumes

In the previous chapters, we learned about Docker and its associated terminologies and took a deeper look into how we can build Docker images using the Dockerfile.

In this chapter, we look at data persistency strategies for Docker containers and learn why we need special strategies for data persistence.

Data Persistence

Traditionally, most compute solutions come with associated ways to persist and save the data. In case of virtual machines, a virtual disk is emulated and the data saved to this virtual disk is saved as a file on the host computer. In the case of cloud providers such as Amazon Web Services (AWS), they provide us with a root volume for persisting data and block storage (Elastic Block Store—EBS) for persisting data.

When it comes to containers, the story is different. Containers were meant and designed for stateless workloads and the design of the container layers shows that. In Chapter 2, we understood that a Docker image is a read-only template consisting of various layers and when the image is run as a container, the container contains a small write-only layer of the data. This means that:

- The data is locked tightly to the host and makes running applications that share data across multiple containers and applications difficult.
- The data doesn't persist when the container is terminated and extracting the data out of the container is difficult.
- Writing to the container's write layer requires a storage driver to manage the filesystem. Storage drivers do not provide an acceptable level of performance in terms of read/write speeds. Large amounts of data written to the container's write layer can lead to the container and the Docker daemon running out of memory.

Example of Data Loss Within Docker Container

To demonstrate the features of the write layer, let's use a container from an Ubuntu base image. We will create a file in the Docker container, stop the container, and note the behavior of the container.

1. Start by creating an nginx container:

```
docker run -d --name nginx-test nginx
```

2. Open a terminal within the container:

```
docker exec -t nginx-test bash
```

3. Create a copy of nginx's default.conf to a new config:

```
cd /etc/nginx/conf.d  
cp default.conf nginx-test.conf
```

4. We won't be modifying the contents of `nginx-test.conf` since it's immaterial. Now we'll stop the container. From the Docker host terminal, type:

```
docker stop nginx-test
```

5. Start the container again:

```
docker start nginx-test
```

6. Open a terminal within the container:

```
docker exec -it nginx-test bash
```

7. Now, see if the changes are still around:

```
cd /etc/nginx/conf.d
ls
default.conf  nginx-test.conf
```

8. Since the container was only stopped, the data persists. Let's stop, remove the container, and then bring up a new one and observe what happens.

```
docker stop nginx-test
```

```
docker rm nginx-test
```

9. Start a new container:

```
docker run -d --name nginx-test nginx
```

10. Now that a new container is up and running, let's connect to the container's terminal:

```
docker exec -it nginx-test bash
```

11. Examine contents of the `conf.d` directory of `nginx`:

```
cd /etc/nginx/conf.d
ls
default.conf
```

Since the container was removed, the write-only layer associated with the container was also removed and the files are no longer accessible. For a containerized stateful application, such as an application that requires a database, the data from the previous container will no longer be accessible when an existing container is removed or a new container is added.

To mitigate this issue, Docker offers various strategies to persist the data.

- `tmpfs` mounts
- Bind mounts
- Volumes

tmpfs Mounts

As the name suggests, a `tmpfs` creates a mount in `tmpfs`, which is a temporary file storage facility. The directories mounted in `tmpfs` appear as a mounted filesystem but are stored in memory, not to persistent storage such as a disk drive.

`tmpfs` mounts are limited to Docker containers on Linux. A `tmpfs` mount is temporary and the data is stored in Docker's hosts memory. Once the container is stopped, the `tmpfs` mount is removed and the files written to `tmpfs` mount are lost.

To create a `tmpfs` mount, you can use the `--mount` or `--tmpfs` flag when running a container, as shown here:

```
docker run -it --name tmpfs-test --mount type=tmpfs, target=/
tmpfs-mount ubuntu bash
docker run -it --name tmpfs-test --tmpfs /tmpfs-mount ubuntu bash
```

Let's examine the container:

```
docker inspect tmpfs-test | jq .[0].Mounts
[
  {
    "Type": "tmpfs",
    "Source": "",
    "Destination": "/tmpfs-mount",
    "Mode": "",
    "RW": true,
    "Propagation": ""
  }
]
```

This output tells us that the mount is of `tmpfs` type, and that the destination of the mount is `/tmpfs-mount`. Since the `tmpfs` mount doesn't let us mount the host directory, the source is empty.

`tmpfs` mounts are best for containers that generate data that doesn't need to be persisted and doesn't have to be written to the container's writable layer.

Bind Mounts

In bind mounts, the file/directory on the host machine is mounted into the container. By contrast, when using a Docker volume, a new directory is created within Docker's storage directory on the Docker host and the contents of the directory are managed by Docker.

Tip While searching for Docker bind mounts/volume articles on the Internet, you are most likely to find articles that refer to use of volumes with the `-v` flag. With Docker version 17.06, Docker encourages everyone to use the `--mount` syntax. To make it easier for you, the examples use both the flags. Also note that the `Mounts` key while issuing `docker inspect` is only available with the `--mount` syntax.

Let's see how we can use bind mounts. We'll try to mount our Docker host's home directory to a directory called `host-home` within the container. To do this, type the following command:

```
docker run -it --name mount-test --mount type=bind,source="$HOME",
target=/host-home ubuntu bash
docker run -it --name mount-test -v $HOME:/host-home ubuntu bash
```

Inspecting the created container tells us the different characteristics about the mount.

```
docker inspect mount-test | jq .[0].Mounts
[
  {
    "Type": "bind",
    "Source": "/Users/sathyabhat",
    "Destination": "/host-home",
    "Mode": "",
    "RW": true,
    "Propagation": "rprivate"
  }
]
```

This output tells us that the mount is of `bind` type, with the source, i.e. the directory of the Docker host being mounted, is `/Users/sathyabhat` (the home directory), and the destination of the mount is `/host-home`. The `"Propagation"` property refers to bind propagation—a property indicating whether or not the mounts created for a bind mount are reflected onto replicas of that mount. Bind propagation is applicable only to Linux hosts, because bind mounts typically don't need to be modified. The `RW` flag indicates that the mounted directory can be written to. Let's examine the contents of the `host-home` to see that the mounts are indeed proper. In the terminal of the container, type the following:

```
cd /host-home
ls
```

The output of the command should be a listing of our Docker host home directory.

Let's try to create a file in the host-home directory. For this, type the following command:

```
cd /host-home
echo "This is a file created from container having kernel
`uname -r`" > host-home-file.txt
```

This command creates a file called `host-home-file.txt`, which contains the text. This is a file created from the container having kernel `4.9.87-linuxkit-aufs` (note that the actual kernel version might be different than what is listed here) in the `/host-home` directory of the container. And since this is a bind mount of the home directory of the Docker host, the file should also be created in the home directory of the Docker host. Let's see if this is indeed the case. Open a new terminal window in your Docker host and type the following command:

```
cd ~
ls -lah host-home-file.txt
```

We should be seeing this output, indicating the presence of the file:

```
-rw-r--r--  1 sathyabhat  sathyabhat    73B Apr 01 11:16 host-
home-file.txt
```

Let's check the context of the file:

```
cat host-home-file.txt
This is a file created from container having kernel
4.9.87-linuxkit-aufs
```

This confirms that the file created in the container is indeed available outside the container. Since we are concerned with data persistence after the container stops, is removed, and started again, let's see what happens.

Stop the container by entering the following command in the Docker host terminal.

```
docker stop mount-test
docker rm mount-test
```

Confirm that the file on the Docker host is still present:

```
cat ~/host-home-file.txt
This is a file created from container having kernel
4.9.87-linuxkit-aufs
```

Bind mounts are of immense help and are most often used during the development phase of an application. By having bind mounts, we can prepare the application for production by using the same container as production while mounting the source directory as a bind mount, allowing for developers to have rapid code-test-iterate cycles without having to rebuild the Docker image.

Caution Remember with bind mounts, the data flow goes both ways on the Docker host as well as the container. Any destructive actions (such as deleting a directory) will negatively impact the Docker host as well.

This is even more important if the mounted directory is a broad one—such as the home directory or even the root directory. A script gone rogue or a mistaken `rm -rf` can bring down the Docker host completely. To mitigate this, we can create a bind mount with the read-only option so that the directory is mounted read-only. To do this, we can provide a read-only parameter to the `docker run` command. The commands are as follows:

```
docker run -it --name mount-test --mount type=bind,source="$HOME",
target=/host-home,readonly ubuntu bash
docker run -it --name mount-test -v $HOME:/host-home:ro ubuntu bash
```

Let's inspect the container that was created:

```
docker inspect mount-test | jq .[0].Mounts
[
  {
    "Type": "bind",
    "Source": "/Users/sabhat",
    "Destination": "/host-home",
    "Mode": "ro",
    "RW": false,
    "Propagation": "rprivate"
  }
]
```

We can see that the "RW" flag is now false and the mode is set as "read-only". Let's try writing to the file as earlier:

```
echo "This is a file created from container having kernel
`uname -r`" > host-home-file.txt
bash: host-home-file.txt: Read-only file system
```

The write fails and bash tells us that it was because the filesystem is mounted read-only. Any destructive operations are also met with the same error:

```
rm host-home-file.txt
rm: cannot remove 'host-home-file.txt': Read-only file system
```

Volumes

Docker volumes are the current recommended method of persisting data stored in containers. Volumes are completely managed by Docker and have many advantages over bind mounts:

- Volumes are easier to back up or transfer than bind mounts

- Volumes work on both Linux and Windows containers
- Volumes can be shared among multiple containers without problems

Docker Volume Subcommands

Docker exposes the Volume API as a series of subcommands. The commands are as follows:

- `docker volume create`
- `docker volume inspect`
- `docker volume ls`
- `docker volume prune`
- `docker volume rm`

Create Volume

The `create volume` command is used to create named volumes. The most common use case is to generate a named volume. The usage for the command is:

```
docker volume create --name=<name of the volume> --label=<any extra metadata>
```

Tip Docker object labels were discussed in [Chapter 4](#).

Example:

```
docker volume create --name=nginx-volume
```

This creates a named volume called `nginx-volume`.

Inspect

The `inspect` command displays detailed information about a volume. The usage for this command is:

```
docker volume inspect <name of the volume>
```

Taking the example of the `nginx-volume` name, we can find more details by typing the following:

```
docker volume inspect nginx-volume
```

This would bring up a result as shown here:

```
docker volume inspect nginx-volume
[
  {
    "CreatedAt": "2018-04-17T13:51:02Z",
    "Driver": "local",
    "Labels": {},
    "Mountpoint": "/var/lib/docker/volumes/nginx-volume/_
                  data",
    "Name": "nginx-volume",
    "Options": {},
    "Scope": "local"
  }
]
```

This command is useful if you want to copy/move/take a backup of a volume. The `mountpoint` property lists the location on the Docker host where the file containing the data of the volume is saved.

List Volumes

The `list` volume command shows all the volumes present on the host. The usage is shown here:

```
docker volume ls
```

Prune Volumes

The `prune` volume command removes all unused local volumes. The usage is shown here:

```
docker volume prune <--force>
```

Docker considers volumes not used by at least one container as unused. Since unused volumes can end up consuming a considerable amount of disk space, it's not a bad idea to run the `prune` command at regular intervals, especially on local development machines. When you use the `--force` flag option, it will not ask for confirmation when the command is run.

Remove Volumes

The `remove` volume command removes volumes whose names are provided as parameters. The usage is shown here:

```
docker volume rm <name>
```

In case of the volume created here, the command would be:

```
docker volume rm nginx-volume
```

Docker will not remove a volume that is in use and will return an error. For instance, we might try to delete the volume `nginx-volume`, which is attached to the container.

Note Even if the container stops, Docker will consider the volume to be in use.

```
docker volume rm nginx-volume
```

```
Error response from daemon: unable to remove volume:
remove nginx-volume: volume is in use -
[6074757a5afafd74aec6d18a5b4948013639ddfef39507dac5d08
50d56edbd82]
```

The long piece of identifier is the ID of the container associated with the volume. If the volume is associated with multiple containers, all the container IDs will be listed. More details about the associated container can be found by using `docker inspect` command:

```
docker inspect 6074757a5afafd74aec6d18a5b4948013639ddfe
f39507dac5d0850d56edbd82
```

Using Volumes When Starting a Container

The syntax for using a volume when starting a container is nearly the same as using a bind host. Let's run the following command:

```
docker run -it --name volume-test --mount target=/data-volume
ubuntu bash
docker run -it --name volume-test -v:/data-volume
```

When compared to `bind mount` command, using the `--mount` flag, we skip the type and source option. When using the `-v` flag, we skip the host directory to bind to (since the source/host directory is maintained by Docker).

Let's examine the created container:

```
docker inspect volume-test | jq .[0].Mounts
[
  {
    "Type": "volume",
    "Name": "5fe950de3ac2b428873cb0af6281f3fb3817af933fbad3
2070b1a3101be4927f",
```



```

    "Source": "/var/lib/docker/volumes/5fe950de3ac2b428873c
        b0af6281f3fb3817af933fbad32070b1a3101be4927f/_
        data",
    "Destination": "/data-volume",
    "Driver": "local",
    "Mode": "z",
    "RW": true,
    "Propagation": ""
  }
]

```

Looking at the mounts section, we can conclude that Docker has created a new volume with an auto-generated name of "5fe950de3ac2b428873cb0af6281f3fb3817af933fbad32070b1a3101be4927f" with the data file for this saved in Docker's data directory, "/var/lib/docker/volumes/5fe950de3ac2b428873cb0af6281f3fb3817af933fbad32070b1a3101be4927f/_data", and mounted to the /data-volume directory of the container.

Working with autogenerated volume names gets tedious fast, so we can generate a volume ahead of time and provide this name to Docker when running a container. We can do this by using the `docker volume` command to create the volume:

```
docker volume create volume-test
```

We can also use `docker volume inspect` to examine the volume's properties:

```

docker volume inspect volume-test
[
  {
    "CreatedAt": "2018-04-15T12:58:32Z",
    "Driver": "local",
    "Labels": {},
    "Mountpoint": "/var/lib/docker/volumes/volume-test/_data",

```

```

    "Name": "volume-test",
    "Options": {},
    "Scope": "local"
  }
]

```

We can now refer to this volume when creating/running a container. Note the extra `source=` flag with the `--mount` flag and the parameter after `-v` flag. These indicate the volume name to which the container has to be attached.

```

docker run -it --name volume-test --mount source=volume-
test,target=/data-volume ubuntu bash
docker run -it --name volume-test -v:volume-test:/data-volume

```

Let's try to create the same file as earlier. From the terminal within the container, type the following:

```

echo "This is a file created from container having kernel
`uname -r`" > docker_kernel_info.txt

```

We'll stop and remove the container:

```

docker stop volume-test
docker rm volume-test

```

In the absence of volumes, when the container was removed, its writable layer would have gotten removed as well. Let's see what happens when we launch a new container with the volume attached. Remember that this is not a bind mount, so we are not forwarding explicitly any of the Docker host directories.

```

docker run -it --name volume-test --mount source=volume-
test,target=/data-volume ubuntu bash
docker run -it --name volume-test -v:volume-test:/data-volume

```

Now we examine the contents of the `/data-volume` directory of the container:

```
cd /data-volume/  
ls  
docker-kernel-info.txt
```

Now we examine the contents of `docker-kernel-info.txt`:

```
cat docker_kernel_info.txt  
This is a file created from container having kernel  
4.9.87-linuxkit-aufs.
```

However, with volumes, we are directing Docker to store the data in a volume file that is managed by Docker itself. When we launch a new container, providing the volume name along with the run command attaches the volume to the container, making previously saved data available to the newly launched container.

VOLUME Instruction in Dockerfile

The `VOLUME` instruction marks the path mentioned succeeding the instruction as an externally stored data volume, managed by Docker. The syntax is as follows:

```
VOLUME ["/data-volume"]
```

The paths mentioned after the instruction can be a JSON array or an array of paths separated by spaces.

Note The `VOLUME` instruction in a Dockerfile doesn't support named volumes and, as a result, when the container is run, the volume name will be an autogenerated name.

Docker Volume Exercises

You've learned a fair bit about volumes, so let's get some hands-on experience creating and attaching volumes to containers.

BUILDING AND RUNNING AN NGINX CONTAINER WITH VOLUMES AND BIND MOUNTS

In this exercise, we build an `nginx` Docker image with a Docker volume attached, which contains a custom `nginx` configuration. Toward the second part of the exercise, we will attach a bind mount and a volume containing a static web page and a custom `nginx` configuration. The intent of the exercise is help the readers understand how to leverage volumes and bind mounts to make local development easy.

Tip The source code and Dockerfile associated with this is available as `docker-volume-bind-mount.zip`. Ensure you extract the contents of the ZIP file and run the commands in the directory to which they were extracted.

We can start with the Dockerfile, as shown here.

Dockerfile Listing

```
FROM nginx:alpine

COPY default.conf /etc/nginx/conf.d

VOLUME ["/var/lib"]

EXPOSE 80
```

This Dockerfile takes a base `nginx` image, overwrites the `default.conf` `nginx` configuration file with our custom `default.conf` `nginx` configuration file, and declares `/var/lib` as a volume. We can build this by using this command:

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```
docker build -t sathyabhat:nginx-volume.  
Sending build context to Docker daemon 3.616MB  
Step 1/4 : FROM nginx:alpine  
---> 91ce6206f9d8  
Step 2/4 : COPY default.conf /etc/nginx/conf.d  
---> Using cache  
---> d131f1bbdeae  
Step 3/4 : VOLUME ["/var/lib"]  
---> Running in fa7d936e3456  
Removing intermediate container fa7d936e3456  
---> 0c94600d506d  
Step 4/4 : EXPOSE 80  
---> Running in 3e42c1c3558a  
Removing intermediate container 3e42c1c3558a  
---> 3ea0e5dafe64  
Successfully built 3ea0e5dafe64  
Successfully tagged sathyabhat:nginx-volume
```

Before we run this image, let's look at our custom nginx `default.conf` contents:

```
server {  
    listen      80;  
    server_name localhost;  
  
    location / {  
        root    /srv/www/starter;  
        index   index.html index.htm;  
    }  
    access_log  /var/log/nginx/access.log;  
    access_log  /var/log/nginx/error.log;  
  
    error_page  500 502 503 504 /50x.html;  
    location = /50x.html {
```

```
    root    /usr/share/nginx/html;
}

}
```

The `nginx` config is a simple config. It tells `nginx` to serve a default file called `index.htm` in `/srv/www/starter`.

Let's run the Docker container. Since `nginx` is listening to port 80, we need to tell Docker to publish the ports using the `-p` flag:

```
docker run -d --name nginx-volume -p 8080:80
sathyabhat:nginx-volume
```

Note that we are publishing from the Docker host's port 8080 to port 80 of the container. Let's try to load the web page by navigating to `http://localhost:8080`. See Figure 5-1.

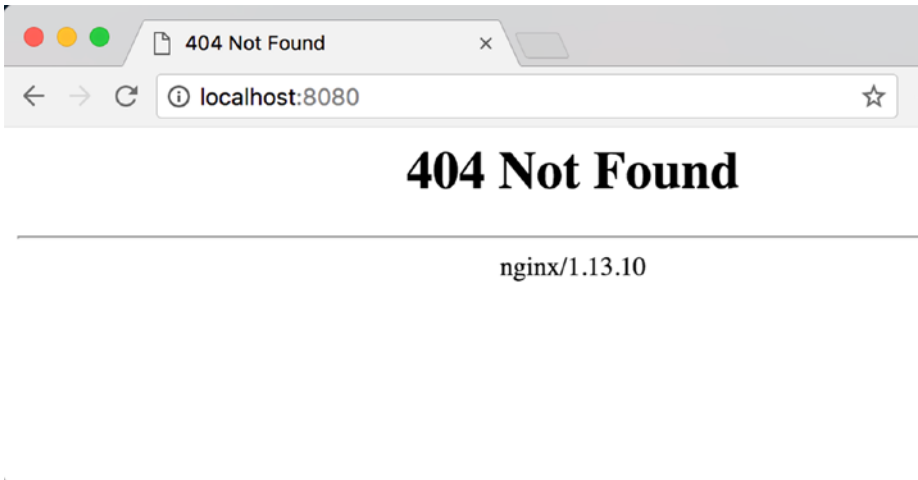


Figure 5-1. The 404 error indicates when a source directory is not mounted

However, when we load the website, we see a HTTP 404 - Page Not Found. This is because in the nginx config file, we directed nginx to server `index.html`. However, we have not copied the `index.html` file to the container, neither have we mounted the location of the `index.html` to the container as a bind mount. As a result, nginx cannot find the `index.html` file.

We can correct this by copying the website files to the container as we did in the previous chapter. In this chapter, we will leverage the bind mount feature we learned about earlier and mount the entire directory containing the sources. All that is needed is to use pass the bind mount flag that we learned about earlier.

The Dockerfile remains the same. The Docker run command is shown here:

```
docker run -d --name nginx-volume-bind -v "$(pwd)"/:/srv/www -p
8080:80 sathyabhat/nginx-volume
```

Confirm that the container is running:

CONTAINER ID	IMAGE	COMMAND
54c857ca065b	sathyabhat/nginx-volume	"nginx -g 'daemon of...'"
6 minutes ago	Up 6 minutes	0.0.0.0:8080->80/tcp hopeful_meitner

Confirm that the volumes and mounts are correct:

```
[
{
  "Type": "bind",
  "Source": "/home/sathyabhat/docker-volume-bind-mount",
  "Destination": "/srv/www",
  "Mode": "",
  "RW": true,
  "Propagation": "rprivate"
},
```

```
{
  "Type": "volume",
  "Name": "190709bbaca54fd0dd8e18dac533e41094522281d65ca
    55718d2eb309e37ff20",
  "Source": "/var/lib/docker/volumes/190709bbaca54fd0dd8e18
    dac533e41094522281d65ca55718d2eb309e37ff20/_data",
  "Destination": "/var/lib",
  "Driver": "local",
  "Mode": "",
  "RW": true,
  "Propagation": ""
}
]
```

Now navigate to the same URL again. If the mounts section looks fine, then you should see the page shown in Figure 5-2.

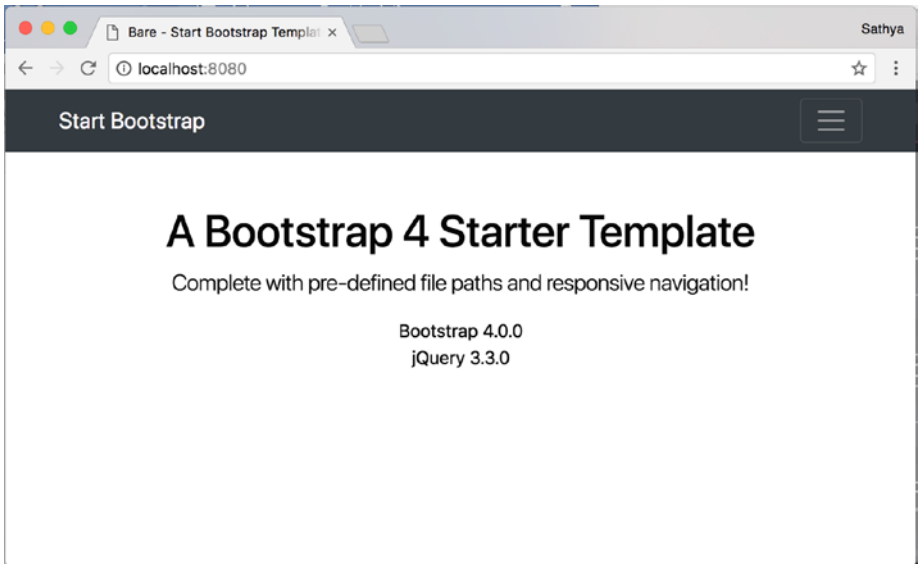


Figure 5-2. *nginx serving the web page successfully*

Success!

ADDING VOLUMES TO OUR PROJECT

In the previous chapters' exercises, we wrote a Dockerfile for our project. However, as you might have noticed, killing the container would reset the state and we need to customize our bot all over again.

For this exercise, we will be working on a slightly modified codebase that has support for saving the preferences to a SQLite DB. We would use Docker Volumes to persist the database across containers.

Let's modify the existing Dockerfile.

Tip The source code and Dockerfile associated with this are available as `docker-subreddit-fetcher-volume.zip`.

Dockerfile Listing

```
FROM python:3-alpine
COPY * /apps/subredditfetcher/
WORKDIR /apps/subredditfetcher/

VOLUME [ "/apps/subredditfetcher" ]
RUN ["pip", "install", "-r", "requirements.txt"]
RUN ["python", "one_time.py"]

ENV NBT_ACCESS_TOKEN=<token>

CMD ["python", "newsbot.py"]
```

Take care to replace `<token>` with the token generated from the earlier chapter. Let's build the image. Note the extra RUN step, which runs `one_time.py`. This script creates the necessary database and tables required for our application. Another notable change is the addition of the VOLUME instruction. As we learned earlier, this is to tell Docker to mark the directory specified to be managed as a volume, even if we did not specify the required volume name in the docker run command. Let's build the image.

```

docker build --no-cache -t sathyabhat:subreddit_fetcher_volume.
Sending build context to Docker daemon 54.27kB
Step 1/7 : FROM python:3-alpine
--> 4fcaf5fb5f2b
Step 2/7 : COPY * /apps/subredditfetcher/
--> 5e14e2d2bcfe
Step 3/7 : WORKDIR /apps/subredditfetcher/
Removing intermediate container e1c430858221
--> 5e3ba7458662
Step 4/7 : RUN ["pip", "install", "-r", "requirements.txt"]
--> Running in 8b8cf1497005
Collecting praw (from -r requirements.txt (line 1))
  Downloading [...]
Building wheels for collected packages: peewee
  Running setup.py bdist_wheel for peewee: started
  Running setup.py bdist_wheel for peewee: finished with status
  'done'
  Stored in directory: /root/.cache/pip/wheels/66/73/41/
cdf4aaa004d0449c3b2d56c0e58ff43760ef71b80b38fcee2f
Successfully built peewee
Installing collected packages: chardet, idna, urllib3, certifi,
requests, prawcore, update-checker, praw, peewee
Successfully installed certifi-2018.4.16 chardet-3.0.4 idna-2.6
peewee-2.10.2 praw-5.4.0 prawcore-0.14.0 requests-2.18.4 update-
checker-0.16 urllib3-1.22
Removing intermediate container 8b8cf1497005
--> 44d125f83421
Step 5/7 : RUN ["python", "one_time.py"]
--> Running in b61182b29479
Removing intermediate container b61182b29479
--> 52d93f651f5a

```

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```
Step 6/7 : ENV NBT_ACCESS_TOKEN="495637361:AAHIhiDTX1UeX17KJy0-  
FsMZEqEtCFYfcP8"
```

```
---> Running in fb1d9e67680e
```

```
Removing intermediate container fb1d9e67680e
```

```
---> 7ae9191753f9
```

```
Step 7/7 : CMD ["python", "newsbot.py"]
```

```
---> Running in c23845327155
```

```
Removing intermediate container c23845327155
```

```
---> d3baeb1e7191
```

```
Successfully built d3baeb1e7191
```

```
Successfully tagged sathyabhat:subreddit_fetcher_volume
```

Let's run our project. Note that we will provide the volume name via the `-v` flag.

```
docker run --name subreddit_fetcher_volume -v subreddit_  
fetcher:/apps/subredditfetcher sathyabhat:subreddit_fetcher_  
volume
```

This run command creates a new container known as `subreddit_fetcher_volume` with an attached volume known as `subreddit_fetcher` mounted on to the `/apps/subredditfetcher` directory from the `sathyabhat:subreddit_fetcher_volume` image.

We should be seeing the logs like so:

```
INFO: _new_conn - Starting new HTTPS connection (1): api.  
telegram.org  
INFO: _new_conn - Starting new HTTPS connection (1): api.  
telegram.org  
INFO: get_updates - received response: {u'ok': True, u'result':  
[]}  
INFO: _new_conn - Starting new HTTPS connection (1): api.  
telegram.org
```

```
INFO: get_updates - received response: {u'ok': True, u'result':
[]}]
INFO: _new_conn - Starting new HTTPS connection (1): api.
telegram.org
INFO: get_updates - received response: {u'ok': True, u'result':
[]}]
```

Let's try setting a subreddit from which the bot should fetch the data, say python. To do this, from telegram, find the bot and type `/source Python`.

The logs from the application should confirm the receipt of the command:

```
INFO: - handle_incoming_messages - Chat text received:/source
python
INFO: - handle_incoming_messages - Sources set for nnn
to python
INFO: - handle_incoming_messages - nnn
INFO: - post_message - posting Sources set as python! to nnn
```

The Telegram Messenger window should look like Figure 5-3.

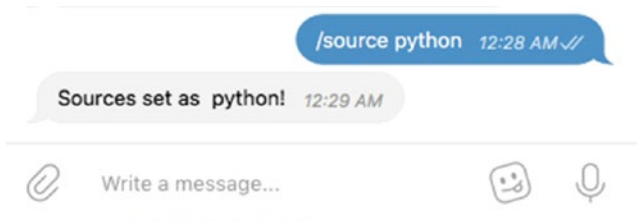


Figure 5-3. Acknowledgement of subreddit source

Let's fetch some content. To do this, type `/fetch` into the bot window. The application should respond with a loading message and another chat with the contents, as shown in Figure 5-4.

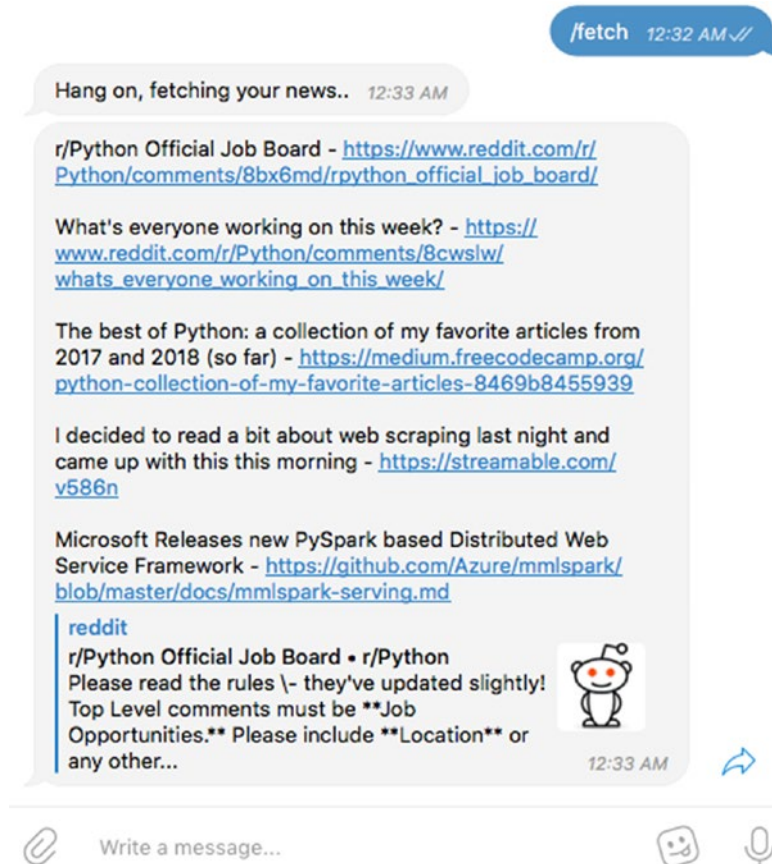


Figure 5-4. The bot fetching contents from subreddit

We will test for data persistency by stopping the bot, removing the container, and creating a new container. To do this, first stop the bot by pressing Ctrl. Next, remove the container by typing the following:

```
docker container rm subreddit_fetcher_volume
```

Create a new container by typing the same command we used previously to launch the container:

```
docker run --name subreddit_fetcher_volume -v subreddit_fetcher:/
apps/subredditfetcher sathyabhat:subreddit_fetcher_volume
```

Now, in Telegram chat window, type `/fetch` again. Since the subreddit source has been saved to the database, we should see the content from the previously configured subreddit.

If you see the content again, the Docker volume setup is working correctly (see Figure 5-5). Congrats! You have successfully set up data persistence for this project.

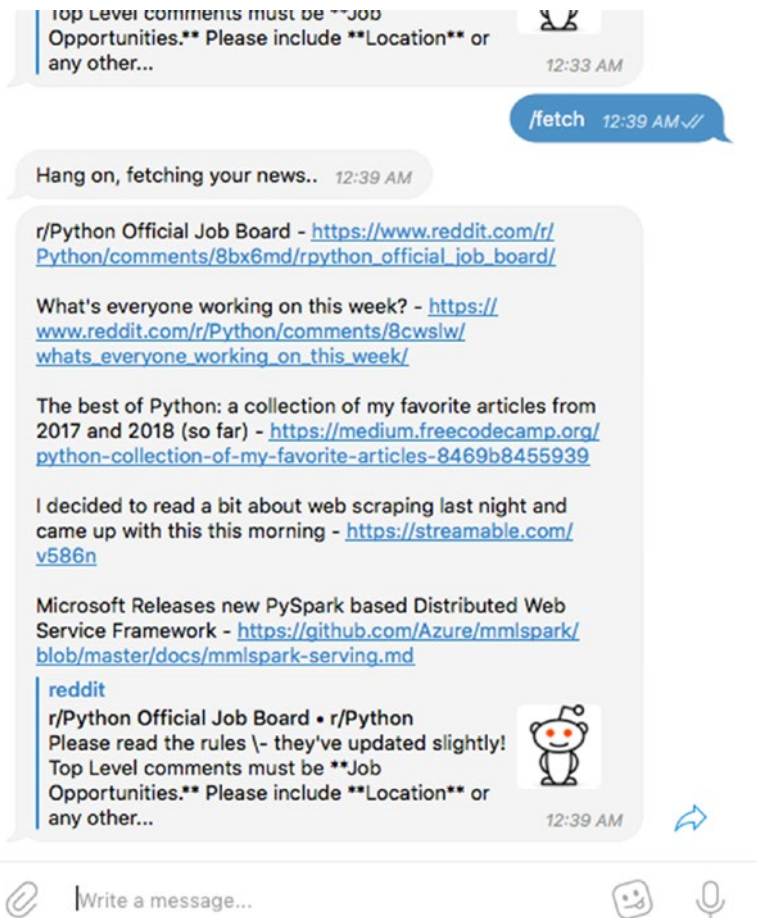


Figure 5-5. The bot fetching contents from subreddit after removing and starting a new container

Summary

In this chapter, you learned about why data persistence is a problem in containers and the different strategies Docker offers for managing data persistence in containers. You also did a deep dive into configuring volumes and how they differ from bind mounts. Finally, you went through some hands-on exercises on how to work with bind mounts and volumes, and you added volumes support for the Newsbot project. In the next chapter, you learn more about Docker networking and learn how and why the containers cannot connect to each other.

CHAPTER 6

Understanding Docker Networks

In the previous chapters, we learned about Docker and its associated terminologies, took a deeper look into how we can build Docker images using the Dockerfile, and learned about how we can persist data generated by containers.

In this chapter, we look at networking in Docker and how containers can talk to each other with the help of Docker's networking features.

Why Do We Need Container Networking?

Traditionally, most compute solutions are thought of as single-purpose solutions. It is not often we come across a single host (or a Virtual Machine) hosting multiple workloads, especially production workloads. With containers, the scenario changes. With lightweight containers and the presence of advanced orchestration platforms such as Kubernetes or DC/OS, it is very common to have multiple containers of different workloads running on the same host with different instances of the application distributed across multiple hosts. In such cases, container networking helps in allowing (or limiting) cross container talk. To facilitate Docker, it also comes with different modes of networks.

Tip Docker's networking subsystem is implemented by pluggable drivers. Docker comes with four drivers out of the box, with more and more drivers being available from Docker Store. It is available at <https://store.docker.com/search?category=network&q=&type=plugin>.

It is important to note that all of Docker's networking modes are achieved via Software Defined Networking (SDN). Specifically, on Linux systems, Docker modifies iptables rules to provide the required level of access/isolation.

Default Docker Network Drivers

With a standard install of Docker, the following network drivers are available:

- bridge
- host
- overlay
- macvlan
- none

Bridge Network

A bridge network is a user-defined network that allows for all containers connected on the same network to communicate. The benefit is that the containers on the same bridge network are able to connect, discover, and talk to each other, while those not on the same bridge cannot communicate directly with each other. Bridge networks are useful when we have containers running on the same host that need to talk to each other. If the containers that need to communicate are on different Docker hosts, the overlay network would be needed.

When Docker is installed and started, a default bridge network is created and newly started containers connect to it. However, it is always better if you create a bridge network yourself. The reasons for this are outlined here:

- Better isolation across containers. As you have learned, containers on the same bridge network are discoverable and can talk to each other. They automatically expose all ports to each other and no ports are exposed to the outside world. Having a separate user-defined bridged network for each application provides better isolation between containers of different applications.
- Easy name resolution across containers. For services joining the same bridged network, containers can connect to each other by name. For containers on the default bridged network, the only way for containers to connect to each other is via IP addresses or by using the `--link` flag, which has been deprecated.
- Easy attachment/detachment of containers on user-defined networks. For containers on the default network, the only way to detach them is to stop the running container and recreate it on the new network.

Host Network

As the name suggests, with a host network, a container is attached to the Docker host. This means that any traffic coming to the host is routed to the container. Since all of containers' ports are directly attached to the host, in this mode, the concept of publishing ports doesn't make sense. Host mode is perfect if we have only one container running on the Docker host.

Overlay Network

The overlay network creates a network spanning multiple docker hosts. It's called an overlay because it overlays the existing host network, allowing containers connected to the overlay network to communicate across multiple hosts. Overlay networks are an advanced topic and are primarily used when a cluster of Docker hosts is set up in Swarm mode. Overlay networks also let you encrypt the application data traffic across the overlay network.

Macvlan Networks

Macvlan networks are a fairly recent introduction to the Docker networking stack. Macvlan networks leverage the Linux kernel's ability to assign multiple logical addresses based on MAC to a single physical interface. This means that you can assign a MAC address to a container's virtual network interface, making it appear as if the container has a physical network interface connected to the network. This introduces unique opportunities, especially for legacy applications that expect a physical interface to be present and connected to the physical network.

Macvlan networks have an additional dependency on the Network Interface Card (NIC) to support what is known as *promiscuous* mode. This is a special mode that allows for a NIC to receive all traffic and direct it to a controller, instead of receiving only the traffic that the NIC expects to receive.

None Networking

As the name suggests, *none* networking is where the container isn't connected to any network interface and does not receive any network traffic. In this networking mode, only the loopback interface is created, allowing the container to talk to itself, but not to the outside world or with the other containers.

Working with Docker Networks

Now that you understand conceptually what the different network modes are, it's time to try some hands-on exercises. For simplicity's sake, we will not be looking at overlay and Macvlan networks. Much like the other subsystems, Docker comes with a subcommand for handling Docker networks. To get started, try the following command:

```
docker network
```

You should see an explanation of which options are available:

```
docker network
```

```
Usage: docker network COMMAND
```

```
Manage networks
```

```
Options:
```

```
Commands:
```

```
  connect    Connect a container to a network
  create     Create a network
  disconnect Disconnect a container from a network
  inspect    Display detailed information on one or more
networks
  ls         List networks
  prune      Remove all unused networks
  rm         Remove one or more networks
```

Let's look at which networks are available. To do this, type the following:

```
docker network ls
```

At the minimum, you should see these:

```
docker network ls
```

NETWORK ID	NAME	DRIVER	SCOPE
c540708fd14e	bridge	bridge	local
45af7af75e0c	host	host	local
d30afbéc4d6b	none	null	local

Each of these corresponds to the three types of networks—the bridge, the host, and the none type. You can examine the details of the network by typing the following:

```
docker network inspect <network id or name>
```

For instance:

```
docker network inspect bridge
```

```
[
  {
    "Name": "bridge",
    "Id": "c540708fd14e77106ebe2582685da1cb1a0f6f0cd097
        fee6d3d9a6266334f20b",
    "Created": "2018-04-17T13:10:43.002552762Z",
    "Scope": "local",
    "Driver": "bridge",
    "EnableIPv6": false,
    "IPAM": {
      "Driver": "default",
      "Options": null,
      "Config": [
        {
          "Subnet": "172.17.0.0/16",
          "Gateway": "172.17.0.1"
        }
      ]
    }
  }
]
```

```

    ]
  },
  "Internal": false,
  "Attachable": false,
  "Ingress": false,
  "ConfigFrom": {
    "Network": ""
  },
  "ConfigOnly": false,
  "Containers": {},
  "Options": {
    "com.docker.network.bridge.default_bridge": "true",
    "com.docker.network.bridge.enable_icc": "true",
    "com.docker.network.bridge.enable_ip_masquerade":
      "true",
    "com.docker.network.bridge.host_binding_ipv4":
      "0.0.0.0",
    "com.docker.network.bridge.name": "docker0",
    "com.docker.network.driver.mtu": "1500"
  },
  "Labels": {}
}
]

```

Among other things, you can see that:

- This bridge is the default.
- IPv6 is disabled for this bridge.
- The subnet is a 172.17.0.0/16, meaning that up to 65,536 containers can be attached to this network (this is derived from the CIDR block of /16).

- The bridge has IP masquerading enabled, which means that the outside world will not be able to see the container's private IP and it will appear that the requests are coming from the Docker host.
- The host binding is 0.0.0.0, which means that the bridge is bound to all interfaces on the host.

By contrast, if you inspect the none network:

```
docker network inspect none
[
  {
    "Name": "none",
    "Id": "d30afbec4d6bafde5e0c1f8ca8f7dd6294bd8d7766a
      9184909188f1a00444fb5",
    "Created": "2017-05-10T10:37:04.125762206Z",
    "Scope": "local",
    "Driver": "null",
    "EnableIPv6": false,
    "IPAM": {
      "Driver": "default",
      "Options": null,
      "Config": []
    },
    "Internal": false,
    "Attachable": false,
    "Ingress": false,
    "ConfigFrom": {
      "Network": ""
    },
    "ConfigOnly": false,
    "Containers": {},
    "Options": {},
```

```

    "Labels": {}
  }
]

```

The driver `null` indicates that no networking will be handled for this.

Bridge Networks

Before we work on creating a bridge network, let's create a MySQL and Adminer container on the default bridge network.

To create the MySQL container, use this command:

```
docker run -d --name mysql -p 3306:3306 -e MYSQL_ROOT_
PASSWORD=dontusethisinprod mysql
```

Since you are starting in detached mode (as specified by the `-d` flag), follow the logs until you are certain the container is up.

```
docker logs -f mysql
```

The result should be along the lines of the following:

```

Initializing database
[...]
Database initialized
[...]
MySQL init process in progress...
[...]
MySQL init process done. Ready for start-up.
[...]
[Note] mysqld: ready for connections.
Version: '5.7.18' socket: '/var/run/mysqld/mysqld.sock' port:
3306 MySQL Community Server (GPL)
[...]

```


If you see the last set of lines, the MySQL database container is ready. Let's create the Adminer container:

```
docker run -d --name adminer -p 8080:8080 adminer
```

Following the logs of Adminer:

```
docker logs -f adminer
PHP 7.2.4 Development Server started
```

That means Adminer is ready. Let's look at the two containers. Specifically, the networking aspects of them.

```
docker inspect mysql | jq .[0].NetworkSettings.Networks
{
  "bridge": {
    "IPAMConfig": null,
    "Links": null,
    "Aliases": null,
    "NetworkID": "96d1b157fb39968514ffef88a07a9204242c9923
        61236853066ba9f390bbf22c",
    "EndpointID": "3b7566eb0e04a6510be1848e06f51a8329ad6db1eb06
        011932790c39764978bc",
    "Gateway": "172.17.0.1",
    "IPAddress": "172.17.0.3",
    "IPPrefixLen": 16,
    "IPv6Gateway": "",
    "GlobalIPv6Address": "",
    "GlobalIPv6PrefixLen": 0,
    "MacAddress": "02:42:ac:11:00:03",
    "DriverOpts": null
  }
}
```

You now know that the MySQL container has been assigned an IP address of 172.17.0.2 on the default bridge network. Now examine the Adminer container:

```
docker inspect adminer | jq .[0].NetworkSettings.Networks
{
  "bridge": {
    "IPAMConfig": null,
    "Links": null,
    "Aliases": null,
    "NetworkID": "96d1b157fb39968514ffef88a07a9204242c9923612
                 36853066ba9f390bbf22c",
    "EndpointID": "bf862e4decc41838c22d251597750f203ed6
                 de2bcb7d69bd69d4a1af7ddd17b3",
    "Gateway": "172.17.0.1",
    "IPAddress": "172.17.0.2",
    "IPPrefixLen": 16,
    "IPv6Gateway": "",
    "GlobalIPv6Address": "",
    "GlobalIPv6PrefixLen": 0,
    "MacAddress": "02:42:ac:11:00:02",
    "DriverOpts": null
  }
}
```

The Adminer container is associated with IP address of 172.17.0.3 within the bridge network. However, since both containers are bound to the host IP of 0.0.0.0 and translated to all interfaces of the Docker host, you should be able to connect to either by its port.

However, as you learned, the default bridge network does not perform DNS resolution by the service name, and neither does it let us connect via the container's service name—only via IPs. To demonstrate this, try to connect to the database via Adminer. Navigate to <http://localhost:8080>.

Enter the server as `mysql` and try to log in. You'll notice that the login will fail, as shown in Figure 6-1.

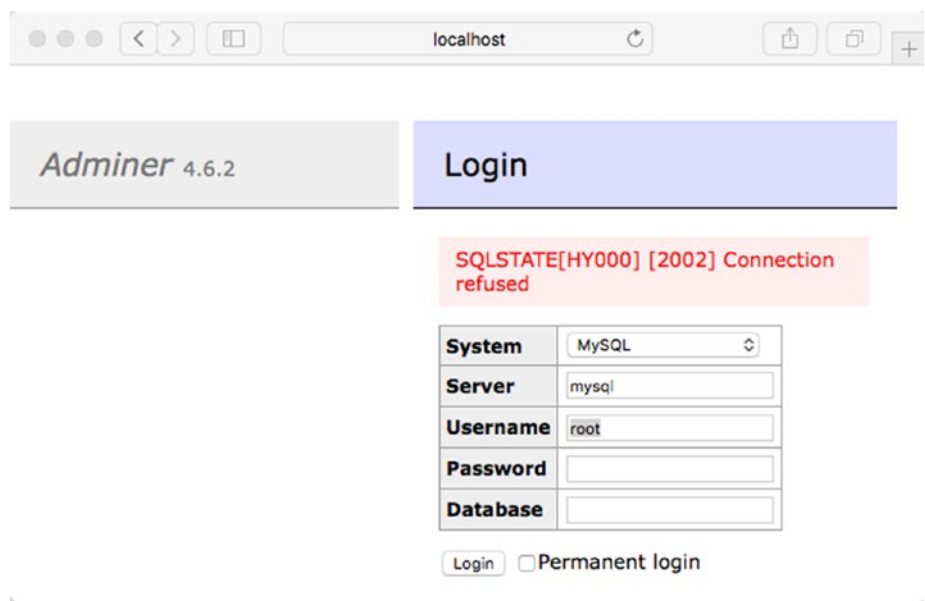
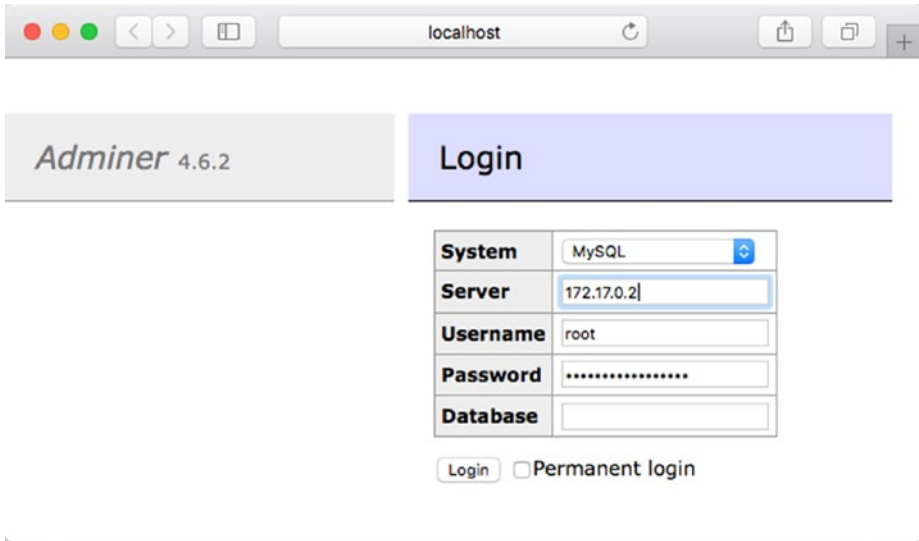


Figure 6-1. Connection to named host fails

Try to log in again. This time in the server box, enter the IP address of the MySQL container, as shown in Figure 6-2.



The screenshot shows a web browser window with the address bar set to 'localhost'. The page displays the Adminer 4.6.2 login interface. On the left is a grey box with 'Adminer 4.6.2'. On the right is a purple box with 'Login'. Below these is a form with the following fields:

System	MySQL
Server	172.17.0.2
Username	root
Password
Database	

At the bottom of the form are two buttons: 'Login' and 'Permanent login' (which is unchecked).

Figure 6-2. Trying to log in with IP address of the container

When you try to log in now, it should be successful, as shown in Figure 6-3.

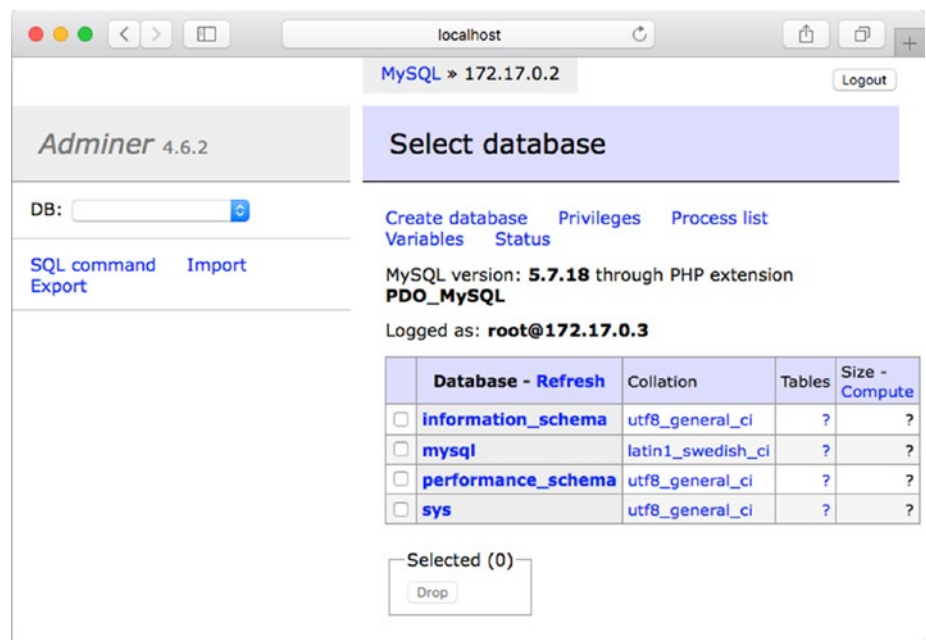


Figure 6-3. Logging in with the IP address is successful

While entering the IP is an acceptable workaround when there is only one dependent container, many current-day applications have multiple dependencies, whereby this approach breaks down.

Creating Named Bridge Networks

Let’s create a database network and try to connect MySQL and the Adminer container to the network. We can create a bridge network by typing the following command:

```
docker network create database <network name>
```

Docker gives you more options in terms of specifying the subnet etc., but for the most part, the defaults are good. Note that the bridge network allows you to create only a single subnet.

Now create a network called database:

```
docker network create database
```

Let's inspect the created network:

```
docker network inspect database
```

```
[
  {
    "Name": "database",
    "Id": "df8124f5f2e662959239592086bea0282e507a60
      4554523b648e1f9e23cbf18e",
    "Created": "2018-04-27T10:29:52.0619506Z",
    "Scope": "local",
    "Driver": "bridge",
    "EnableIPv6": false,
    "IPAM": {
      "Driver": "default",
      "Options": {},
      "Config": [
        {
          "Subnet": "172.25.0.0/16",
          "Gateway": "172.25.0.1"
        }
      ]
    },
    "Internal": false,
    "Attachable": false,
    "Ingress": false,
    "ConfigFrom": {
```

```

        "Network": ""
    },
    "ConfigOnly": false,
    "Containers": {},
    "Options": {},
    "Labels": {}
}
]

```

Note that the created network has a subnet of 172.25.0.0/16. Let's stop and remove the existing containers:

```

docker stop adminer
docker rm adminer
docker stop mysql
docker rm mysql

```

Now launch the MySQL container, this time connected to the database network. The command will be as follows:

```

docker run -d --network database --name mysql -p 3306:3306 -e
MYSQL_ROOT_PASSWORD=dontusethisinprod mysql

```

Note the additional `--network` flag, which tells Docker what network it should attach the container to. Wait for bit for the container to initialize. We can also check the logs and ensure that the container is ready:

```

docker logs -f mysql

```

The result should be along the lines of the following:

```

Initializing database
[...]
Database initialized
[...]

```

```
MySQL init process in progress...
[...]
MySQL init process done. Ready for start up.
[...]
[Note] mysqld: ready for connections.
Version: '5.7.18' socket: '/var/run/mysqld/mysqld.sock'
port: 3306 MySQL Community Server (GPL)
[...]
```

Now examine the container:

```
docker inspect mysql | jq .[0].NetworkSettings.Networks
{
  "database": {
    "IPAMConfig": null,
    "Links": null,
    "Aliases": [
      "e9508a98faf8"
    ],
    "NetworkID": "df8124f5f2e662959239592086bea0282e507
      a604554523b648e1f9e23cbf18e",
    "EndpointID": "66db8ac356bad4b0c966a65987d1bda3a05d37
      435039c8c6a3f464c528f4e350",
    "Gateway": "172.25.0.1",
    "IPAddress": "172.25.0.2",
    "IPPrefixLen": 16,
    "IPv6Gateway": "",
    "GlobalIPv6Address": "",
    "GlobalIPv6PrefixLen": 0,
    "MacAddress": "02:42:ac:19:00:02",
    "DriverOpts": null
  }
}
```


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Notice that the container is part of the database network. We can confirm this by inspecting the database network as well.

```
docker network inspect database | jq .[0].Containers
"e9508a98faf8e4f1c55e04e1a4412ee79a1ac1e78e965
52ce4ee889d196eac23": {
  "Name": "mysql",
  "EndpointID":
  "66db8ac356bad4b0c966a65987d1bda3a05d37435039c8
c6a3f464c528f4e350",
  "MacAddress": "02:42:ac:19:00:02",
  "IPv4Address": "172.25.0.2/16",
  "IPv6Address": ""
}
```

Note that the containers key in the database network now has the MySQL container. Let's launch the Adminer container as well. Type the following command:

```
docker run -d --name adminer -p 8080:8080 adminer
```

Notice that we omitted the `--network` command. This means Adminer will be connected to the default bridge network.

```
docker inspect adminer | jq .[0].NetworkSettings.Networks
{
  "bridge": {
    "IPAMConfig": null,
    "Links": null,
    "Aliases": null,
    "NetworkID": "c540708fd14e77106ebe2582685da1cb1a0f6f0cd097
fee6d3d9a6266334f20b",
    "EndpointID": "a4d1df412e61a4baeb63a821f71ea0cd5899ace54362
34ef0bab688a5636dea7",
```

```

"Gateway": "172.17.0.1",
"IPAddress": "172.17.0.2",
"IPPrefixLen": 16,
"IPv6Gateway": "",
"GlobalIPv6Address": "",
"GlobalIPv6PrefixLen": 0,
"MacAddress": "02:42:ac:11:00:02",
"DriverOpts": null
}

```

Connecting Containers to Named Bridge Networks

Docker lets us connect a container to another network on the fly very easily. To do this, type the following command:

```
docker network connect <network name> <container name>
```

Since you need to connect the Adminer container to the database network, the command looks as so:

```
docker network connect database adminer
```

Let's inspect the Adminer container now:

```

docker inspect adminer | jq .[0].NetworkSettings.Networks
{
  "bridge": {
    "IPAMConfig": null,
    "Links": null,
    "Aliases": null,
    "NetworkID": "c540708fd14e77106ebe2582685da1cb1a0f6f0cd0
                  97fee6d3d9a6266334f20b",
    "EndpointID": "a4d1df412e61a4baeb63a821f71ea0cd5899ace54
                  36234ef0bab688a5636dea7",
    "Gateway": "172.17.0.1",

```

```

    "IPAddress": "172.17.0.2",
    "IPPrefixLen": 16,
    "IPv6Gateway": "",
    "GlobalIPv6Address": "",
    "GlobalIPv6PrefixLen": 0,
    "MacAddress": "02:42:ac:11:00:02",
    "DriverOpts": null
  },
  "database": {
    "IPAMConfig": {},
    "Links": null,
    "Aliases": [
      "9602c2384418"
    ],
    "NetworkID": "df8124f5f2e662959239592086bea0282e507a60
      4554523b648e1f9e23cbf18e",
    "EndpointID": "3e9591d59b31fe941ad39f8928898c2ad97230a7
      e1f07afff0b8df061ea1bfdb",
    "Gateway": "172.25.0.1",
    "IPAddress": "172.25.0.3",
    "IPPrefixLen": 16,
    "IPv6Gateway": "",
    "GlobalIPv6Address": "",
    "GlobalIPv6PrefixLen": 0,
    "MacAddress": "02:42:ac:19:00:03",
    "DriverOpts": null
  }
}

```

Notice that the `Networks` key has two networks—the default bridge network and the database network that we just connected to. Since the container doesn't need to be connected to the default bridge network, let's disconnect it. To do this, use this command:

```
docker network disconnect <network name> <container name>
```

In this case, the command is as follows:

```
docker network disconnect bridge adminer
```

Examine the Adminer container:

```
docker inspect adminer | jq .[0].NetworkSettings.Networks
{
  "database": {
    "IPAMConfig": {},
    "Links": null,
    "Aliases": [
      "9602c2384418"
    ],
    "NetworkID": "df8124f5f2e662959239592086bea0282e507a6
      04554523b648e1f9e23cbf18e",
    "EndpointID": "3e9591d59b31fe941ad39f8928898c2ad97230a7e
      1f07afff0b8df061ea1bfdb",
    "Gateway": "172.25.0.1",
    "IPAddress": "172.25.0.3",
    "IPPrefixLen": 16,
    "IPv6Gateway": "",
    "GlobalIPv6Address": "",
    "GlobalIPv6PrefixLen": 0,
    "MacAddress": "02:42:ac:19:00:03",
    "DriverOpts": null
  }
}
```

The bridge network is no longer attached to the Adminer network. Launch Adminer by navigating to `http://localhost:8080`.

In the Server field, type the name of the container that you want to connect to, i.e. the database container named `mysql`. See Figure 6-4.

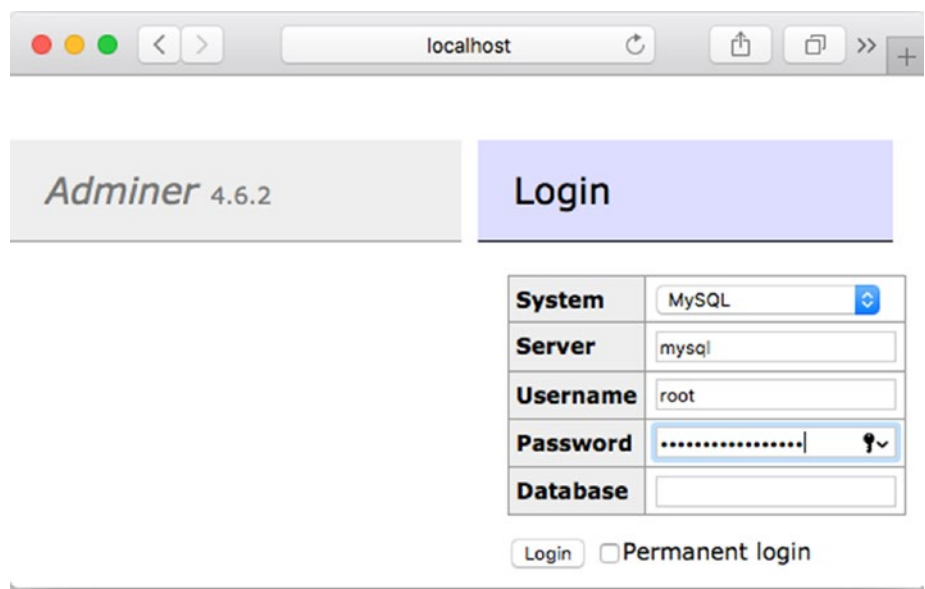


Figure 6-4. *Connecting to a container via named host*

Enter the details and click on Login. The login screen is shown in Figure 6-5.

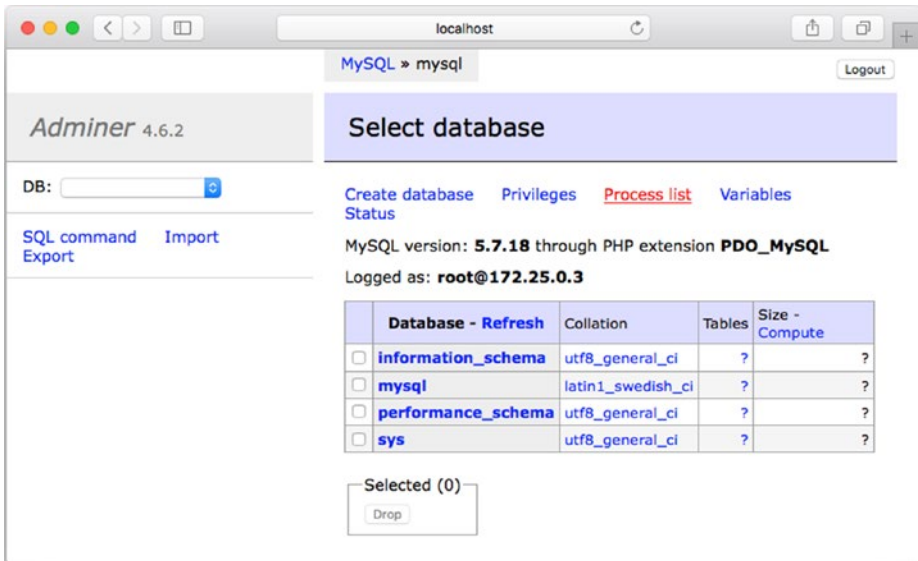


Figure 6-5. Named host resolves to IP and connects successfully

Thus, user-defined bridged networks make connecting services very easy without having to search for the IP addresses. Docker makes it easy by letting us connect to the services by using the name of the container as the host. Docker handles the behind-the-scenes translation of the container name to IP address.

Host Networks

As you learned earlier, in host network, Docker doesn't create a virtual network for the container. Rather, the Docker host's network interface is bound to the container.

Host networks are excellent when we have only one container running on the host and we don't need any bridge networks to be created and don't need network isolation. Let's create an `nginx` container running in host mode to see how we can run it.

Earlier you saw that there already exists a network called `host`. It's not the name that governs whether or not the network is a host network, it's the driver. We noticed that the host network has a host driver, and hence any container connected to the host network will run in host network mode.

To start the container, you just have to pass the parameter `--network host`. Try the following command to start an `nginx` container and publish port 80 of the container to the host's 8080 port.

```
docker run -d --network host -p 8080:80 nginx:alpine
```

WARNING: Published ports are discarded when using host network mode

Notice that Docker warns you that the port publishing isn't being used. Since the container's ports are directly bound to the Docker port, the concept of a published port doesn't arise. The actual command should be as follows:

```
docker run -d --network host -p 8080:80 nginx:alpine
```

Docker Networking Exercises

You've have learned a fair bit about Docker networks, so it's time to get some hands-on experience creating and attaching a network to your project.

CONNECTING THE MYSQL CONTAINER TO THE PROJECT CONTAINER

In the previous chapter exercises, you wrote a Dockerfile for this project and built the container. You then used Docker Volumes to persist the database across containers. In this exercise, you will modify the project so that the data, instead of saving to a SQLite database, persists to a MySQL database. You will then create a custom bridge network to connect the project container and the MySQL container.

Let's modify the existing Dockerfile.

Tip The source code and Dockerfile associated with this is available as `docker-subreddit-fetcher-network.zip`.

Dockerfile Listing

```
FROM python:3-alpine

COPY * /apps/subredditfetcher/
WORKDIR /apps/subredditfetcher/

VOLUME [ "/apps/subredditfetcher" ]
RUN ["pip", "install", "-r", "requirements.txt"]

ENV NBT_ACCESS_TOKEN=<token>

CMD ["python", "newsbot.py"]
```

Take care to replace `<token>` with the token generated from the earlier chapter. Let's build the image. Note the extra `RUN` step, which runs `one_time.py`. This script creates the necessary database and tables required for our application. Another notable change is the addition of the `VOLUME` instruction. As you learned earlier, this is to tell Docker to mark the directory specified to be managed as a volume, even if you did not specify the required volume name in the `docker run` command. Let's build the image.

```
docker build --no-cache -t sathyabhat:subreddit_fetcher_network .
Sending build context to Docker daemon 55.3kB
Step 1/7 : FROM python:3-alpine
--> 4fcaf5fb5f2b
Step 2/7 : COPY * /apps/subredditfetcher/
--> 87315ae6c5b5
Step 3/7 : WORKDIR /apps/subredditfetcher/
```


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```
Removing intermediate container af83d09dac2c
---> 647963890330
Step 4/7 : VOLUME [ "/apps/subredditfetcher" ]
---> Running in fc801fb00429
Removing intermediate container fc801fb00429
---> d734a17f968b
Step 5/7 : RUN ["pip", "install", "-r", "requirements.txt"]
---> Running in a5db3fab049d
Collecting praw (from -r requirements.txt (line 1))
[....]
Successfully built peewee
Installing collected packages: chardet, urllib3, idna, certifi,
requests, prawcore, update-checker, praw, peewee, PyMySQL
Successfully installed PyMySQL-0.8.0 certifi-2018.4.16
chardet-3.0.4 idna-2.6 peewee-2.10.2 praw-5.4.0 prawcore-0.14.0
requests-2.18.4 update-checker-0.16 urllib3-1.22
Removing intermediate container a5db3fab049d
---> e5715fb6dda7
Step 6/7 : ENV NBT_ACCESS_TOKEN="<token"
---> Running in 219e16ddea10
Removing intermediate container 219e16ddea10
---> ae8bd5570edd
Step 7/7 : CMD ["python", "newsbot.py"]
---> Running in c195a952708f
Removing intermediate container c195a952708f
---> 93cd7531c6b0
Successfully built 93cd7531c6b0
Successfully tagged sathyabhat:subreddit_fetcher_network
```

Let's create a new network called `subreddit_fetcher` to which the containers will be connected. To do this, type the following:

```
docker network create subreddit_fetcher
```

Now create the required volumes for the app and the database:

```
docker volume create subreddit_fetcher_app
docker volume create subreddit_fetcher_db
```

Let's bring up a new MySQL container and connect it to this network. Since we'd like the data to persist, we will also mount the MySQL database to a volume called `subreddit_fetcher_db`. To do this, type the following command:

```
docker run -d --name mysql --network subreddit_fetcher
-v subreddit_fetcher_db:/var/lib/mysql -e MYSQL_ROOT_
PASSWORD=dontusethisinprod mysql
```

Let's follow the logs and check that the MySQL database is up and running:

```
docker logs -f subreddit_fetcher_db
Initializing database
[...]
Database initialized
[...]
MySQL init process in progress
[...]
MySQL init process done. Ready for start up.
[...]
2018-04-27T12:41:15.295013Z 0 [Note] mysqld: ready for
connections.
Version: '5.7.18' socket: '/var/run/mysqld/mysqld.sock' port:
3306 MySQL Community Server (GPL)
```

The last couple of lines indicate that the MySQL database is up and running.

Now let's bring up our project container while connecting it to the `subreddit_fetcher` network that we created. To do this, type the following:

```
docker run --name subreddit_fetcher_app --network subreddit_fetcher -v subreddit_fetcher_app:/apps/subreddit_fetcher sathyabhat:subreddit_fetcher_network
```

You should see the logs like so:

```
INFO: <module> - Starting up
INFO: <module> - Waiting for 60 seconds for db to come up
INFO: <module> - Checking on dbs
INFO: get_updates - received response: {'ok': True,
    'result': []}
INFO: get_updates - received response: {'ok': True,
    'result': []}
```

Since you created a new volume, the sources that were set in the previous chapter are not available.

Let's set the subreddit again from which the bot should fetch the data, say `docker`. To do this, from Telegram, find the bot and type `/source docker`. The logs from the application should confirm the receipt of the command:

```
INFO: handle_incoming_messages - Chat text received: /source
    docker
INFO: handle_incoming_messages - Sources set for 7342383
    to docker
INFO: handle_incoming_messages - 7342383
INFO: post_message - posting Sources set as docker! to 7342383
```

```
INFO: get_updates - received response: {'ok': True,
    'result': []}
INFO: get_updates - received response: {'ok': True,
    'result': []}
INFO: get_updates - received response: {'ok': True,
    'result': []}
INFO: get_updates - received response: {'ok': True,
    'result': []}
```

The Telegram window should look like the one shown in Figure 6-6.

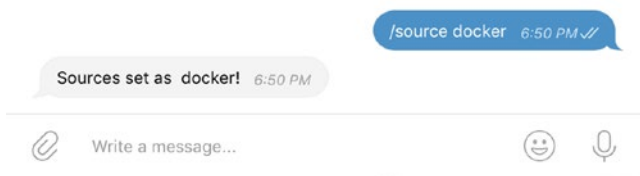


Figure 6-6. *Acknowledgement of the subreddit source*

Let's fetch some content. To do this, type `/fetch` in the bot window. The application should respond with a loading message and another chat with the contents, as shown in Figure 6-7.

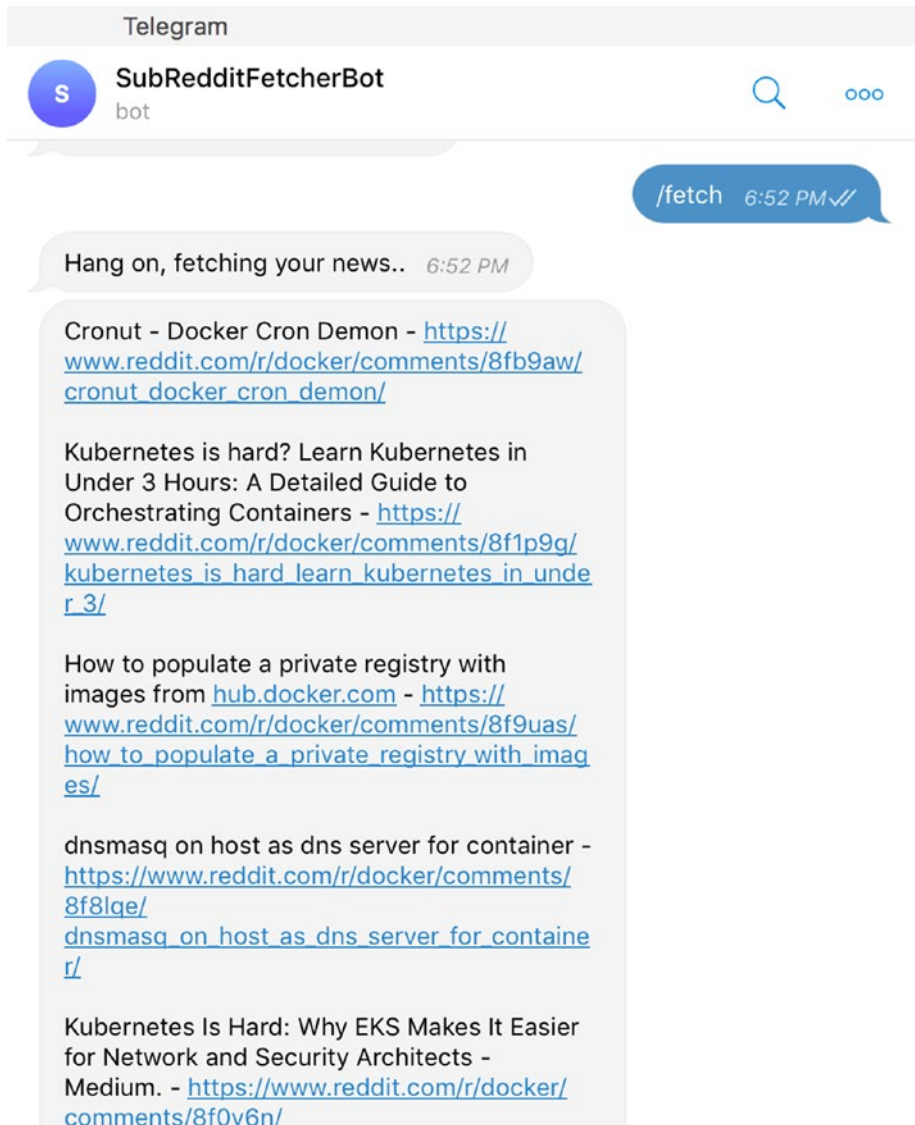


Figure 6-7. The bot fetching contents from subreddit

Let's confirm that the bot is indeed saving the sources to the database.

We will bring up another container, Adminer, which is a web UI for MySQL database, and connect it to the `subreddit_fetcher` network. To do this, open a new Terminal window and type the following commands:

```
docker run --network=subreddit_fetcher -p 8080:8080 adminer
```

You should see the logs like so:

```
PHP 7.2.4 Development Server started
```

Open Adminer by navigating to `http://localhost:8080`. See Figure 6-8.

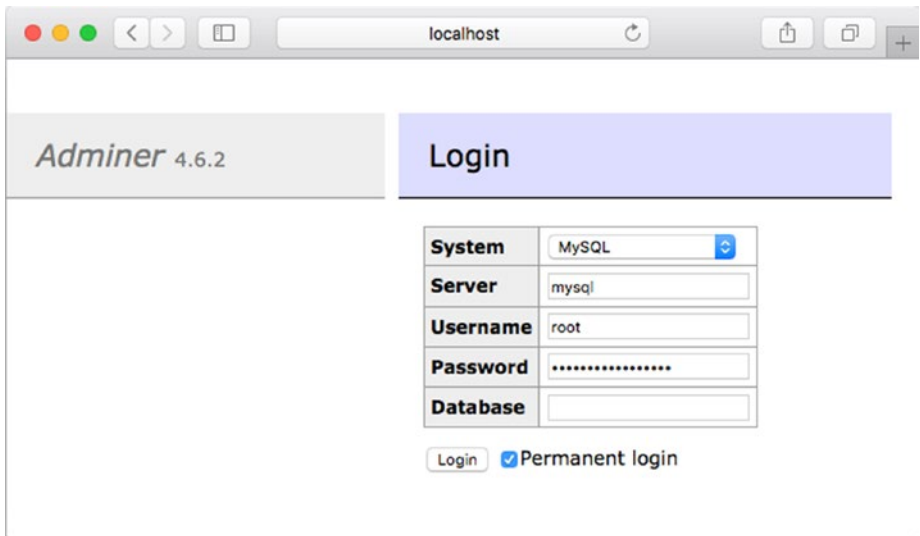


Figure 6-8. Logging into the linked MySQL container

Enter the server as `mysql`, enter the credentials, and then click on Login. You should see the database called `newsbot`, which corresponds to the MySQL database that you created.

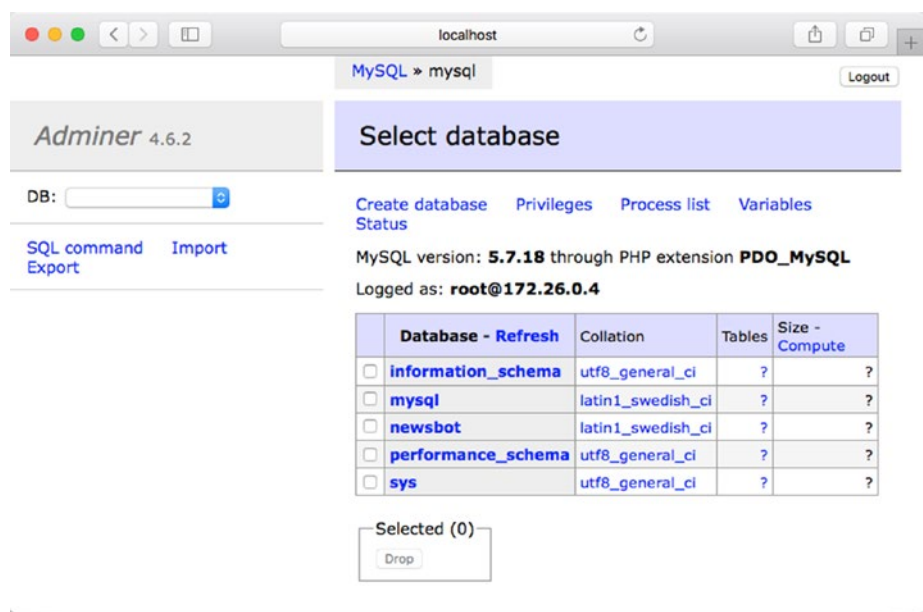


Figure 6-9. Successfully connecting to the project database

Congrats! You have successfully created a network and connected two separate containers to it!

Summary

In this chapter, you learned about the basics of container networking and the different modes of Docker networking. You also learned how to create and work with custom Docker bridged networks and got insights into Docker host networks. Finally, you performed some hands-on exercises on creating a separate database container (using MySQL) and learned how to connect the database container to the Newsbot project. In the next chapter, we will cover Docker Compose and discuss how easy Docker Compose makes it to run multiple, dependent containers.

CHAPTER 7

Understanding Docker Compose

In the previous chapters, you learned about Docker and its associated terminology, took a deeper look into how to build Docker images using the Dockerfile, learned how to persist data generated by containers, and linked various running containers with the help of Docker's network features.

In this chapter, we look at Docker Compose, which is a tool for running multi-container applications, bringing up various linked, dependent containers, and more—all with help of just one config file and a command.

Overview of Docker Compose

As software gets more complicated and as we move toward the microservices architecture, the number of components that need to be deployed increases considerably as well. While microservices might help in keeping the overall system fluid by encouraging loosely coupled services, from an operations point of view, things get more complicated. This is especially challenging when you have dependent applications—for instance, for a web application to start working correctly, it would need its database to be working before the web tier can start responding to requests.

Docker makes it easy to tie each microservice to a container, and Docker Compose makes orchestration of all of these containers very easy. Without Docker Compose, our container orchestration steps would involve building the various images, creating the required networks, and then running the application by a series of Docker run commands in the necessary order. As and when the number of containers increases and as the deployment targets increase, running these steps manually becomes infeasible and we need to go toward automation.

From a local development point of view, bringing up multiple, linked services manually gets very tedious and painful. Docker Compose simplifies this a lot. By just providing a YAML file describing the containers required and the relation between the containers, Docker Compose lets us bring up all the containers with a single command.

It's not just about bringing up the containers; Docker Compose lets you do the following as well:

- Build, stop, and start the containers associated with the application
- Tail the logs of the running containers, saving us the trouble of having to open multiple terminal sessions for each container
- View the status of each container

Docker Compose helps you enable continuous integration. By providing multiple, disposable, reproducible environments, Docker compose lets you run integration tests in isolation, allowing for a clean-room approach to the automated test cases. This enables you to run the tests, validate the results, and then tear down the environment cleanly.

Installing Docker Compose

- On Mac and Windows, Docker Compose is installed as part of the standard Docker install and doesn't require any additional steps to get started.
- On Linux systems, you can download Docker Compose binary from its [GitHub Release page](#). Alternatively, you can run the following `curl` command to download the correct binary.

```
sudo curl -L https://github.com/docker/compose/releases/  
download/1.21.0/docker-compose-$(uname -s)-$(uname -m) -o /usr/  
local/bin/docker-compose
```

Note Ensure the version number in this command matches the latest version of Docker Compose on the GitHub Releases page. Otherwise, you will end up with an outdated version.

- Once the binary has been downloaded, change the permissions so that it can be executed using the following command:

```
sudo chmod +x /usr/local/bin/docker-compose
```

If the file was downloaded manually, take care to copy the downloaded file to the `/usr/local/bin` directory before running the command. To confirm that the install was successful and is working correctly, run the following command:

```
docker-compose version
```

The result should be versions of Docker Compose, something similar to the following:

```
docker-compose version 1.20.1, build 5d8c71b
docker-py version: 3.1.4
CPython version: 3.6.4
OpenSSL version: OpenSSL 1.0.2n 7 Dec 2017
```

Docker Compose Basics

Unlike the Dockerfile, which is a set of instructions to the Docker engine about how to build the Docker image, the Compose file is a YAML configuration file that defines the services, networks, and volumes that are required for the application to be started. Docker expects the compose file to be present in the same path into which the `docker-compose` command is invoked having a file name of `docker-compose.yaml` (or `docker-compose.yml`). This can be overridden by using the `-f` flag followed by the path to the compose filename.

Compose File Versioning

Although the compose file is a YAML file, Docker uses the version key at the start of the file to determine which features of the Docker Engine are supported. Currently, there are three versions of the Compose file format:

- Version 1: Version 1 is considered a legacy format. If a Docker Compose file doesn't have a version key at the start of the YAML file, Docker considers it to be version 1 format.
- Version 2.x: Version 2.x identified by the `version: 2.x` key at the start of the YAML file.
- Version 3.x: Version 3.x identified by the `version: 2.x` key at the start of the YAML file.

The differences between the three major versions are described next.

Version 1

Docker Compose files that do not have a version key at the root of the YAML file are considered to be Version 1 compose files. Version 1 will be deprecated and removed in a future version of Docker Compose and, as such, we do not recommend writing Version 1 files. Besides the deprecation, Version 1 has the following major drawbacks:

- Version 1 files cannot declare named services, volumes, or build arguments
- Container discovery is enabled only by using the links flag

Version 2

Docker Compose Version 2 files has a version key with value 2 or 2.x. Version 2 introduces a few changes that make version 2 incompatible with previous versions of Compose files. These include:

- All services must be present under the services key.
- All containers are located on an application-specific default network and the containers can be discovered by the hostname specified by the service name.
- Links is made redundant.
- The depends_on flag is introduced, allowing us to specify dependent containers and the order in which the containers are brought up.

Version 3

Docker Compose Version 3 is the current major version of Compose having a version key with value 3 or 3.x. Version 3 removes several deprecated options, including volume_driver, volumes_from, and many more. Version 3 also adds a deploy key, which is used for deployment and running of services on Docker Swarm.

A sample reference Compose file looks like the following:

```
version: '3'
services:
  database:
    image: mysql
    environment:
      MYSQL_ROOT_PASSWORD: dontusethisinprod
  webserver:
    image: nginx:alpine
    ports:
      - 8080:80
    depends_on:
      - cache
      - database
  cache:
    image: redis
```

Similar to the Dockerfile, the Compose file is very readable and makes it easy to follow along. This Compose file is for a typical web application, which includes a web server, a database server, and a caching server. The Compose file declares that when Docker Compose runs, it will bring up three services—the webserver, the database server, and the caching server. The web server depends on the database and the cache service, which means that unless the database and the cache service are brought up, the web service will not be brought up. The cache and the database keys indicate that for cache, Docker must bring up the Redis image and the MySQL image for the database.

To bring up all the containers, issue the following command:

```
docker-compose up
```

Once the command is issued, Docker will bring up all the services in the foreground and we can see the logs as shown here:

```
docker-compose up
Creating network "dockercomposebasic_default" with the default
driver
Creating dockercomposebasic_database_1 ... done
Creating dockercomposebasic_cache_1 ... done
Creating dockercomposebasic_webserver_1 ... done
Attaching to dockercomposebasic_cache_1, dockercomposebasic_
database_1, dockercomposebasic_webserver_1
[...]
cache_1      | # Server started, Redis version 3.2.9
cache_1      | * The server is now ready to accept connections
              | on port 6379
database_1   | Initializing database
database_1   | Database initialized
database_1   | Initializing certificates
[...]
database_1   | [Note] mysqld: ready for connections.
database_1   | Version: '5.7.18' socket: '/var/run/mysqld/
              | mysqld.sock' port: 3306 MySQL Community Server
              | (GPL)
```

Note that Docker will aggregate the STDOUT of each container and will be streaming them when they run in the foreground. Note that even though our Compose file has the definition of the database first, the webserver second, and the cache as the last, Docker still brings up the caching container as the first and the web server as the last container. This is because we defined the `depends_on` key for the webserver as following:

```
depends_on:
- cache
- database
```

This tells Docker to bring up the cache and the database containers first before bringing up the webserver. Stopping the containers is as simple as issuing the following command:

```
docker-compose stop
```

```
Stopping dockercomposebasic_webserver_1 ... done
Stopping dockercomposebasic_database_1   ... done
Stopping dockercomposebasic_cache_1      ... done
```

To resume the containers, we can issue the following command:

```
docker-compose start
```

```
Starting database ... done
Starting cache    ... done
Starting webserver ... done
```

To view the logs of the containers, we can issue the following command:

```
docker-compose logs
```

```
Attaching to dockercomposebasic_webserver_1,
dockercomposebasic_database_1, dockercomposebasic_cache_1
database_1 | Initializing database
```

By default, `docker-compose logs` will only show a snapshot of the logs. If you want the logs to be streamed continuously, you can append the `-f` or `--follow` flag to tell Docker to keep streaming the logs. Alternatively, if you want to see the last n logs from each container, you can type:

```
docker-compose logs --tail=n
```

where n is the required number of lines.

To completely tear down the containers, we can issue the following:

```
docker-compose down
```

This will stop all containers and will also remove the associated containers, networks, and volumes created when `docker-compose up` was issued.

```
docker-compose down
Stopping dockercomposebasic_webserver_1 ... done
Stopping dockercomposebasic_database_1  ... done
Stopping dockercomposebasic_cache_1     ... done
Removing dockercomposebasic_webserver_1 ... done
Removing dockercomposebasic_database_1  ... done
Removing dockercomposebasic_cache_1     ... done
Removing network dockercomposebasic_default
```

Docker Compose File Reference

We mentioned earlier that the Compose file is a YAML file for configuration that Docker uses to read and set up the compose job. Let's look at what the different keys in the Docker Compose File do.

Services

Services is the first root key of the Compose YAML and is the configuration of the container that needs to be created.

build

The `build` key contains the configuration options that are applied at build time. The `build` key can be a path to the build context or a detailed object consisting of the context and optional Dockerfile location.

```
services:
  app:
    build: ./app
```



```
services:
  app:
    build:
      context: ./app
      Dockerfile: dockerfile-app
```

context

The context key sets the context of the build. If the context is a relative path, then the path is considered relative to the compose file location.

```
build:
  context: ./app
  Dockerfile: dockerfile-app
```

image

If the image tag is supplied along with the build option, Docker will build the image and name and tag the image with the supplied image name and tag.

```
services:
  app:
    build: ./app
    image: sathyabhat:app
```

environment/env_file

The environment key sets the environment variables for the application, while env_file provides the path to the environment file, which is read for setting the environment variables. Both environment as well as env_file can accept a single file or multiple files as an array. The YAML entry is as follows:

```
version: '3'
services:
  app:
```

```

    image: mysql
    environment:
        PATH: /home
        API_KEY: thisisnotavalidkey

version: '3'
services:
    app:
        image: mysql
        env_file: .env

version: '3'
services:
    app:
        image: mysql
        env_file:
            - common.env
            - app.env
            - secrets.env

```

depends_on

This key is used to set the dependency requirements across various services. Consider this config:

```

version: '3'
services:
    database:
        image: mysql
    webserver:
        image: nginx:alpine
        depends_on:
            - cache
            - database

```

```
cache:
  image: redis
```

When `docker-compose up` is issued, Docker will bring up the services as per the defined dependency order. In this case, Docker will bring up cache and database services before bringing up the webserver service.

Caution With the `depends_on` key, Docker will only bring up the services in the defined order. Docker will not wait for each of the services to be ready and then bring up the successive service.

image

This key specifies the name of the image to be used when a container is brought up. If the image doesn't exist locally, Docker will attempt to pull it if the `build` key is not present. If the `build` key is present in the Compose file, Docker will attempt to build and tag the image.

```
version: '3'
services:
  database:
    image: mysql
```

ports

This key specifies the ports that will be exposed to the port. While providing this key, we can specify either port—the Docker host port to which the container port will be exposed or just the container port, in which case a random, ephemeral port number on the host is selected.

```
version: '3'
services:
  database:
```

```

    image: nginx
    ports:
      - "8080:80"

version: '3'
services:
  database:
    image: nginx
    ports:
      - "80"

```

volumes

Volumes is available as a top-level key as well as suboption available to a service. When volumes is referred to as a top-level key, it lets us provide the named volumes that will be used for services at the bottom. The configuration for this looks like the following:

```

version: '3'
services:
  database:
    image: mysql
    environment:
      MYSQL_ROOT_PASSWORD: dontusethisinprod
    volumes:
      - "dbdata:/var/lib/mysql"
  webserver:
    image: nginx:alpine
    depends_on:
      - cache
      - database
  cache:
    image: redis

```

```
volumes:
```

```
  dbdata:
```

In the absence of the top-level volumes key, Docker will throw an error when creating the container. Consider the following configuration, where the volumes key has been skipped:

```
version: '3'
```

```
services:
```

```
  database:
```

```
    image: mysql
```

```
    environment:
```

```
      MYSQL_ROOT_PASSWORD: dontusethisinprod
```

```
    volumes:
```

```
      - "dbdata:/var/lib/mysql"
```

```
  webserver:
```

```
    image: nginx:alpine
```

```
    depends_on:
```

```
      - cache
```

```
      - database
```

```
  cache:
```

```
    image: redis
```

Trying to bring up the containers:

```
docker-compose up
```

```
ERROR: Named volume "db:/var/lib/mysql:rw" is used in service
"database" but no declaration was found in the volumes section.
```

It is possible to use bind mounts as well—instead of referring to the named volume, all we have to do is provide the path. Consider the following configuration:

```
version: '3'
```

```
services:
```

```

database:
  image: mysql
  environment:
    MYSQL_ROOT_PASSWORD: dontusethisinprod
  volumes:
    - "./dbdir:/var/lib/mysql"
webserver:
  image: nginx:alpine
  depends_on:
    - cache
    - database
cache:
  image: redis

```

The volume key has value of `./dbdir:/var/lib/mysql`, which means Docker will mount the `/var/lib/mysql` directory of the container to the `dbdir` directory. Relative paths are considered in relation to the directory of the Compose file.

Restart

The `restart` key provides the restart policy for the container. By default, the restart policy is set to `"no"`, which means Docker will not restart the container, no matter what. The following restart policies are available:

- `no`: Container will never restart
- `always`: Container will always restart after exit
- `on-failure`: Container will restart if it exits due to an error
- `unless-stopped`: Container will always restart unless exited explicitly or if the Docker daemon is stopped

Docker Compose CLI Reference

The `docker-compose` command comes with its own set of subcommands; let's try to understand them.

build

The `build` command reads the Compose file, scans for build keys, and then proceeds to build the image and tag the image. The images are tagged as `project_service`. If the Compose file doesn't have a build key then Docker will skip building any images. The usage is shown here:

```
docker-compose build <options> <service...>
```

If the service name is provided, Docker will proceed to build the image for just that service; otherwise, it will build images for all the services. Some of the commonly used options are as follows:

- `--compress`: Compresses the build context
- `--no-cache` Ignore the build cache when building the image

down

The `down` command stops the containers and will proceed to remove the containers, volumes, and networks. The usage is shown here:

```
docker-compose down
```

exec

The Compose `exec` command is equivalent to the Docker `exec` command. It lets you run ad hoc commands on any of the containers. The usage is shown here:

```
docker-compose exec <service> <command>
```

logs

The `logs` command displays the log output from all the services. The usage is shown here:

```
docker-compose logs <options> <service>
```

By default, logs will only show the last logs for all services. You can show logs for just one service by providing the service name. The `-f` option follows the log output.

stop

The `stop` command stops the containers. The usage is shown here:

```
docker-compose stop
```

Docker Volume Exercises

You learned about Docker Compose and the Compose file, so let's get some hands-on experience building multi-container applications.

BUILDING AND RUNNING A MYSQL DATABASE CONTAINER WITH A WEB UI FOR MANAGING THE DATABASE

In this exercise, you will build a multi-container application consisting of a container for the MySQL database and another container for Adminer, a popular Web UI for MySQL. Since we already have prebuilt images for MySQL and Adminer, we won't have to build them.

Tip The `docker-compose.yml` file associated with this is available as `docker-compose-adminer.zip`. Be sure to extract the contents of the ZIP file and run the commands in the directory to which they were extracted.

We can start with the Docker Compose file, as shown here.

The docker-compose.yml Listing

```
version: '3'
services:
  mysql:
    image: mysql
    environment:
      MYSQL_ROOT_PASSWORD: dontusethisinprod
    ports:
      - "3306:3306"
    volumes:
      - "dbdata:/var/lib/mysql"
  adminer:
    image: adminer
    ports:
      - "8080:8080"

volumes:
  dbdata:
```

This Compose file uses everything that we have learned in this book in one concise file. At the start of the Compose file, we define that we will be using version 3 of the Compose API. Under `services`, we define two services—one for the database that pulls in a Docker image called `mysql`. When the container is created, an environment variable called `MYSQL_ROOT_PASSWORD` sets the root password for the database and port 3306 from the container is published to the host. The data of the MySQL database is stored in a volume

known as `dbdata`, which is mounted onto the directory `/var/lib/mysql` of the container. This is where MySQL stores the data. In other words, any data saved to the database in the container is handled by the volume named `dbdata`.

The other service, called `Adminer`, pulls in a Docker image called `Adminer` and publishes port 8080 from the container to the host.

Let's validate the Compose file by typing the following:

```
docker-compose config
```

If everything is okay, Docker will print the Compose file as it is parsed. It should look like this:

```
services:
  adminer:
    image: adminer
    ports:
      - 8080:8080/tcp
  mysql:
    environment:
      MYSQL_ROOT_PASSWORD: dontusethisinprod
    image: mysql
    ports:
      - 3306:3306/tcp
    volumes:
      - dbdata:/var/lib/mysql:rw
version: '3.0'
volumes:
  dbdata: {}
```

CHAPTER 7 UNDERSTANDING DOCKER COMPOSE

Let's run the service by typing the following:

```
docker-compose up
```

We should be seeing a log like the one below

```
Creating network "dockercomposeadminer_default" with the default driver
```

```
Creating volume "dockercomposeadminer_dbdata" with default driver
```

```
Creating dockercomposeadminer_mysql_1 ... done
```

```
Creating dockercomposeadminer_adminer_1 ... done
```

```
Attaching to dockercomposeadminer_adminer_1,  
dockercomposeadminer_mysql_1
```

```
adminer_1 | PHP 7.2.4 Development Server started
```

```
mysql_1 | Initializing database
```

```
[...]
```

```
mysql_1 | Database initialized
```

```
mysql_1 | Initializing certificates
```

```
[...]
```

```
mysql_1 | MySQL init process in progress...
```

```
[...]
```

```
mysql_1 | MySQL init process done. Ready for start up.
```

```
[...]
```

```
mysql_1 | [Note] mysqld: ready for connections.
```

```
mysql_1 | Version: '5.7.18' socket: '/var/run/mysqld/mysqld.  
sock' port: 3306 MySQL Community Server (GPL)
```

This tells us that the Adminer UI and MySQL database is ready. Now try logging in by navigating to <http://localhost:8080>, as shown in Figure 7-1.

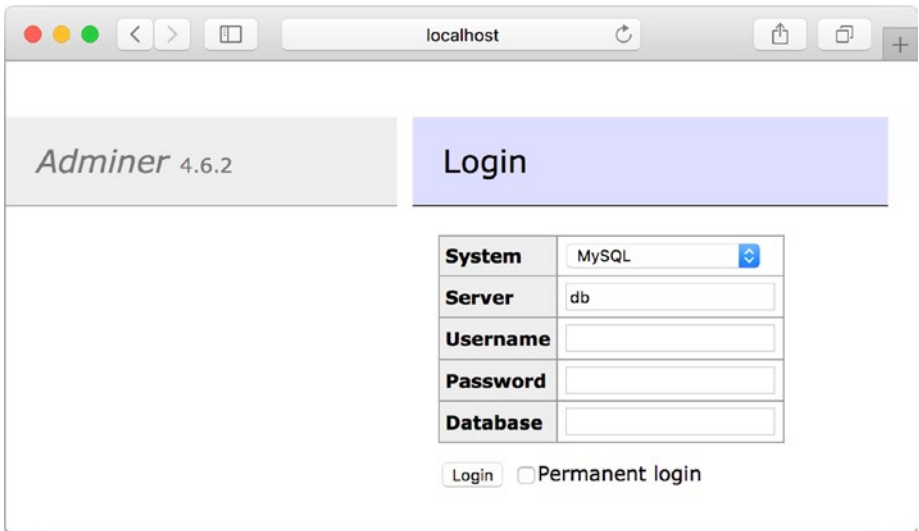


Figure 7-1. *The Adminer login page*

We should be seeing the screen shown in Figure 7-1. You'll notice that the server has been populated with `db`. Since Docker Compose creates its own network for the application, the hostname for each container is the service name. In our case, the MySQL database service name is `mysql` and the database will be accessible via the hostname `mysql`. Enter the username as `root` and the password as the one entered in the `MYSQL_ROOT_PASSWORD` environment variable. See Figure 7-2.

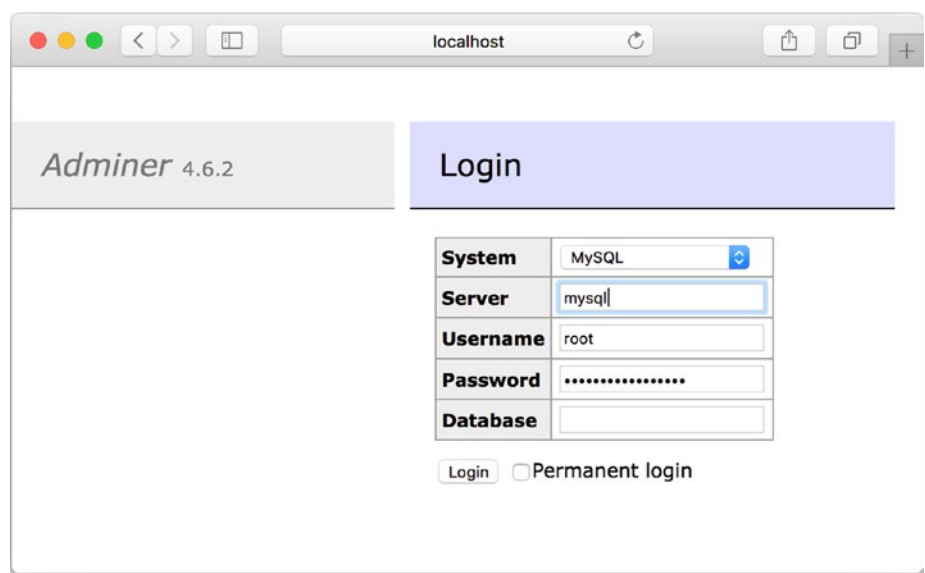


Figure 7-2. Adminer Login details

If the details are correct, you will see the page shown in Figure 7-3.

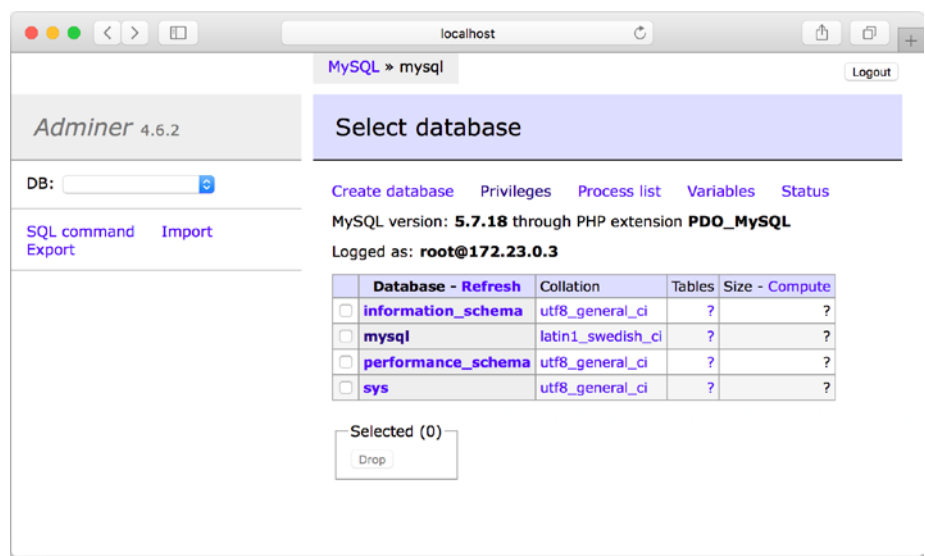


Figure 7-3. Database details available once logged in

CONVERTING THE PROJECT TO DOCKER COMPOSE

In the previous chapter's exercises, you wrote a Dockerfile for your project. Later, you added volumes and the data was persisted to SQLite. In this exercise, you change the project to use MySQL instead of SQLite.

For this exercise, you will be working on a slightly modified codebase, which has support for saving the preferences to a SQLite DB. We would use Docker Volumes to persist the database across containers.

Let's modify the existing Docker Compose file

Tip The source code, the Dockerfile, and the Docker Compose file associated with this are available as `subreddit-fetcher-compose.zip`.

The docker-compose.yaml Listing

```
version: '3'
services:
  app:
    build: .
    depends_on:
      - mysql
    restart: "on-failure"
    volumes:
      - "appdata:/apps/subredditfetcher"
  mysql:
    image: mysql
    volumes:
      - "dbdata:/var/lib/mysql"
    environment:
      - MYSQL_ROOT_PASSWORD=dontusethisinprod
```

```
volumes:
  dbdata:
  appdata:
```

Expanding on our MySQL Docker Compose discussed earlier, we add our application details to the service section. Since our application requires that MySQL needs to be started before the application, we add the `depends_on` key. Additionally, we mount the `appdata` volume declared as a top-level key under `volumes` and mount it to the `/apps/subredditfetcher` directory in the container.

We also add a restart policy to restart the container upon failure. Finally, we add the top-level keys for the volumes declared as `dbdata` and `appdata`, for persisting MySQL and the application data.

Let's verify that the Compose file is correct and valid:

```
docker-compose config
services:
  adminer:
    image: adminer
    ports:
      - 8080:8080/tcp
  app:
    build:
      context: /home/sathyabhat/code/subreddit_fetcher_compose
    depends_on:
      - mysql
    restart: on-failure
    volumes:
      - appdata:/apps/subredditfetcher:rw
  mysql:
    environment:
```

```

    MYSQL_ROOT_PASSWORD: dontusethisinprod
  image: mysql
  volumes:
    - dbdata:/var/lib/mysql:rw
version: '3.0'
volumes:
  appdata: {}
  dbdata: {}

```

Let's run the Compose application:

```
docker-compose up --build
```

The `--build` flag forces Docker to rebuild the images even if nothing has changed, and it can be skipped. We should see a result like so:

```

docker-compose up --build
Creating network "subredditfetchercompose_default" with the
default driver
Creating volume "subredditfetchercompose_dbdata" with default
driver
Creating volume "subredditfetchercompose_appdata" with default
driver
Building app
Step 1/7 : FROM python:3-alpine
----> 4fcaf5fb5f2b
Step 2/7 : COPY * /apps/subredditfetcher/
----> a1ae719d8b90
Step 3/7 : WORKDIR /apps/subredditfetcher/
Removing intermediate container f6c4e85952ff
----> 7702ecd8eec6
Step 4/7 : VOLUME [ "/apps/subredditfetcher" ]
----> Running in 69fedd2fffe5
Removing intermediate container 69fedd2fffe5

```


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```
---> 4ff33274be32
Step 5/7 : RUN ["pip", "install", "-r", "requirements.txt"]
---> Running in 1060110739f6
[...]
Installing collected packages: idna, chardet, urllib3, certifi,
requests, update-checker, prawcore, praw, peewee, PyMySQL
Successfully installed PyMySQL-0.8.0 certifi-2018.4.16
chardet-3.0.4 idna-2.6 peewee-2.10.2 praw-5.4.0 prawcore-0.14.0
requests-2.18.4 update-checker-0.16 urllib3-1.22
You are using pip version 9.0.3, however version 10.0.1 is
available.
You should consider upgrading via the 'pip install --upgrade
pip' command.
Removing intermediate container 1060110739f6
---> 307613a1e95e
Step 6/7 : ENV NBT_ACCESS_TOKEN="495637361:AAHIhDTX1UeX17KJyO-
FsMZEqEtCFYfcP8"
---> Running in Offaed2488b4
Removing intermediate container Offaed2488b4
---> 9faabd11d518
Step 7/7 : CMD ["python", "newsbot.py"]
---> Running in c350455c6121
Removing intermediate container c350455c6121
---> e876df59bafo
Successfully built e876df59bafo
Successfully tagged subredditfetchercompose_app:latest
Creating subredditfetchercompose_mysql_1 ... done
Creating subredditfetchercompose_app_1 ... done
Attaching to subredditfetchercompose_mysql_1,
subredditfetchercompose_app_1
```

```

mysql_1 | Initializing database
[...]
app_1   | INFO: <module> - Starting up
app_1   | INFO: <module> - Waiting for 60 seconds for db to
come up
[...]
mysql_1 | Database initialized
mysql_1 | Initializing certificates
[...]
mysql_1 | Certificates initialized
mysql_1 | MySQL init process in progress...
[...]
mysql_1 | [Note] mysqld: ready for connections.
mysql_1 | Version: '5.7.18' socket: '/var/run/mysqld/mysqld.
sock' port: 0 MySQL Community Server (GPL)
[...]
mysql_1 | MySQL init process done. Ready for start up.
[...]
mysql_1 | [Note] mysqld: ready for connections.
mysql_1 | Version: '5.7.18' socket: '/var/run/mysqld/mysqld.
sock' port: 3306 MySQL Community Server (GPL)
[...]
app_1   | INFO: <module> - Checking on dbs
app_1   | INFO: get_updates - received response: {'ok': True,
'result': []}
app_1   | INFO: get_updates - received response: {'ok': True,
'result': []}

```

The last line indicates that the bot is working. Let's try setting a source and fetching the data by typing `/sources docker` and then `/fetch` into the telegram bot. If all goes well, you should see a result similar to the one shown in Figure 7-4.

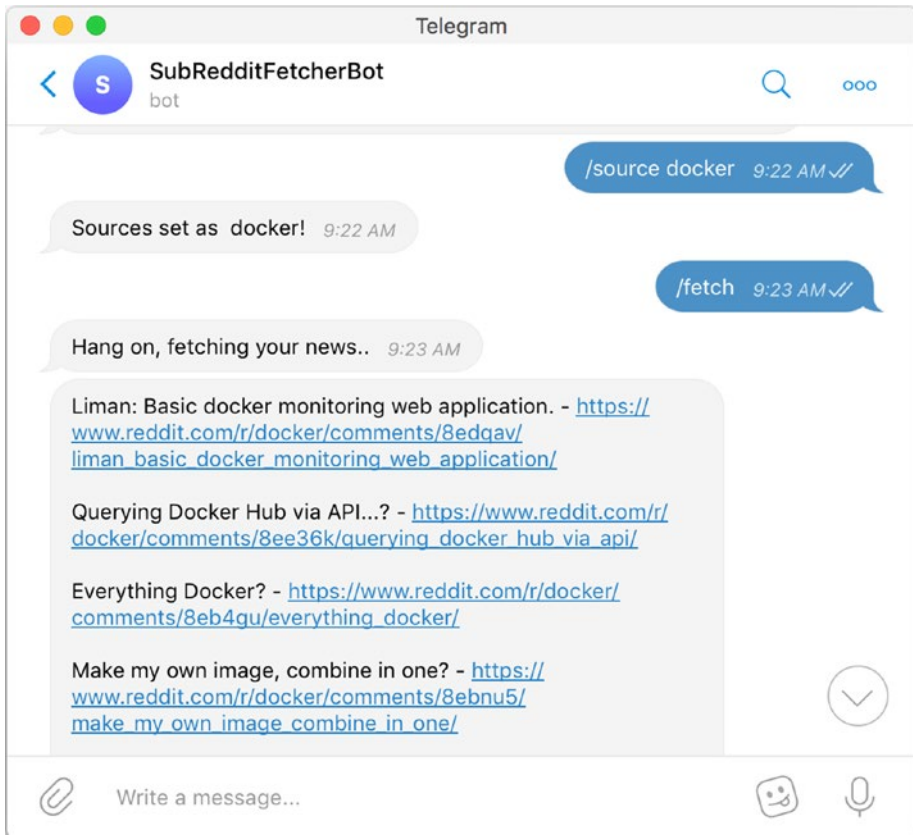


Figure 7-4. Our project, the subreddit fetcher bot in action

We can go one step further by modifying our Compose file to include the Adminer service so that we have a Web UI to check that the contents are being saved to the database. For this, modify the existing Docker Compose file to include the Adminer service, as shown here:

```
version: '3'
```

```
services:
```

```
  app:
```

```
    build: .
```

```
    depends_on:
```

```
      - mysql
```

```

    restart: "on-failure"
    volumes:
      - "appdata:/apps/subredditfetcher"
mysql:
  image: mysql
  volumes:
    - "dbdata:/var/lib/mysql"
  environment:
    - MYSQL_ROOT_PASSWORD=dontusethisinprod
adminer:
  image: adminer
  ports:
    - "8080:8080"

volumes:
  dbdata:
  appdata:

```

Let's confirm that the Compose file is valid:

```

docker-compose config
services:
  adminer:
    image: adminer
    ports:
      - 8080:8080/tcp
  app:
    build:
      context: /home/sathyabhat/code/subreddit_fetcher_compose
    depends_on:
      - mysql
    restart: on-failure
    volumes:

```

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```
- appdata:/apps/subredditfetcher:rw
mysql:
  environment:
    MYSQL_ROOT_PASSWORD: dontusethisinprod
  image: mysql
  volumes:
    - dbdata:/var/lib/mysql:rw
version: '3.0'
volumes:
  appdata: {}
  dbdata: {}
```

Let's tear down the existing Compose and bring up a new Compose application. Since the data is persisted to volumes, we shouldn't be worried about data loss.

```
docker-compose down
Stopping subredditfetchercompose_app_1 ... done
Stopping subredditfetchercompose_mysql_1 ... done
Removing subredditfetchercompose_app_1 ... done
Removing subredditfetchercompose_mysql_1 ... done
Removing network subredditfetchercompose_default
```

Bring up the service again:

```
docker-compose up
Creating network "subredditfetchercompose_default" with the
default driver
Creating subredditfetchercompose_adminer_1 ... done
Creating subredditfetchercompose_mysql_1 ... done
Creating subredditfetchercompose_app_1 ... done
Attaching to subredditfetchercompose_mysql_1,
subredditfetchercompose_adminer_1, subredditfetchercompose_app_1
[...]
```

```

adminer_1 | PHP 7.2.4 Development Server started
[...]
mysql_1   | [Note] mysqld: ready for connections.
mysql_1   | Version: '5.7.18'  socket: '/var/run/mysqld/mysqld.
          | sock'  port: 3306  MySQL Community Server (GPL)
[...]
app_1     | INFO: <module> - Starting up
app_1     | INFO: <module> - Waiting for 60 seconds for db to
          | come up
app_1     | INFO: <module> - Checking on dbs
app_1     | INFO: get_updates - received response: {'ok': True,
          | 'result': []}
app_1     | INFO: get_updates - received response: {'ok': True,
          | 'result': []}

```

Now navigate to Adminer by heading to `http://localhost:8080` and checking for the data; see Figure 7-5.

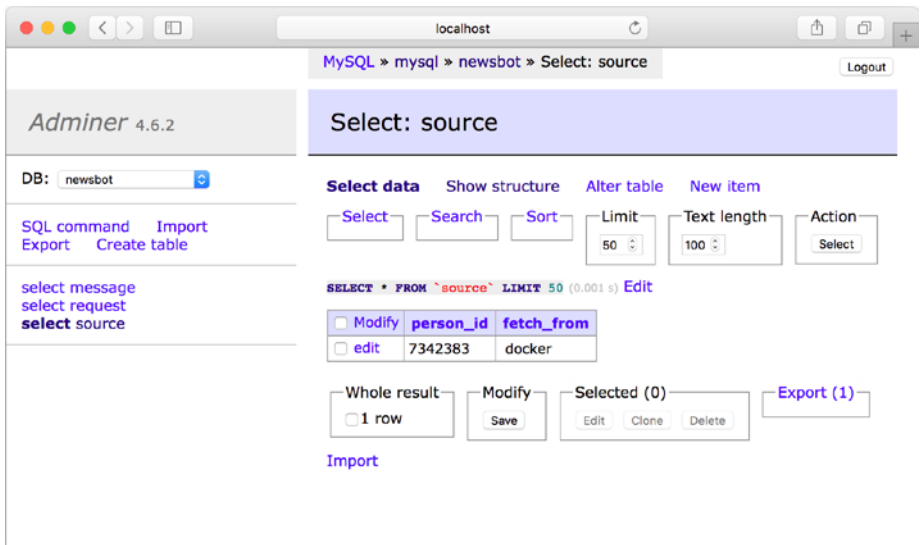


Figure 7-5. The project, running with data saved to the database

Success! The application is running and the data is saved to the database despite you removing and recreating the containers.

Summary

In this chapter, you learned about Docker Compose, including how to install it and why it is used. You also did a deep dive into the Docker Compose file and the CLI. Finally, you ran through some exercises on building multi-containers applications with Docker Compose and learned how to extend the Newsbot project to a multi-container application using Docker Compose, adding a linked database and a Web UI to edit the database.

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