

CMPSC 100-03 Lab Session 1: Docker & Unix

- Assigned: 2 September 2019
- Due: 9 September 2019, by 11:59 PM
- Point value: 30 pts

In this laboratory session, we concentrate our efforts on in-depth learning about how Docker & Unix (Ubuntu "flavor") work. We explore (in a partially particular order):

- Building Docker files
- Running Docker files
- Adventures in Unix
- Commands such as: `cd`, `ls`, `pwd`, `mv`, `rm`, `mkdir`
- Traversing directories
- Reading files
- ...& more!

General guidelines for laboratory sessions

- **Follow steps carefully.** Laboratory sessions often get a bit more complicated than their preceding Practical sessions. Especially for early sessions which expose you to platforms with which you may not be familiar, take notes on commands you run and their corresponding effects/outputs. If you find yourself stuck on a step, let a TL or the professor know! Laboratory sessions do not mean that we won't help you in the same way we do during Practicals.
- **Regularly ask and answer questions.** Some of you may have more experience with the topics we're discussing than others. We can use this knowledge to our advantage. But, like in Practicals, let students try things for a while before offering help (**always offer first**). To ask questions, use our Slack (<https://cmpsc100fall2019.slack.com>)'s #1abs channel.
- **Store and transfer files using GitHub.** Various forms of file storage are more or less volatile. *You* are responsible for backing up and storing files. If you're unsure of files which have been changed, you can always type `git status` in the terminal for your working folder to determine what you need to back up.
- **Keep all of your files.** See above, but also remember that you're responsible for the files you create.
- **Back up your files regularly.** See above (& above-above).
- **Review the Honor Code** (<https://sites.allegcheny.edu/about/honor-code/>) **regularly when working.** If you're taking a solution from another student or the Internet at-large (*especially* Stack Overflow (<https://stackoverflow.com>)), bear in mind that using these

solutions *can* constitute a form of plagiarism that violates the Allegheny Honor Code. While it may seem easy and convenient to use these sources, it is equally easy and convenient to rely on them and create bad habits which include not attributing credit or relying exclusively on others to solve issues. Neither are productive uses of your intellect. Really.

Further helpful reading for this assignment

If you have not already done so, I recommend reading the GitHub Guides (<https://guides.github.com>) which GitHub makes available. In particular, the guides:

- Mastering markdown (<https://guides.github.com/features/mastering-markdown/>)
- Documenting your projects on GitHub (<https://guides.github.com/features/wikis/>)
- GitHub Handbook (<https://guides.github.com/introduction/git-handbook/>)

In addition, you may find a cheatsheet for Unix commands helpful throughout your time here. I recommend this one (<https://files.fooswire.com/2007/08/fwunixref.pdf>) from FOSSwire. You may not need all of these in this course, but someday I guarantee you'll have to do something obscure in Unix. This sheet, of course, is only a start to the many, many different strange (& often accidental) combinations that you can make with commands and "piping."

As for a markdown cheatsheet, this GitHub repository (<https://github.com/adam-p/markdown-here/wiki/Markdown-Cheatsheet>) serves as a useful guide.

If you find either helpful, I suggest bookmarking them.

Table of Contents

- A deeper dive into Docker
 - Running a container
- First foray into Unix
 - The Unix prompt
 - Basic commands
 - Working inside a container
- Second foray into Unix
 - Building another image
 - Working with mounted drives
- Meowtown: a Docker game
- Finishing & reflecting on the activity

Your assignment

Broadly this sessions goals are:

- To learn how to build and run Docker containers from "images"
- To learn how to work with GitHub & GitHub Classroom
- To discover basic operations in the Unix operating system (OS)
- To help Prof. Luman find his cat

Beginning the assignment

Accepting the assignment

- ☐ Log into the #1abs channel in our class Slack (<https://cmpsc100fall2019.slack.com>)
- ☐ Click the link provided for the lab assignment and accept it in GitHub classroom
- ☐ Once the assignment finishes building, click the link for your personal repository assignment

Cloning the repository

Getting the right download link

- ☐ On the resulting repository's page, click the Clone or download button
- ☐ In the upper right corner of the box that appears, click Use SSH
- ☐ Copy the link that appears in the textbox below the phrase "Use a password with a protected key."
- ☐ Open a terminal window using:
 - Your operating system's native terminal (Mac OS & Unix)
 - Git Bash (Windows)
 - Git Bash is located in the "Start" menu under the "Git" entry.

Adding your SSH key

- ☐ In the terminal window, type `eval "$(ssh-agent -s)"`
- This starts a process called ssh-agent. The -s flag starts it "silently."
- ☐ Next, type `ssh-add ~/.ssh/id_Rsa`
- You will need to supply the password that you created in the practical for this SSH key.

Cloning

- ☐ Type `cd ~` to go to your home directory, or choose an easily-accessible, memorable location
- ☐ In the terminal window clone the repository
- If I (the instructor) were to clone my own repository, I'd enter:

```
git clone git@github.com:allegheny-college-cmpsc-100-fall-2019/cmpsc-fall-2019-lab-01-dluman
```

- ☐ Once finished, cd to the directory where the repository was cloned

A deeper dive into Docker



Docker relies on three (3) fundamental object types:

- images
- The Dockerfile
- containers

In general terms the relationship between the three is described as: Dockerfile -> image -> container

images

This is an image:

The Boss

But, it's not what we mean when we say image when we talk about Docker.

The term image, in this context, refers to a "snapshot" of a computer's *secondary memory*. The complete picture of everything on your computer *right now* could constitute an image. In fact, we *could* build a image of your computer and install it on someone else's, effectively creating a copy of your entire file system.

Docker uses the term image to describe the product of a "snapshot" of a virtual system, and is created by a Dockerfile.

The Dockerfile

These files contain commands which help build an image. They can be simple or complex, depending on what a user needs a container to do. General practice for using containers is to pack "light," or only include the *absolute minimum* necessary to perform a specific operation or run a specific program. The following is an example of a Dockerfile that builds a simple Unix container:

```
FROM ubuntu
```

Here, ubuntu is what is referred to as a *base image*, or the minimum possible configuration for starting a commonly-used resource--in this case, the Unix distribution named "Ubuntu" (the same Unix "flavor" that we will use in this course). We will use two Dockerfiles using this image later in this exercise.

You will not need to build any images from scratch in this course.

containers

A container is simply an image that is *currently running*. This is the product of a Docker command (run) that we will also look at below. For now, the relationship between a Docker image,

Dockerfile, and a container is all we need to know. However, I recommend exploring Docker functionality on your own time to enhance your understanding.

Running a container

In this part of the exercise, we will run the Ubuntu *base image*.

Docker Desktop users

- [] Open a terminal window

Docker Toolbox users

- [] Open the "Docker Quickstart Terminal"
- When this lab assignment uses the word `terminal`, it is interchangeable with the Docker Quickstart Terminal

Base images

- [] In your terminal window, type `docker image`
- Make a note of what you see; what does this list display?
- Are there any items there? Where did they come from (think back to the last Practical)?

We need to acquire the "Ubuntu" *base image* so that we can begin our work. We will use the `pull` command.

- [] In the terminal, type `docker pull ubuntu` and press Enter

Docker will always look *locally* (that is, on your computer) for images first. If it does not find any with the name specified (here `ubuntu`), it will look at a common location known as "Docker Hub" (in the cloud) and download the matching name. You will see something like the following:

```
➤ Using default tag: latest
latest: Pulling from library/ubuntu
Digest: sha256:d1d454df0f579c6be4d8161d227462d69e163a8ff9d20a847533989cf0c94d90
Status: Downloaded newer image for ubuntu:latest
```

- [] Type `docker image` again and press Enter
- What appears in the terminal now?

These images are available to you wherever you're working on your system and can use Docker.

Making a container

To turn the `ubuntu` image into a container, we need to use the `docker run` command. But, before you do, we need to review a bit about how commands work.

commands & flags

In this assignment, we've already used some commands and programs.

- [] Which have been programs and which have been commands?
- Hint: docker is a program.

Many commands feature options referred to as flags. These are usually prefixed by a single dash (-) or double dash (--). - flags generally represent "shortcuts," and -- flags are the direct, generally longer, names. Not all flags have both - and -- prefix versions, though. This is a program-by-program preference/issue.

For future reference and help, both programs and commands generally contain a --help or -help flag. Try it now:

- [] In the terminal, type `docker --help`.
- What does this list (are they programs, commands, or flags)?
- [] In the terminal type `docker run --help`.
- What appears here (programs, commands, or flags)?

We will revisit this conversation as we explore Unix further today.

The container

- [] In a your terminal window, type `docker run -it ubuntu` and press Enter
- What are -i and -t (programs, commands, or flags)?
 - -i initiates what is called an "interactive" session (using something called STDIN to allow you to type in the container)
 - -t begins a TTY (literally, "talk to yourself") session which displays what the operating system "says" back to you (something called STDOUT)
 - When supplying two (2) flags to a command, generally we can combine them unless we have more specific instructions for each flag.
- What happened when the command & flags executed? What displays in the screen?
- [] Type `docker images` in the terminal window and press Enter`
- What happens? Why?
 - Hint: are you still interacting with *your* computer or something else?

First foray into Unix

As if magic (but it really is magic), you have been transported into a Unix operating system session on your computer which *runs a completely different operating system*. Think of this like the "picture-in-picture" feature on a TV; yes, you can watch two "channels" at once. You are inside a running container which "boots" directly to a command prompt.

Unlike a terminal session, which may allow some of the same commands, this is a fully-fledged Unix system. However, thinking back to the brief discussion of the purpose of images and containers above, it's *extremely minimal*. Not everything is available. But, let's explore what we can do.

The Unix prompt

You should see something similar to the following:

```
root@0659308ad943: /#
```

This is the Unix command prompt in "bash" format. This format display the user name, an @ symbol, the machine's "host name," followed by colon and the current working directory in which the operating system is mounted, or accessed.

- What is the user?
- What is the host name?

First I must caution you, young Jedi: with great power, great responsibility.

In this container you have assumed the magical guise of a user known as **root**. This is a very powerful position. Within reason, as **root**, you can do *anything you want* in a computer system. Be careful, because here you will get the result which match exactly what you asked the system to do, whether it was want you wanted or not. A reminder of this power is that the character which ends the command prompt is an octothorpe # (a.k.a. "pound" or "hash" sign).

Basic commands

Traversing a file system

- [] At the command prompt, type **ls** (short for **list**) and press Enter
- This command displays a listing of files in the current "working directory."
- [] To find the "current working directory," type **pwd** and press Enter
- This command's syntax stands for "**p**ath to **w**orking **d**irectory."
- What displays?

File systems in Unix begin with / characters. The / path represents that this is the **lowest** level. From here, we can access various other file systems. Some here include:

- /bin: The place where basic binaries (Unix programs & commands) live
- /root: The root user's home space
- /home: The directory where other system users can find their home space
- /var: A file system which often contains log files for various programs and processes
- & others

It is not necessary to memorize these for this class except to know that most of the time, you'll want to be working in the /home file system.

- To explore the /bin file system, we need a mechanism for changing directories.
 - If you had to guess, what a short command might we use to **change d**irectories?

- [] Type `cd bin` at the command prompt and press Enter
- How does the command prompt change?
- What does this change reflect?
- [] Type `pwd`
- What displays?
- Is this what you expected?
- [] Type `ls`
- What displays?

Here, you can see a list of all of the commands and basic programs available in this image of the operating system (Ubuntu). In many systems, this directory is quite a bit larger. Here, because the basic principle of containers is to package only what is *necessary* only the most commonly used functions are available.

There are a number of shortcuts that one can use to "traverse" (or, move around) a file system. For example, let's return to the previous level of the file system. To do this:

- [] Type `cd ..` and press Enter
- What did this command do?
- The `..` (the value we entered) is referred to as a parameter or value

We can go forward only if we know exactly where we want to go:

- [] Type `cd /var/log` and press Enter
- We have traversed the var file system to a depth of 2, here.

However we can go back if we either know:

- The exact location we want to go to, or
- The relative depth of where we are
- [] Type `cd ../../` and press Enter
- [] Type `pwd` and press Enter
- Where are you now?
- What does `../../` represent?

Creating files

- [] Type `ls /bin` and press Enter
- What did this command do?

In the list generated by this `ls` command, you should see a program called `touch`. This program creates files without opening them. Let's create a file in our root user's home directory, `/root`.

- [] Type the command required to get there.
- If you're stuck here, ask a neighbor and then a TL or the professor!
- [] Once in the root file system, type `ls` and press Enter
- What appears?
- Why might the result of this command be what it is?
- [] Type `touch testfile` and press Enter
- [] Type `ls` and press Enter
- What appears now?
- Did the output change? Why?
- [] Type `touch file1 file2 file3 file4` and press Enter
- [] Type `ls` and press Enter
- What was the result of the last two commands?

Making directories

To make a directory in Unix, use the `mkdir` command.

- [] Type `mkdir testdir` and press Enter

You should be able to traverse to this directory now.

- [] Enter the command to change to this new directory.
- How might you do it?
- How do you know you're in the directory?

The `mv` command

Renaming in Unix may seem a little less straight-forward than other operating systems (OS). However other OSs merely orchestrate the same operation that Unix does to make the process appear differently. Essentially, when you're renaming a file in an OS, you're moving it from one memory location to another.

- [] Type `mv testfile testfile.old` and press Enter
- [] Type `ls` and press Enter
- What appears?
- Note: the `cp`, or **copy** command, works the same way! Instead of moving files, it makes a copy.

The `rm` command

To delete a file, Unix uses the command `rm`.

- [] Traverse back to the /root directory.
- [] Type `rm testfile.old` and press Enter
- [] List the contents of the directory

- What happened to your file?
- [] Type `rm testdir` and press Enter
- What happened?

Directories require users to add an additional piece to the `command` to remove directories.

- What is that piece called?
- [] Type the correct `command` to remove the directory
- [] List the directory again
- Is your directory gone?

Exiting a container

To exit a container:

- [] Type `exit` at the command prompt and press Enter
- Where are you now?
- How do you know?

Working inside a container

Now, let's return to our container and work on `file1 - file4`

- [] Re-run the previous container
- See above for the `command`, or, if stuck, as a neighbor, TL, or the professor
- [] Traverse back to the `/root` file system.
- [] List the contents of the directory.

Uh...where's your work?

Oh, you lost it. Good job.

I don't accept the "container ate my homework" excuse. Nice try.

Actually, that was **my** fault. I didn't explain a key concept about containers: they're what we refer to as *transient*. Think back to the previous discussion the class had about *main memory* and its relationship to containers.

- How does this explain what just happened?
- Call a TL or the professor over and discuss your thoughts. Take notes on your discussion.
- [] `exit` the container

Second foray into Unix

For this adventure, we're going to access a `Dockerfile` written specifically for this class session. If you were to open the file in your text editor, you'd see quite a few different instructions written so that Docker can build a more specific image.

In your computer's terminal (be careful that you're not still in a container, if so: `exit`):

- [] Ensure that you're back in the main directory where you cloned the repository
- Protip: in Unix and Unix-like terminals, if you write **part** of the title of the folder or file you'd like to access, hitting the `Tab` key often completes it at the prompt. Try it. If you have difficulties call a TL or the professor over to demonstrate.
- [] Change directories to the `1-ubuntu-explore` folder.
- [] In this folder, type `docker build . -t ubuntu-explore`
- This command uses a parameter and a flag.
 - The `-t` flag for the `build` command is different than that of the `run` command. Here, `-t` means "tag," which labels the image for easy access.
 - The `.` tells Docker to build the `Dockerfile` at the current working directory's "absolute" path. To find the absolute path type `pwd` at your terminal and press `Enter`.

Building another image

Once the process completes, you should have a new image titled ("tagged") "ubuntu-explore."

We're going to add another flag to this Docker instance to avoid the issue we just had when we attempted to access a container and found all of our files gone.

- [] At your terminal prompt, type:

```
❏ docker run -it --mount type=bind,source="$(pwd)",target=/home/cmpsc100/mount  
--hostname ubuntu-explore ubuntu-explore
```

Here we added two flags with several parameters. Let's break them down:

--mount

Like any computer, users have to attach *secondary memory* to store files in a semi-permanent manner. The last example disposed of all of the files because containers load into *main memory* only. Here, we're attaching (mounting) our hard drive's current working directory to the container so that we're saving our work.

The parameters we've added include:

- `type=bind`
 - This creates a "bi-directional" connection to your local computer's *secondary memory*. This is a read-write connection, meaning that any changes we make in

the container are written and saved to **your** machine. `*source=$(pwd)`

- This is a bit of a magic trick. Here, we use `$(...)` to leverage the output of the `pwd` command so that we don't have to worry about knowing *exactly* where we are. This is the place that files written while in the container will end up.
- Protip: the `$(...)` structure works for a ton of commands. Looking up how others use it will open up a world of Unix command prompt wizardry to you.
`*target=/home/cmpsc100`
- Again: MAGIC! As part of the `Dockerfile` I created, there's a `/home/` directory where we'd like to work with and save items. This is the place *in the container* where any files in the current working directory `$(pwd)`

--hostname

To avoid the word salad that is a general container's name (I for one don't know what `f9f90b2f4cf1` means, for example) we can provide a name to the container at what we refer to as "runtime." Here, we've chosen `ubuntu-explore`, but it really could be *anything*.

- Note: for the remainder of this lab, the document will refer to the general ideas of commands rather than the commands themselves. If introducing new content, it will be described and specified.

Working with mounted drives

You should now be in your brand new, shiny container.

- What user are you now?
 - How do you know?
- Did you start in a different directory?
 - How do you know that, too?
- What else is different about the command prompt?
- [] Determine where you are, and what the directory's contents are.
- It looks like there's something there, and it's very important...let's inspect.
- [] Traverse to the new directory
- [] List the directory's contents

Let's peek into some files to see what they contain.

- [] Type `less all.csv`
- `less` is a quick way to view the contents of a file.
 - To scroll up and down, use the `Page Up` and `Page Down` keys.
 - To exit `less` hit the `q` key.
 - If you get stuck in `less` (which is possible) let a TL or the professor know.

It looks like someone has shipped us some very important data in this container, and we want

to save it. Thankfully, *we mounted our drive, and can move it all to a safe place!*

But! The Gator Wizard is upset. He sees that there are CSV files in this directory and thinks that the extension stands for "Crocodile Save Version!" He wants us to cast a spell to **delete** them!

Thankfully, we have a handy trick to do that.

- [] In the terminal window, type `rm *.csv`
- This leverages the `*` character, a "wildcard" which allows us to specify deletion for any file with the extension `*.csv`
- [] To move all of the files to our mounted drive, in the terminal type `mv *.txt ../mount`
- This command:
 - Traverses one directory level **lower**
 - Enters and moves files to the `mount` directory--the directory connected to our local drive
- For those looking for a shortcut, the `~` is useful convention in Unix. It represents the user's `/home/` directory.
 - At any time, you can `cd ~` to return to `/home/cmpsc100` or
 - `mv` items to `~/mount`

To test this (**on your local machine, leaving your container running in the terminal**):

- [] Open the `1-ubuntu-explore` folder
- [] Check that the contents are there

Test **in the container**:

- [] Traverse to the `mount` directory
- [] List the directory's contents.

Once you've verified that the transaction has taken place:

- [] `exit` the container

Meowtown: a Docker Game

This game involves everything you've learned so far in this lab exercise, which includes:

- Building images
- Running containers
- Basic Unix skills
- Using Unix commands to:

- Traverse file systems
- Manipulate files

The goal of this game is to find Prof. Luman's cat wherever it lives in your container's file system! This is randomly generated on each build, so no two users' experiences will be the same.

- At any time, type `rules` in the terminal to display the message given at container start-up

Back on your local machine:

- [] Traverse to the `2-meowtown` directory.
- [] build the Docker image, and tag it `meowtown`
- [] run the container:
- binding your local machine's drive current working directory to the `/home/cmpsc100/mount` directory
- Setting the `hostname` to `"meowtown"`
- Refer to the sections on mounting, bind, source, target, and hostname above.
- As always, if you're stuck, ask a neighbor, TL, or the professor!

Rules

This game involves moving through directories and copying or moving or copying files.

- There are several pictures of my cat, Ulysses, scattered among the various directories in the image.
- Your job is to find them all and copy them to the `/home/cmpsc100/mount` OR `~/mount` (samed place) directory.
- When you are finished, type `done` at the command prompt to finish the game.
- Hints:
 - In the container, type `answers` at the command prompt to check how many pictures of Ulysses there are.
 - At any time, typing `done` at the command prompt will update you on your progress.

When finished:

- Where did all of the files end up?
 - You may need to look through all of the directories in the repository.
- A file titled `"Answers"` should be in the folder as well.
 - In a text editor, add a line at the bottom reading: `Prof. Luman, I found Ulysses.` and save the file.

Finishing & reflecting on the activity

Now that you have completed the first lab, there are two items remaining on your checklist to receive credit (using your local machine, not a container):

- To write a reflection on your experience (using Atom (<https://atom.io>), or another text editor)
- To commit your working repository to GitHub

Write a reflection

- [] In the main folder of the repository, create a file named `reflection.md`
- [] Using markdown (see resources above), write a reflection on difficulties, successes, joys, frustrations of the lab experience in addition to answering:
 - Given your experience with this assignment, how would you describe the relationship of Dockerfiles, containers, and images in your own words?
 - About what points do you still have questions?

Commit your repository

For the following tasks, you will need to use a terminal.

- [] In the main folder of the repository (`cmpsc-100-fall-2019-lab-01`) type:

```
❏ git add .
```

- This command searches the directory for anything you've changed or added and "stages" them for transmission to GitHub.
- [] Then, type:

```
❏ git commit -m "{DESCRIPTIVE COMMIT MESSAGE HERE}"
```

- This adds a message to your commit detailing what you've change **or** the purpose of the commit (e.g. "Turning in the assignment.")
- [] Finally, type:

```
❏ git push origin master
```

- This will send all of your files to the GitHub repository for your version of the assignment.

After the commit, the additional files should appear on the page for your repository.