

Lab 7: Docker Storage

In this lab, you will learn how Docker manages data. It is crucial to know where to store your data and how your services will access it. This lab will explore running stateless versus stateful Docker containers, and will delve into the configuration setup options for storage for different applications. By the end of the lab, you will be able to distinguish between the different storage types in Docker and identify the container's life cycle and its various states. You will also learn how to create and manage Docker volumes.

Exercise 7.01: Transitioning through the Common States for a Docker Container

Pinging www.google.com is a common practice to verify that the server or your cluster's node is connected to the internet. In this exercise, you will transit through all the states for a Docker container while checking whether the server or your cluster's node is connected to the internet.

You will use two terminals in this exercise. One terminal will be used to run a container to ping www.google.com, and the other one will be used to control this running container by executing the previously mentioned commands.

To ping www.google.com, you will craft a container called `testevents` from the `ubuntu:14.04` image:

1. Open the first terminal and execute the `docker container run` command to run a container. Use the `--name` option to give the container a specific nickname --- for example, `testevents`. Don't let the Docker host generate a random name for your container. Use the `ubuntu:14.04` image and the `ping google.com` command to verify that the server is running on the container:

```
docker container run --name testevents ubuntu:14.04 ping google.com
```

The output will be as follows:

```
PING google.com (172.217.165.142) 56(84) bytes of data.  
64 bytes from lax30s03-in-f14.1e100.net (172.217.165.142):  
icmp_seq=1 ttl=115 time=68.9 ms  
64 bytes from lax30s03-in-f14.1e100.net (172.217.165.142):  
icmp_seq=2 ttl=115 time=349 ms  
64 bytes from lax30s03-in-f14.1e100.net (172.217.165.142):  
icmp_seq=3 ttl=115 time=170 ms
```

As you can see in the preceding output, the pinging has started. You will find the packets being transmitted to `google.com`.

2. Dedicate the first terminal to the pinging output. Now, control this container by executing the commands in another terminal. In the second terminal, execute `docker container ls` to list all the running containers:

```
docker container ls
```

Look for the container with the name `testevents`. The status should be `Up`:

CONTAINER ID	IMAGE	COMMAND	CREATED
STATUS	PORTS	NAMES	
10e235033813	ubuntu:14.04	"ping google.com"	10 seconds ago
Up 5 seconds		testevents	

3. Now, run the `docker container pause` command in the second terminal to pause the running container in the first terminal:

```
docker container pause testevents
```

You will see that the pinging has stopped, and no packets are being transmitted anymore.

4. List the running containers again by using `docker container ls` in the second terminal:

```
docker container ls
```

As you can see in the following output, the status of `testevents` is `Up(Paused)`. This is because you ran the `docker container pause` command previously:

CONTAINER ID	IMAGE	COMMAND	CREATED
STATUS	PORTS	NAMES	
10e235033813	ubuntu:14.04	"ping google.com"	26 seconds ago
Up 20 seconds (Paused)		testevents	

5. Use `docker container unpause` in the second terminal to start the paused container and make it resume sending packets:

```
docker container unpause testevents
```

You will find that the pinging resumes and new packets are transmitted in the first terminal.

6. In the second terminal, run the `docker container ls` command again to see the container's current status:

```
docker container ls
```

You will see that the status of the `testevents` container is `Up`:

CONTAINER ID	IMAGE	COMMAND	CREATED
STATUS	PORTS	NAMES	
10e235033813	ubuntu:14.04	"ping google.com"	43 seconds ago
Up 37 seconds		testevents	

7. Now, run the `docker container stop` command to stop the container:

```
docker container stop testevents
```

You will observe that the container exits and the shell prompt returns in the first terminal:

```
64 bytes from lax30s03-in-f14.1e100.net (142.250.64.110):  
icmp_seq = 42 ttl=115 time=19.8 ms  
64 bytes from lax30s03-in-f14.1e100.net (142.250.64.110):  
icmp_seq = 43 ttl=115 time=18.7 ms
```

8. Now, run the `docker container ls` command in any terminal:

```
docker container ls
```

You will see that the `testevents` container is not in the list anymore because the `docker container ls` subcommand displays the up-and-running containers only:

CONTAINER ID	IMAGE	COMMAND	CREATED
STATUS	PORTS	NAMES	

9. Run the `docker container ls -a` command to display all the containers:

```
docker container ls -a
```

You can see that the status of the `testevents` container is now `Exited`:

CONTAINER ID	IMAGE	COMMAND	CREATED
STATUS	PORTS	NAMES	
10e235033813	ubuntu:14.04	"ping google.com"	1 minute ago
Exited (137)	13 seconds ago	testevents	

10. Use the `docker container start` command to start the container. Also, add the `-a` option to attach local standard input, output, and error streams to the container and see its output:

```
docker container start -a testevents
```

As you can see in the following snippet, the pinging resumes and is executed in the terminal:

```
64 bytes from lax30s03-in-f14.1e100.net (142.250.64.110):  
icmp_seq = 55 ttl=115 time=63.5 ms  
64 bytes from lax30s03-in-f14.1e100.net (142.250.64.110):  
icmp_seq = 56 ttl=115 time=22.2 ms
```

11. Run the `docker ls` command again in the second terminal:

```
docker container ls
```

You will observe that `testevents` returns back to the list, its status is `Up`, and it is running:

CONTAINER ID	IMAGE	COMMAND	CREATED
STATUS	PORTS	NAMES	
10e235033813	ubuntu:14.04	"ping google.com"	43 seconds ago
Up 37 seconds		testevents	

12. Now, remove the `testevents` container using the `rm` command with the `-f` option. The `-f` option is used to force-remove the container:

```
docker container rm -f testevents
```

The first terminal stops executing the `ping` command and the second terminal will return the name of the container:

```
testevents
```

13. Run the `ls -a` command to check whether the container is running or not:

```
docker container ls -a
```

You will not find the `testevents` container in the list because we just removed it from our system.

14. Run the following command to see the `CREATED` status. Craft a container named `testcreate` from the `ubuntu:14.04` image using the `docker container run` command:

```
docker container run --name testcreate ubuntu:14.04 time
```

The `time` command will generate an **error** because there is no such command inside `ubuntu:14.04`.

15. Now, list the running containers:

```
docker container ls
```

You will see that the list is empty:

CONTAINER ID	IMAGE	COMMAND	CREATED
STATUS	PORTS	NAMES	

16. Now, list all the containers by adding the `-a` option:

```
docker container ls -a
```

Look in the list for the container named `testcreate`; you will observe that its status is `Created`:

CONTAINER ID	IMAGE	COMMAND	CREATED
STATUS	PORTS	NAMES	
C262e6718724	ubuntu:14.04	"time"	30 seconds ago
Created		testcreate	

If a container is stuck in the `CREATED` state, this is an indication that an error has been generated, and Docker was unable to get the container up and running.

So far, we have focused on the container's statuses and not its size. In the next exercise, we will learn how to determine the size of the memory occupied by the container.

Exercise 7.02: Checking the Container Size on Disk

When you first craft a container, it has the same size as the base image with a top read/write layer. With every layer that is added to the container, its size increases. In this exercise, you will create a container that has `ubuntu:14.04` as its base image. Update and install `wget` on top of it to highlight the effect of state transition on data retention:

1. Run the `docker container run` command with the `-it` option to create a container named `testsize`. The `-it` option is used to have an interactive terminal to run commands inside the running container:

```
docker container run -it --name testsize ubuntu:14.04
```

The prompt will now look like `root@<container ID>:/#`, where the container ID is a number that the Docker Engine generates. Therefore, you will have a different number when you run this command on your machine. As mentioned before, being inside a container means that the container will be in the `UP` state.

2. Dedicate the first terminal to the running container and execute the commands in the second terminal. Having **two terminals** saves us from detaching the container to run a command and then reattaching to

the container to run another command inside it.

Now, verify that the container initially has the size of the base image, which is `ubuntu:14.04`. List the images using the `docker image ls` command in the second terminal. Check the size of the `ubuntu:14.04` image:

```
docker image ls
```

As you can see in the following output, the size of the image is `188MB`:

REPOSITORY	TAG	IMAGE ID	CREATED
SIZE			
ubuntu	14.04	971bb3841501	23 months ago
188MB			

3. Now, check the size of the container by running the `docker container ls -s` command to get the container's size:

```
docker container ls -s
```

Look for the `testsize` container. You will observe that the size is `0B (virtual 197MB)`:

CONTAINER ID	IMAGE	COMMAND	CREATED
STATUS	PORTS	NAMES	SIZE
9f2d2d1ee3e0	ubuntu:14.04	"/bin/bash"	6 seconds ago
Up 6 minutes		testsize	0B (virtual 197MB)

The `SIZE` column indicates the size of the thin read/write layer of the container only, while the virtual size indicates the size of the thin read/write layer and all the previous layers encapsulated in the container. Thus, in this case, the thin layer equals `0B`, and the virtual size equals the image size.

4. Now, install the `wget` package. Run the `apt-get update` command in the first terminal. A general recommendation, in Linux, is to run `apt-get update` before installing any packages to update the latest versions of the packages that are currently on your system:

```
root@9f2d2d1ee3e0: apt-get update
```

5. Run the following command when the container finishes updating to install the `wget` package on top of the base image. The `-y` option is used to answer yes automatically to all the installation questions:

```
root@9f2d2d1ee3e: apt-get install -y wget
```

6. When it finishes installing `wget` on top of `ubuntu:14.04`, recheck the container's size by running the `ls -s` command in the second terminal:

```
docker container ls -s
```

As you can see from the following snippet, the size of the `testsize` container is `2.98MB (virtual 199MB)`:

CONTAINER ID	IMAGE	COMMAND	CREATED
STATUS	PORTS	NAMES	SIZE

```
9f2d2d1ee3e0    ubuntu:14.04    "/bin/bash"    9 seconds ago
Up 9 minutes      testsize      27.8MB (virtual 216MB)
```

Now, the thin layer equals 27.8MB, and the virtual size equals the size of all the layers. In this exercise, the layers are the base image, with a size of 188 MB; the update; and the `wget` layer, which has a size of 27.8 MB. Therefore, the total size will be 216 MB after approximation.

In this exercise, you learned about the function of the `-s` option used with the `docker container ls` subcommand. This option is used to display the size of the base image and the size of the top writable layer. Knowing the size that every container consumes is useful to avoid an out-of-disk-space exception. Moreover, it can help us in troubleshooting and setting a maximum size for every container.

Exercise 7.04: Deploying a Stateful Service, MySQL

In this exercise, you will deploy a single stateful MySQL container to be the database as a backend component.

To install MySQL, follow the steps at https://hub.docker.com/_/mysql in the `via stack deploy` section. Select and copy the `stack.yml` file to memory:

1. Use an editor to paste the `stack.yml` file. You can open a text editor and paste the following code:

```
# Use root/example as user/password credentials
version: '3.1'
services:
  db:
    image: mysql
    command: --default-authentication-plugin=mysql_native_password
    restart: always
    environment:
      MYSQL_ROOT_PASSWORD: example
  adminer:
    image: adminer
    restart: always
    ports:
      - 8080:8080
```

In this YAML file, you have two services: `db` and `adminer`. The `db` service is based on the `mysql` image, while the `adminer` image is the base image of the `adminer` service. The `adminer` image is a database management tool. In the `db` service, you enter the command and set the environment variable, which has the database password with a policy to always restart if it fails for any reason. Also, in the `adminer` service, the policy is set to always restart if it fails for any reason.

2. If the code is correct, deploy the `YML` file by using the `docker stack deploy` subcommand:

```
docker stack deploy -c stack.yml mysql
```

You should see an output like the following:

```
Ignoring unsupported options: restart
Creating network mysql_default
Creating service mysql_db
Creating service mysql_adminer
```

3. Use the `docker stack ls` subcommand to list the stacks:

```
docker stack ls
```

You should see an output like the following:

NAME	SERVICES	ORCHESTRATOR
mysql	2	Swarm

4. Use the `docker stack rm` subcommand to remove the stack:

```
docker stack rm mysql
```

When removing the stack, Docker will remove the two services: `db` and `adminer`. It will also remove the network that it created by default to connect all the services:

```
Removing service mysql_adminer
Removing service mysql_db
Removing network mysql_default
```

In this exercise, you deployed a stateful service, MySQL, and were able to access the database service from the browser. Again, we used the Docker playground as our platform to execute the exercise.

We have learned that containers need persistent storage that outlives the container life cycle but have not yet covered how to do that. In the next section, we will learn about volumes to save persistent data.

Exercise 7.05: Managing a Volume outside the Container's Scope and Mounting It to the Container

In this exercise, you will create a volume that is not confined to a container. You will start by creating a volume, mounting it to a container, and saving some data on it. You will then delete the container and list the volume to check whether the volume persists even when you do not have a container on your system:

1. Create a volume named `vol1` using the `docker volume create` command:

```
docker volume create vol1
```

The command will return the name of the volume, as shown:

```
vol1
```

2. List all the volumes using the `docker volume ls` command:

```
docker volume ls
```

This will result in the following output:

DRIVER	VOLUME NAME
Local	vol1

3. Inspect the volume to get its mount point using the following command:

```
docker volume inspect vol1
```

You should get an output like the following:

```
[
  {
    "CreatedAt": "2020-06-16T16:44:13-04:00",
    "Driver": "local",
    "Labels": {},
    "Mountpoint": "/var/lib/docker/volumes/voll/_data",
    "Name": "voll",
    "Options": {},
    "Scope": "local"
  }
]
```

The volume inspection shows the date and time of its creation, its mount path, its name, and its scope.

4. Mount the volume to a container and modify its contents. Any data that is added to `voll` will be copied to the volume inside the container:

```
docker container run -it -v voll:/container_vol --name container1 ubuntu:14.04
bash
```

In the preceding command, you have crafted a container from the `ubuntu:14.04` image with the `bash` command. The `bash` command allows you to enter the commands inside the container. The `-it` option is used to have an interactive terminal. The `-v` option is for synchronizing the data between `voll` at the host and `container_vol` inside the container. Use the `--name` option to name the container `container1`.

5. The prompt changes, indicating that you are now inside the container. Write the word `hello` in a file called `new_file.txt` onto the volume. The volume inside the container is called `container_vol`. In this case, this volume is shared between the host and the container. From the host, the volume is called `voll`:

```
root@acc8900e4cf1:/# echo hello > /container_vol/new_file.txt
```

6. List the contents of the volume to verify that the file is saved:

```
root@acc8900e4cf1:/# ls /container_vol
```

7. Exit the container using the `exit` command:

```
root@acc8900e4cf1:/# exit
```

8. Check the new file exists by running the following command:

```
docker container run -it -v voll:/container_vol --name testvolume ubuntu:14.04
ls /container_vol
```

The command will return the name of the new file:

```
new_file.txt
```


9. Remove the container with the `-v` option to remove any volumes that are created within the container's scope:

```
docker container rm -v container1
docker container rm -v tesatvolume
```

The command will return the name of the container:

```
container1
```

10. Verify that the volume still exists by listing all the volumes:

```
docker volume ls
```

The volume, `vol1`, is listed, indicating that the volume was created outside the container, and even by using the `-v` option, it will not be removed when the container is removed:

DRIVER	VOLUME NAME
Local	vol1

11. Now, remove the volume using the `rm` command:

```
docker volume rm vol1
```

The command should return the name of the volume:

```
vol1
```

12. Verify that the volume is removed by listing the current list of volumes:

```
docker volume ls
```

An empty list will be displayed, indicating that the volume has been removed:

DRIVER	VOLUME NAME
--------	-------------

In this exercise, you learned how to create volumes as independent objects in Docker without being within the container's scope, and how to mount this volume to a container. The volume was not removed when you removed the container because the volume was created outside the container's scope. In the end, you learned how to remove these types of volumes.

In the next exercise, we will create, manage, and remove an unnamed or anonymous volume that is within the container's scope.

Exercise 7.06: Managing a Volume within the Container's Scope

You do not need to create the volume before running the container as in the previous example. Docker will create an unnamed volume for you automatically. Again, the volume will not be removed when the container is removed, unless you specify the `-v` option in the `docker container rm` subcommand. In this exercise, you will create an anonymous volume within the container's scope and then learn how to remove it:

1. Create a container with an anonymous volume using the following command:

```
docker container run -itd -v /newvol --name container2 ubuntu:14.04 bash
```

The command should return a long hex digit number, which is the volume ID.

2. List all the volumes:

```
docker volume ls
```

Observe that this time, `VOLUME NAME` is a long hex digit number and not a name. This type of volume is called an anonymous volume and can be removed by adding the `-v` option to the `docker container rm` subcommand:

DRIVER	VOLUME NAME
Local	8f4087212f6537aafde7eaca4d9e4a446fe99933c3af3884d0645b66b16fbfa4

3. Remove the container with the volume, this time. Use the `-f` option to force remove the container since it is in detached mode and running in the background. Add the `v` option (making this `-fv`) to remove the volume as well. If this volume is not anonymous, and you named it, it will not be removed by this option and you must use `docker volume rm <volume name>` to remove it:

```
docker container rm -fv container2
```

The command will return the name of the container.

4. Verify that the volume has been removed. Use the `docker volume ls` subcommand, and you will observe that the list is empty:

```
docker volume ls
```

Compared to the previous exercise, the volume was removed when the container was removed by using the `-v` option in the `rm` subcommand. Docker removed the volume this time because the volume was initially created within the container's scope.

Now, we are going to see some more examples of volumes being used with stateful containers. Remember that using volumes with stateful containers as databases is the best practice. Containers are ephemeral, while data on databases should be saved as a persistent volume, where any new container can pick up and use the saved data. Therefore, the volume must be named, and you should not leave Docker to automatically generate an anonymous volume with a hex digit number as its name.

In the next exercise, you will run a PostgreSQL database container with a volume.

Exercise 7.07: Running a PostgreSQL Container with a Volume

Say you work in an organization where a PostgreSQL container with a database volume is used and the container gets deleted due to some mishap. However, the data persisted and outlived the container. In this exercise, you will run a PostgreSQL container with a database volume:

1. Run a PostgreSQL container with a volume. Name the container `db1`. If you do not have the image locally, Docker will pull the image for you. Create a container called `db1` from the `postgres` image. Use the `-v` option to share the `db` volume at the host with `/var/lib/postgresql/data` inside the container

and the `-e` option to echo SQL to the standard output stream as well. Use the `POSTGRES_PASSWORD` option to set the database password and the `-d` option to run this container in detached mode:

```
docker container run --name db1 -v db:/var/lib/postgresql/data -e
POSTGRES_PASSWORD=password -d postgres
```

2. Use the `exec` command to interact with the container from `bash`. The `exec` command does not create a new process but rather replaces `bash` with the command to be executed. Here, the prompt will change to `postgres=#` to indicate that you are inside the `db1` container:

```
docker container exec -it db1 psql -U postgres
```

The `psql` command allows you to interactively enter, edit, and execute SQL commands. The `-U` option is used to enter the database's username, which is `postgres`.

3. Create a table, `PEOPLE`, with two columns -- `Name` and `age`:

```
CREATE TABLE PEOPLE(NAME TEXT, AGE int);
```

4. Insert some values into the `PEOPLE` table:

```
INSERT INTO PEOPLE VALUES ('ENGY', '41');
INSERT INTO PEOPLE VALUES ('AREEJ', '12');
```

5. Verify that the values are inserted correctly in the table:

```
SELECT * FROM PEOPLE;
```

The command will return two rows, which verifies that the data has been inserted correctly:

```
postgres=# SELECT * FROM PEOPLE;
 name | age
-----+-----
 ENGY |  41
 AREEJ |  12
(2 rows)
```

6. Exit the container to quit the database. The shell prompt will return:

```
\q
```

7. Verify that your volume is a named one and not anonymous using the `volume ls` command:

```
docker volume ls
```

You should get an output like the following:

DRIVER	VOLUME NAME
Local	db

8. Remove the `db1` container with the `-v` option:

```
docker container rm -fv db1
```

The command will return the name of the container:

```
db1
```

9. List the volumes:

```
docker volume ls
```

The list shows that the volume is still there and is not removed with the container:

DRIVER	VOLUME NAME
Local	db

10. As in *step 1*, create a new container called `db2` and mount the volume, `db` :

```
docker container run --name db2 -v db:/var/lib/postgresql/data -e  
POSTGRES_PASSWORD=password -d postgres
```

11. Run the `exec` command to execute the commands from `bash` and verify that the data persists even when `db1` is removed:

```
docker container exec -it db2 psql -U postgres  
  
postgres=# SELECT * FROM PEOPLE;
```

The preceding commands will result in an output like the following:

```
postgres=# SELECT * FROM PEOPLE;  
 name | age  
-----+-----  
 ENGY | 41  
 AREEJ | 12  
(2 rows)
```

12. Exit the container to quit the database:

```
\q
```

13. Now, remove the `db2` container using the following command:

```
docker container rm -f db2
```

The command will return the name of the container:

```
db2
```

14. Remove the `db` volume using the following command:

```
docker volume rm db
```

The command will return the name of the volume:

```
db
```

In this exercise, you used a named volume to save your database to keep the data persistent. You saw that the data persisted even after you removed the container. The new container was able to catch up and access the data that you saved in your database.

In the next exercise, you will run a PostgreSQL database without a volume to compare its effect with that of the previous exercise.

Exercise 7.08: Running a PostgreSQL Container without a Volume

In this exercise, you will run a default PostgreSQL container without a database volume. You will then remove the container and its anonymous volume to check whether the data persisted after the removal of the container:

1. Run a PostgreSQL container without a volume. Name the container `db1` :

```
docker container run --name db1 -e POSTGRES_PASSWORD=password -d postgres
```

2. Run the `exec` command to execute the commands from `bash` . The prompt will change to `postgres=#` to indicate that you are inside the `db1` container:

```
docker container exec -it db1 psql -U postgres
```

3. Create a table, `PEOPLE` , with two columns -- `NAME` and `AGE` :

```
CREATE TABLE PEOPLE(NAME TEXT, AGE int);
```

4. Insert some values in the `PEOPLE` table:

```
INSERT INTO PEOPLE VALUES ('ENGY', '41');  
INSERT INTO PEOPLE VALUES ('AREEJ', '12');
```

5. Verify that the values are inserted correctly in the table:

```
SELECT * FROM PEOPLE;
```

The command will return two rows, which verifies that the data is inserted correctly:

```
postgres=# SELECT * FROM PEOPLE;  
name  | age  
-----+-----  
ENGY   | 41  
AREEJ  | 12  
(2 rows)
```

6. Exit the container to quit the database. The shell prompt will return:

```
\q
```

7. List the volumes using the following command:

```
docker volume ls
```

Docker has created an anonymous volume for the `db1` container, as evident from the following output:

DRIVER	VOLUME NAME
Local	6fd85fbb83aa8e2169979c99d580daf2888477c654c62284cea15f2fc62a42c32

8. Remove the container with its anonymous volume using the following command:

```
docker container rm -fv db1
```

The command will return the name of the container:

```
db1
```

9. List the volumes using the `docker volume ls` command to verify that the volume is removed:

```
docker volume ls
```

You will observe that the list is empty:

DRIVER	VOLUME NAME
--------	-------------

As opposed to the previous exercise, this exercise used an anonymous volume rather than a named one. Thus, the volume was within the container's scope and was removed from the container.

We can therefore conclude that the best practice is to share the database on a named volume to ensure that the data saved in the database will persist and outlive the container's life.

Up to now, you have learned how to list the volumes and inspect them. But there are other more powerful commands to get the information about your system and Docker objects, including the volumes. These will be the subject of the next section.

Miscellaneous Useful Docker Commands

A lot of commands can be used to troubleshoot and inspect your system, some of which are described as follows:

- Use the `docker system df` command to find out the size of all the Docker objects in your system:

```
docker system df
```

As shown in the following output, the number of images, containers, and volumes are listed with their sizes:

TYPE	TOTAL	ACTIVE	SIZE	RECLAIMABLE
Images	6	2	1.261GB	47.9MB (75%)
Containers	11	2	27.78MB	27.78MB (99%)
Local Volumes	2	2	83.26MB	0B (0%)
Build Cache			0B	0B

- You can get more detailed information about the Docker objects by adding the `-v` option to the `docker system df` command:

```
docker system df -v
```

It should return an output like the following:

Images space usage:							
REPOSITORY	TAG	IMAGE ID	CREATED	SIZE	SHARED SIZE	UNIQUE SIZE	CONTAINERS
ankidemon/hit_counter	latest	9ab3d6d78623	10 hours ago	234.7MB	88.31MB	154.4MB	0
python	alpine	8cf3965d8456	42 hours ago	88.31MB	88.31MB	0B	0
jenkinsci/blueocean	latest	97e7fd2ffbef	2 weeks ago	561.9MB	0B	561.9MB	0
sonargube	latest	ce76b6b9372a	2 weeks ago	460.9MB	5.612MB	455.3MB	0
<none>	<none>	b166e1572623	3 weeks ago	90.44MB	5.572MB	84.87MB	0
opnshift/origin-control-plane	v3.11	871070b4e04c	3 weeks ago	832.7MB	236.6MB	596.1MB	0
opnshift/origin-hyperkube	v3.11	b5a6889ed0ec	3 weeks ago	509.9MB	236.6MB	273.3MB	0
opnshift/origin-hypershift	v3.11	ee52ebaa8e03	3 weeks ago	550.4MB	226.6MB	313.8MB	0
opnshift/origin-haproxy-router	v3.11	55c25a5f52d	6 weeks ago	411.7MB	384.2MB	27.50MB	0
opnshift/origin-node	v3.11	7c5749f6569d	6 weeks ago	1.19GB	832.7MB	356.9MB	0
<none>	<none>	16e9eae7d18	6 weeks ago	832.7MB	832.7MB	0B	0
opnshift/origin-deployer	v3.11	915486d3e368	6 weeks ago	304.2MB	384.2MB	0B	0
<none>	<none>	f5ee81e01f9a	6 weeks ago	550.4MB	236.6MB	313.8MB	0
<none>	<none>	d1d99ae3c375	6 weeks ago	509.9MB	236.6MB	273.3MB	0
opnshift/origin-cli	v3.11	db843dc34dfc	6 weeks ago	384.2MB	384.2MB	0B	0
opnshift/origin-pod	v3.11	9babafef5cd0	6 weeks ago	262.1MB	236.6MB	25.55MB	0
nginx	latest	2622ebcca/eb	7 weeks ago	132.1MB	0B	132.1MB	0
<none>	<none>	53541024b053	2 months ago	919MB	919MB	0B	0
python	3.7	5c996c5d7c99	2 months ago	919MB	919MB	0B	0
postgres	latest	acff2b126dda8	2 months ago	313MB	69.21MB	243.8MB	0
mysql	5.7	b8468d0ba7db	2 months ago	448.1MB	69.21MB	378.9MB	0
packworkshops/the-docker-workshop	chapter3-pta-web	48332e89a9fb	2 months ago	1.01GB	0B	1.01GB	0
swarmpt/install	1.8	0c92a03c8f86	3 months ago	252.5MB	5.612MB	246.9MB	0
covid-tracker	0.0.1-SNAPSHOT	9f2fc5938b3b	3 months ago	683.4MB	643MB	40.48MB	0
golang	1.12.10-alpine	6e420771795	3 months ago	359.0MB	5.612MB	354MB	0
packworkshops/the-docker-workshop	chapter3-pta-nginx	9a177d62f436	5 months ago	21.2MB	0B	21.2MB	0
wordpress	latest	126aa08ecc0c	5 months ago	539.5MB	0B	539.5MB	0
mysql	latest	c8ad2be0a22	5 months ago	465.4MB	0B	465.4MB	0
lucasalbert/curl	7.67.0-r0	6ec97a0a086a	6 months ago	6.942MB	0B	6.942MB	0
busybox	latest	6c3fcef5ff17	7 months ago	1.22MB	0B	1.22MB	0
ubuntu	14.04	6e4f1fe22ff1	7 months ago	196.5MB	0B	196.5MB	2
opnshift/origin-docker-registry	v3.11	9cf42abdf1ad	10 months ago	310.1MB	0B	310.1MB	0
opnshift/origin-web-console	v3.11	be30b6cce5fa	21 months ago	338.6MB	230.1MB	108.5MB	0
opnshift/origin-service-serving-cert-signer	v3.11	47dadf9d43b6	21 months ago	275.6MB	230.1MB	45.57MB	0
rustashp/ubutu-sshd	14.04	7e5f6d3cf120	2 years ago	286.1MB	0B	286.1MB	0
openjdk	8u121-jdk	9766c638ee8e	3 years ago	643MB	643MB	0B	0
Containers space usage:							
CONTAINER ID	IMAGE	COMMAND	LOCAL VOLUMES	SIZE	CREATED	STATUS	NAMES
02484c96876c	ubuntu:14.04	"/bin/bash"	0	16.8MB	30 minutes ago	Exited (0) 13 minutes ago	testsize
a94730fe1999	ubuntu:14.04	"tine"	0	0B	31 minutes ago	Created	testcreate

- Run the `docker volume ls` subcommand to list all the volumes that you have on your system:

```
docker volume ls
```

Copy the name of the volume so that it can be used to get the name of the container that uses it:

DRIVER	VOLUME NAME
local	a7675380798d169d4d969e133f9c3c8ac17e733239330397ed
	ba9e0bc05e509fc
local	db

Then, run the `docker ps -a --filter volume=<Volume Name>` command to get the name of the container that is using the volume:

```
docker ps -a --filter volume=db
```

So far, we have been sharing volumes between containers and the Docker host. This sharing type is not the only type available in Docker. You can also share volumes between containers. Let's see how to do that in the next section.

Exercise 7.09: Sharing Volumes between Containers

Sometimes, you need a data container to share data between various containers, each running a different operating system. It is useful to test the same data across different platforms before sending the data to production. In this exercise, you will use the data container, which will share volumes between containers using `--volume-from`:

- Create a container, `c1`, with a volume, `newvol`, that is not shared with the host:

```
docker container run -v /newvol --name c1 -it ubuntu:14.04 bash
```

- Move to the `newvol` volume:

```
cd newvol/
```

3. Save a file inside this volume:

```
echo hello > /newvol/file1.txt
```

4. Press the escape sequences, *CTRL + P* and then *CTRL + Q*, so that the container runs in a detached mode in the background.
5. Create a second container, `c2`, that mounts the `c1` container's volume using the `--volumes-from` option:

```
docker container run --name c2 --volumes-from c1 -it ubuntu:14.04 bash
```

6. Verify that `c2` can access `file1.txt`, which you saved from `c1`, using the `ls` command:

```
cd newvol/  
ls
```

7. Add another file, `file2.txt`, inside `c2`:

```
echo hello2 > /newvol/file2.txt
```

8. Verify that `c2` can access `file1.txt` and `file2.txt`, which you saved from `c1`, using the `ls` command:

```
ls
```

You will see that both the files are listed:

```
file1.txt  file2.txt
```

9. Attach the local standard input, output, and error streams to `c1`:

```
docker attach c1
```

10. Check that `c1` can access the two files using the `ls` command:

```
ls
```

You will see that both the files are listed:

```
file1.txt  file2.txt
```

11. Exit `c1` using the following command:

```
exit
```

12. List the volumes using the following command:

```
docker volume ls
```

You will observe that the volume still exists even when you have exited `c1`:

DRIVER	VOLUME NAME
local	2d438bd751d5b7ec078e9ff84a11dbc1f11d05ed0f82257c4e8004ecc5d93350

13. Remove `c1` with the `-v` option:

```
docker container rm -v c1
```

14. List the volumes again:

```
docker volume ls
```

You will find that the volume has not been removed with `c1` because `c2` is still using it:

DRIVER	VOLUME NAME
local	2d438bd751d5b7ec078e9ff84a11dbc1f11d05ed0f82257c4e8004ecc5d93350

15. Now, remove `c2` with the `-v` option to remove its volumes as well. You must use the `-f` option as well to force-remove the container because it is up and running:

```
docker container rm -fv c2
```

16. List the volumes again:

```
docker volume ls
```

You will find that the volume list is empty now:

DRIVER	VOLUME NAME
--------	-------------

This verifies that the ephemeral volumes are removed when all the containers using the volumes are removed.

In this exercise, you used the `--volumes-from` option to share volumes between containers. Also, this exercise demonstrated that the best practice is to always remove the container with the `-v` option. Docker will not remove the volume as long as there is at least one container that is using that volume.

If we committed any of these two containers, `c1` or `c2`, to a new image, the data saved on the shared volume still will not be uploaded to that new image. The data on any volume, even if the volume is shared between a container and host, will not be uploaded to the new image.

In the next section, we will see how to engrave this data into the newly committed image using the filesystem, rather than volumes.

Volumes versus Filesystem and Images

Note that volumes are not part of images, so the data saved on volumes won't be uploaded or downloaded with images. The volumes will be engraved in the image, but not its data. Therefore, if you want to save certain data in an image, save it as a file, not as a volume.

The next exercise will demonstrate and clarify the different outputs between saving data on volumes and when saving it on files.

Exercise 7.10: Saving a File on a Volume and Committing It to a New Image

In this exercise, you will run a container with a volume, save some data on the volume, commit the container to a new image, and craft a new container based on this new image. When you check the data from inside the container, you will not find it. The data will be lost. This exercise will demonstrate how the data will be lost when committing the container to a new image. Remember that the data on the volumes will not be engraved in the new image:

1. Create a new container with a volume:

```
docker container run --name c1 -v /newvol -it ubuntu:14.04 bash
```

2. Save a file inside this volume:

```
echo hello > /newvol/file.txt  
cd newvol
```

3. Navigate to the `newvol` volume:

```
cd newvol
```

4. Verify that `c1` can access `file.txt` using the `ls` command:

```
ls
```

You will see that the file is listed:

```
file.txt
```

5. View the content of the file using the `cat` command:

```
cat file.txt
```

This will result in the following output:

```
hello
```

6. Exit from the container using the following command:

```
exit
```

7. Commit this container to a new image called `newimage` :

```
docker container commit c1 newimage
```

8. Inspect the image to verify that the volume is engraved inside it:

```
docker image inspect newimage --format={{.ContainerConfig.Volumes}}
```

This will result in the following output:

```
map[/newvol:{}]
```

9. Craft a container based on the `newimage` image that you just created:

```
docker container run -it newimage
```

10. Navigate to `newvol` and list the files in the volume and its data. You will find that the file and the word `hello` were not saved in the image:

```
cd newvol
ls
```

11. Exit the container using the following command:

```
exit
```

From this exercise, you learned that the data on a volume is not uploaded to the image. To solve this issue, use the filesystem instead of a volume.

Assume that the word `hello` is important data we want to be saved in `file.txt` inside the image so that we can access it when we craft a container from this image. You will see how to do that in the next exercise.

Exercise 7.11: Saving a File in the New Image Filesystem

In this exercise, you will use the filesystem instead of a volume. You will create a directory instead of a volume and save the data in this new directory. Then, you will commit the container to a new image. When you craft a new container using this image as its base image, you will find the directory in the container and the data saved in it:

1. Remove any container that you might have from previous labs. You can concatenate several Docker commands to each other:

```
docker container rm -f $(docker container ls -aq)
```

Note: Above command should be run in `git bash` only. It will not work in `cmd/powershell`.

The command will return the IDs of the containers that will be removed.

2. Create a new container without a volume:

```
docker container run --name c1 -it ubuntu:14.04 bash
```

3. Create a folder named `new` using the `mkdir` command and open it using the `cd` command:

```
mkdir new
cd new
```

4. Navigate to the `new` directory and save the word `hello` in a new file called `file.txt`:

```
echo hello > file.txt
```

5. View the content of the file using the following command:

```
cat file.txt
```

The command should return `hello`:

```
hello
```

6. Exit `c1` using the following command:

```
exit
```

7. Commit this container to a new image called `newimage` :

```
docker container commit c1 newimage
```

8. Craft a container based on the `newimage` image that you just created:

```
docker container run -it newimage
```

9. List the files using the `ls` command:

```
ls
```

10. Navigate to the `new` directory and verify that the container can access `file.txt` using the `ls` command:

```
cd new/  
ls
```

You will see that the file is listed:

```
file.txt
```

11. Use the `cat` command to display the contents of `file.txt` :

```
cat file.txt
```

It will show that the word `hello` is saved:

```
hello
```

12. Exit from the container using the following command:

```
exit
```

In this exercise, you saw that data is uploaded to the image when the filesystem is used, compared to the situation we saw when data was saved on volumes.

Summary

This lab covered the life cycle of Docker containers and various events. It compared stateful and stateless applications and how each one saves its data. If we need the data to be persistent, we should use volumes. The lab covered the creation and management of a volume. It further discussed the different types of volumes, as well as the difference between the usage of volumes and the filesystem, and how the data in both is affected when the container is committed to a new image.