Efficient distribution of processes over the network

Containerization with Docker

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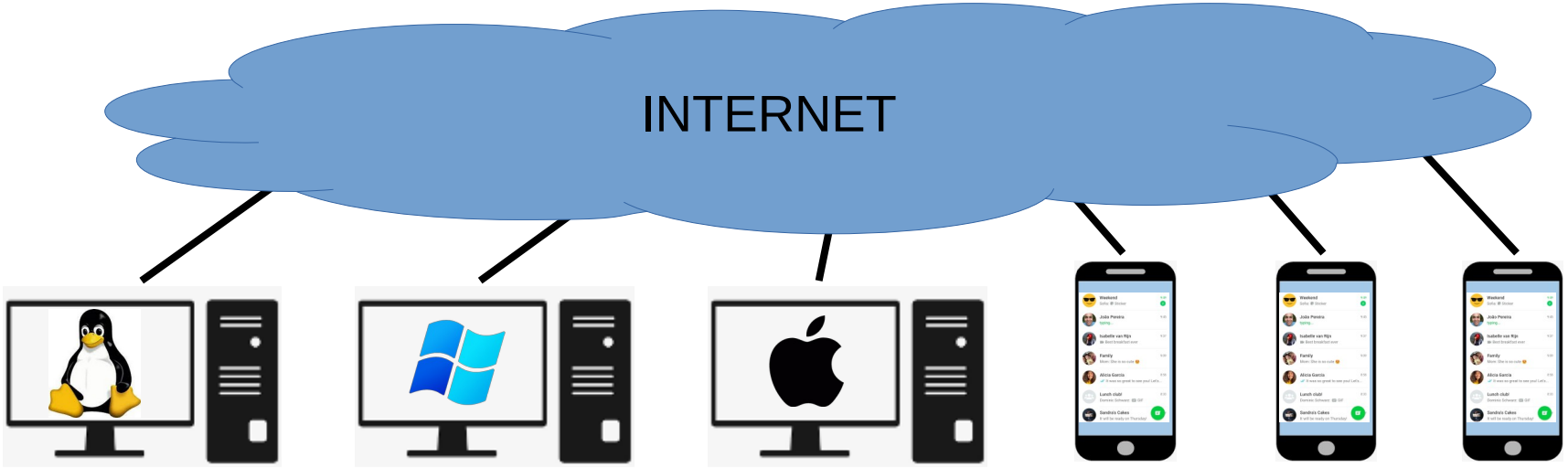
Motivation 1

Hosts are always connected through the network which simplifies the distribution of software.

How to adapt to the heterogeneity of library versions, operating systems and CPUs?

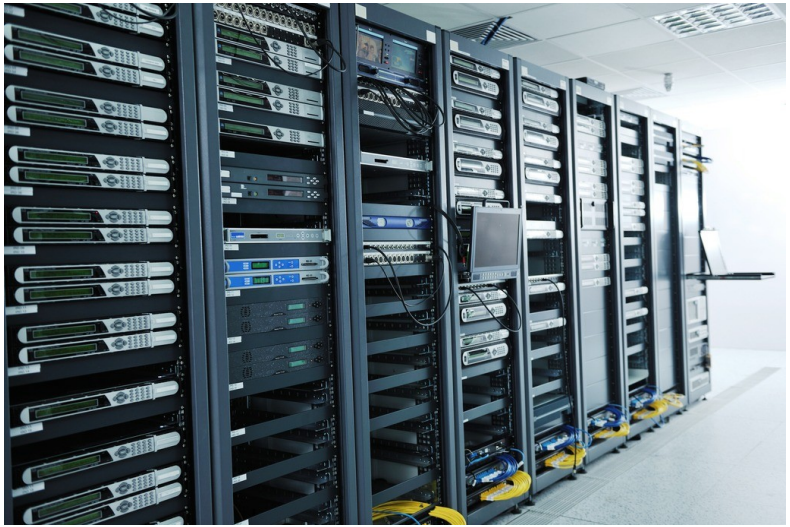


Motivation 2

Well-known network applications are not hosted in isolated computers, but rather in:

- **Clusters**: groups of tens of computers connected by a high-performance LAN
- **Data centers**: groups of thousands of computers connected by a hierarchical set of high-performance LANs

cluster

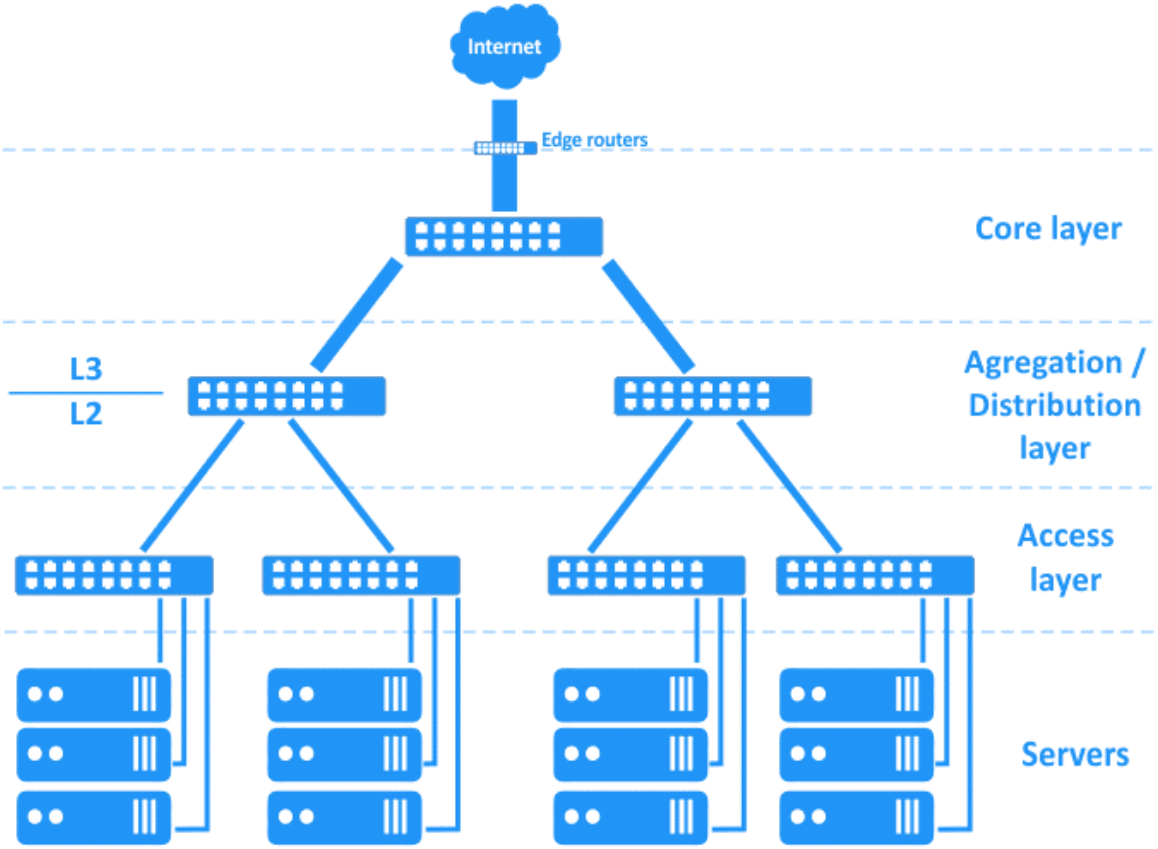


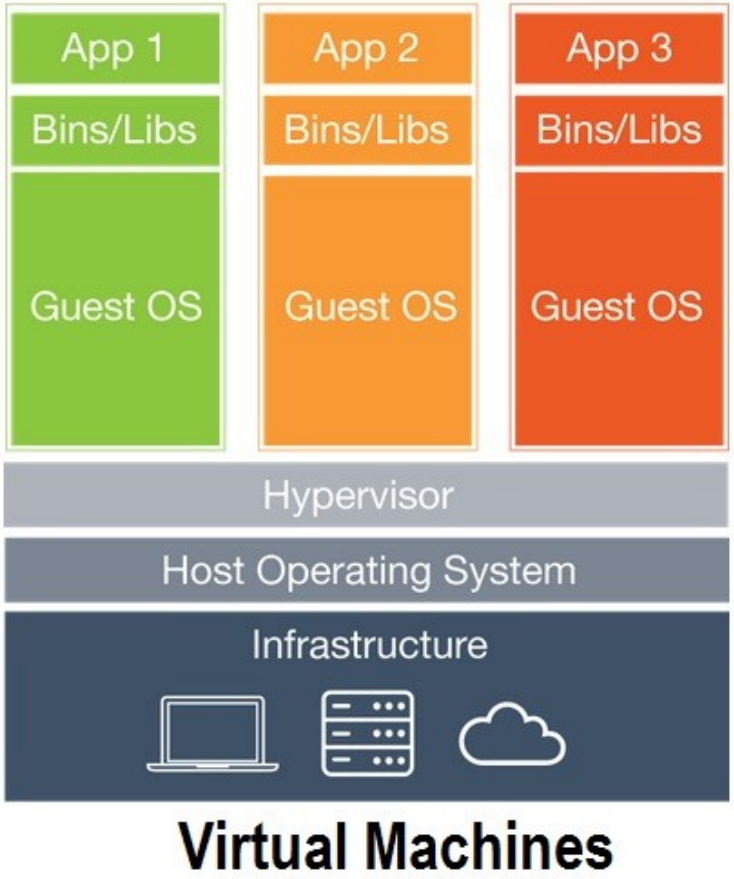
data center

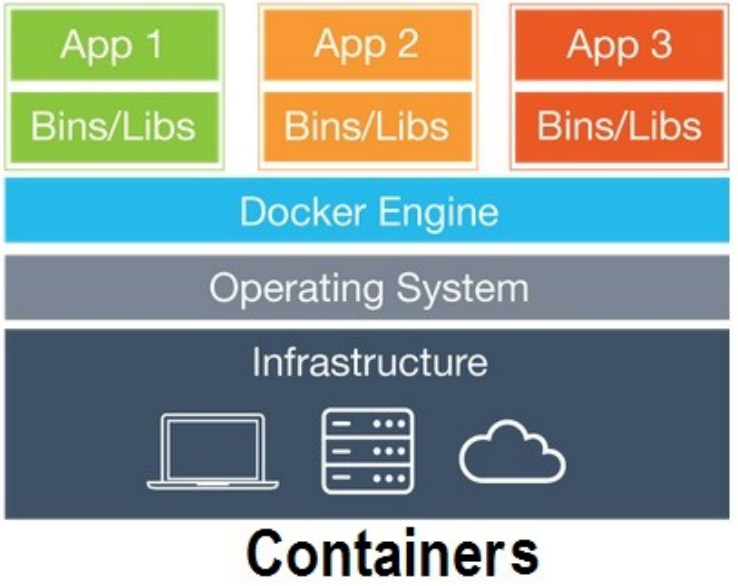
Data center topology

How to distribute efficiently many instances of server processes over the various computers?

- Load balancing
- No interference







Virtualization versus Containarization

What does “containerization” mean?

It is used to package, ship and deploy software so it can run on any hardware.

This concept is similar to the more traditional virtualization, but with less overhead to drastically increase scalability and performances.

Why containers?

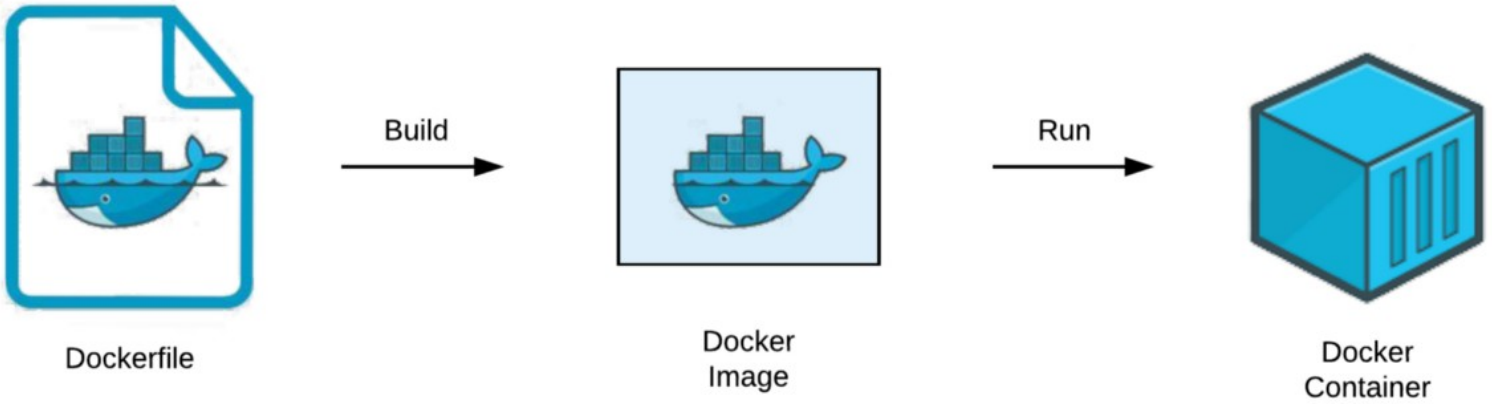
Using a container to ship an application, we are sure that our app will be executed with a specific set of software resources like: a specific OS distribution, a particular framework version and various dependencies such as libraries or modules.

Deploying on a container instead of bare metal increases:

- security through process-level isolation
- scalability since containers dynamically take and free resources
- portability through operating systems and hardware platforms
- stability avoiding conflicts between applications and preventing system updates to impact on the containerized application.

Life cycle of a containerized application (with Docker)

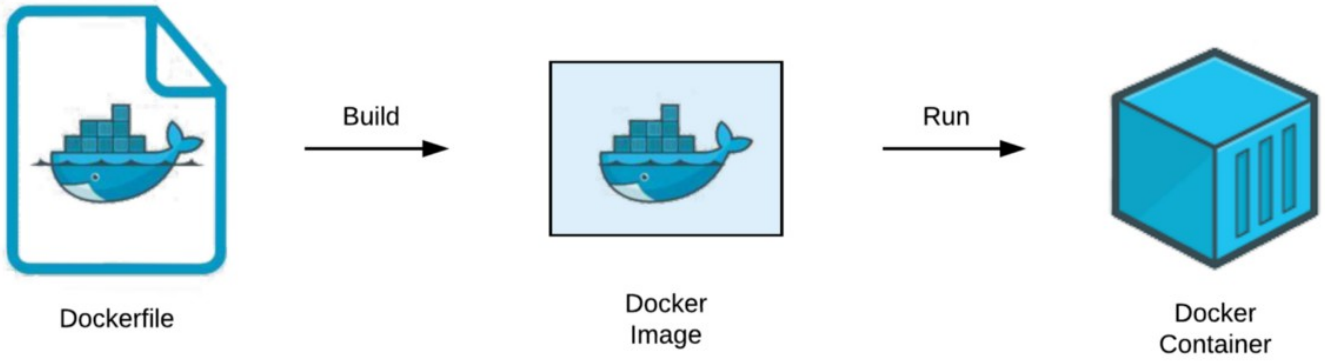
Write a Dockerfile, build it into a Docker Image and run the image to deploy the actual Docker Container.



Conceptualization

This is just a hint to help remembering! Not an official definition!

Docker world



Traditional single-platform world

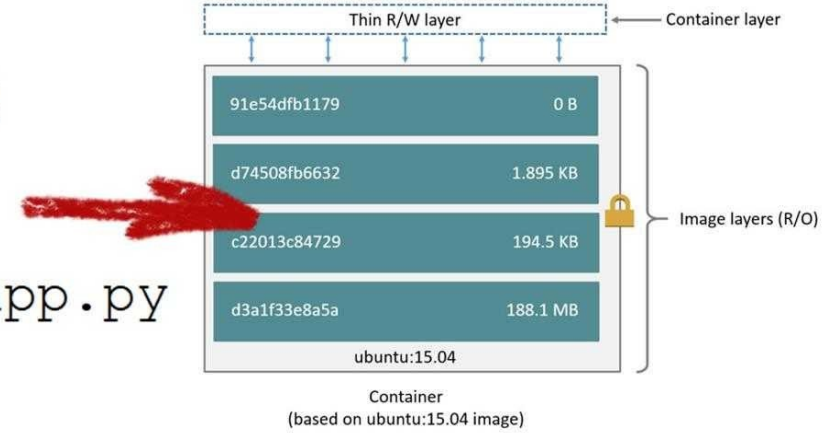
MAKEFILE **EXECUTABLE** **PROCESS**

DOCKERFILE

A Dockerfile is a list of instruction for the containerization engine to build a custom image that will contain the application we want to deploy.
In other words, it defines the specific environment we want for our app.

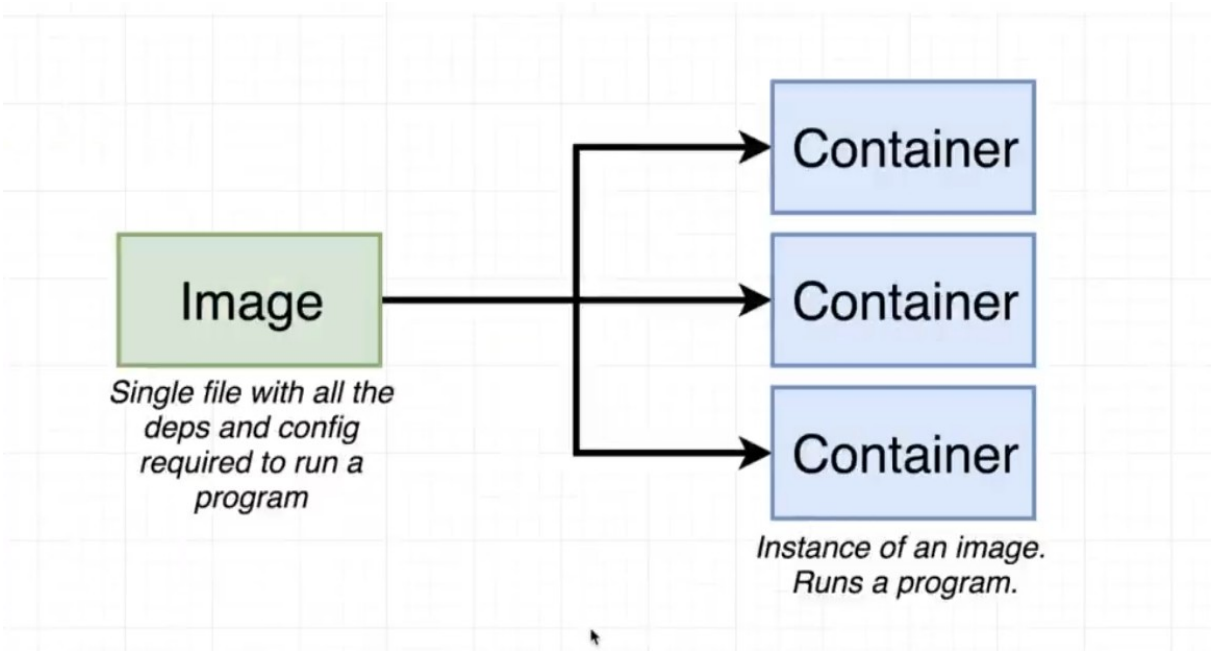
Dockerfile

```
FROM ubuntu:15.04
COPY . /app
RUN make /app
CMD python /app/app.py
```



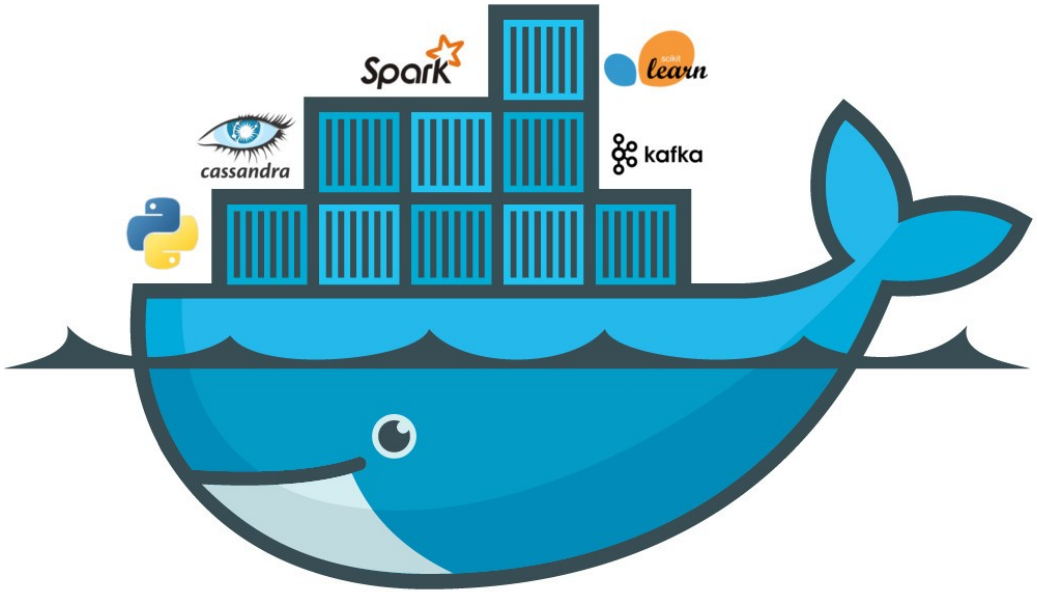
Docker image

A Docker image is a template for running a Docker container.
Once we build an image we can use it across different systems to run the same container.



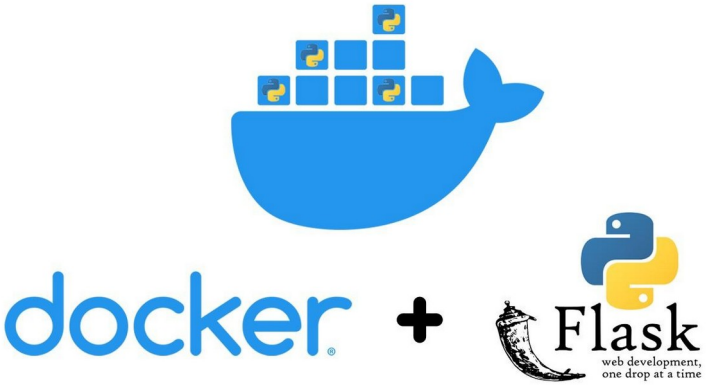
Docker Container

A running process on top of the Host OS, isolated from other processes but it can provide services through open network ports.



A practical example:

Flask server in a Docker Container



Setting up Docker

Installation on Windows/Mac

Docker Desktop on Windows/Mac: https://www.docker.com/products/docker-desktop/

Linux installation

Docker on Ubuntu from the docker repository: official documentation
(make sure to uninstall older docker versions)

or

Quick and easy Linux installation running the get-docker script:
https://get.docker.com/

Install Visual Studio Code

Download Visual studio code and it's Docker extension (test the integrity of the installations by running the command *docker* in the VSCode terminal).

Useful docker commands

docker ps	Give a list of all running containers on the system, every container has an id and a link to the image that generated it. Note: use option -a to list all the containers.
docker build	Build an image from a Dockerfile.
docker pull	Download a pre-built image from the **Docker Hub**
docker images	List available images.
docker run	Create a container from an image and the start it.
docker start/stop/restart/kill	Commands for starting, stopping, restarting and killing an existing container.
docker rm	Delete a container.

Write a simple web-app in Python using Flask

Create a directory (e.g. *flask_web*) containing a python module (e.g. *app.py*) and a requirements file *(requirements.txt*).

```python
from flask import Flask

app = Flask(__name__)


@app.route('/')
def docker_test():
    return 'Docker and Flask are working!'


if __name__ == '__main__':
    app.run(debug=True, host='0.0.0.0')

```

app.py

```
Flask==2.1.2
```

requirements.txt

Writing a Dockerfile

When we write a Dockerfile we specify the layers our image will have, Dockerfiles usually start from a base layer containing a pre-built image of, for example, an operative system. There are all kind of pre-built images that can be found in the docker-hub.

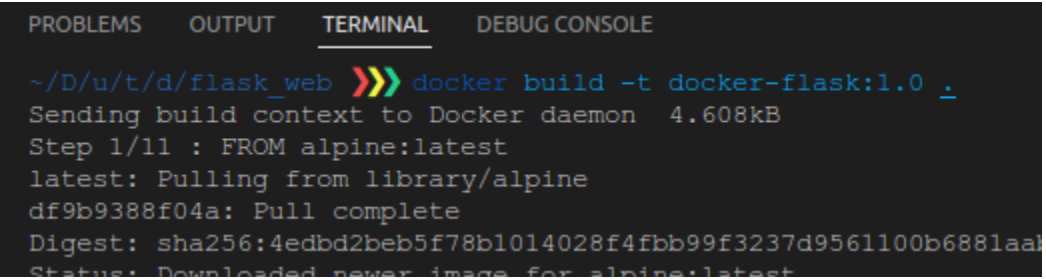
Dockerfile flask_web/Dockerfile/...

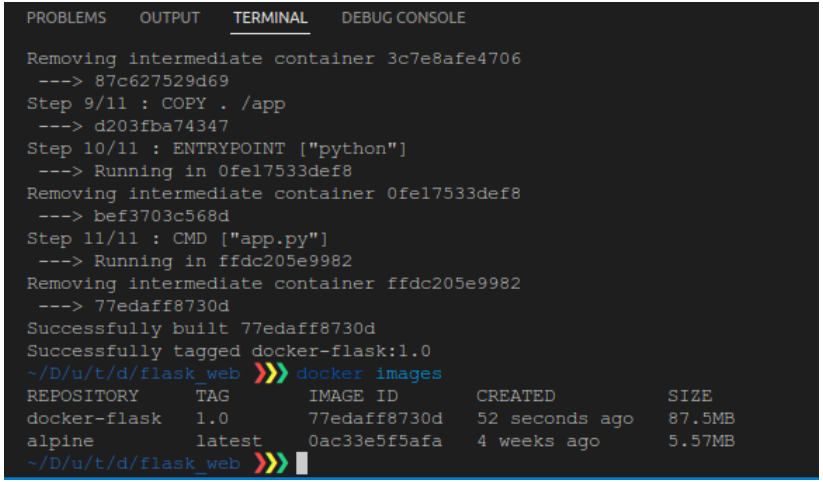
```
# Our image is built starting from the pre-built image Alpine:
# A minimal Docker image based on Alpine Linux
FROM alpine:latest

# installing Python and pip in Alpine
# with the keyword "ENV" we can set enviroment variables
ENV PYTHONBUFFERED=1
# using the command "RUN" we can execute shell commands while building an Image
RUN apk add --update --no-cache python3 && ln -sf python3 /usr/bin/python
RUN python3 -m ensurepip
RUN pip3 install --no-cache --upgrade pip setuptools

# Using the COPY command we can copy files from the local filesystem to
# the image's one and vice-versa
COPY ./requirements.txt /app/requirements.txt
```

```

# setting the working directory
WORKDIR /app

RUN pip install -r requirements.txt

COPY . /app

# With the keyword ENTRYPOINT we can set an executable to be run
# when the container starts up
ENTRYPOINT ["python"]
# we can use the CMD command to specify arguments for the executable
CMD ["app.py"]


```

Building the Docker Image

After writing the dockerfile we can use it to build an image using the command *docker build* we can add the *-t* flag to specify the tag our container will have so we can identify the container easily.





Creating and starting the container

After building the image we can start the container with the following command:

```
docker run -d -p 5000:5000 docker-flask:1.0
```

Options and arguments explanation:

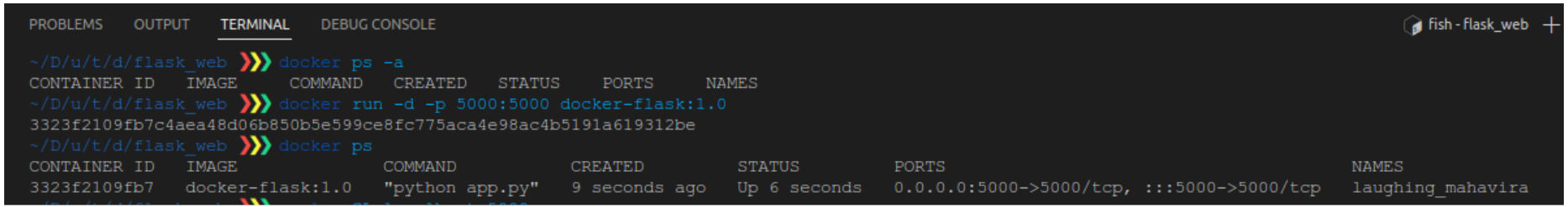
-d is used to run the image in a separated container

-p is used to map program port(s) to host's port(s); port order is *host:program*

docker-flask:1.0 is the tag of the image we built with the previous command.

We can add the –name='name' option to give a custom name to the container, otherwise docker will generate a random one.

Creating and starting the container



Then open a web browser at `http://localhost:5000`

if the browser does not show a nice message, use its command-line replacement

```
curl -sSL localhost:5000
```

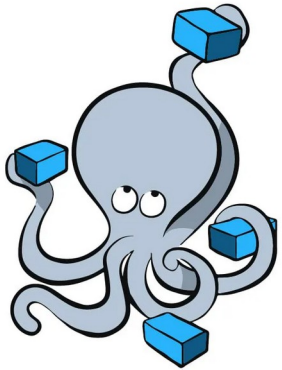
Exercises

1)Stop, restart and kill the previously created container and see what happens by using the command “docker ps -a”

2)Remove the container and create a new one listening on the port 8000

3)Execute the same image in two different containers on the port 7000 and 8000, respectively.

Multi-containers projects



docker
Compose

Multi-containers projects

When a project needs a Docker Image providing a variety of services, developers often rely on a tool called Docker Compose. Note: if you followed the linux installation using the get-docker script, you may need to run the command *sudo apt install docker-compose* to install this tool.

With Docker Compose, developers can write a YAML file describing all the application services, then with a single command the user can run all the containers providing those services needed to start the application. For example we can use Docker Compose to ship a project that provides two services: a front-end application and a database, running in two communicating containers, when we access the front-end service, it can interact with the database to reply using stored data.

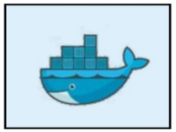
Creating such complex projects is out of the scope of this overview, but, we can easily run this type of project using Docker Compose.
Once we have retrieved the image we want to start the container(s) from (for example using the command *docker pull* to download an image from docker hub) we should download the *docker-compose.yml* file, provided by the developers who made the image, and start all the containers at once with the command *docker compose up* (or *docker-compose up* for older versions).
We can add various flags/options when launching this command, for example we can start a container in detached mode with the -d option.

Next step?

Docker world

Dockerfile

Build



Docker Image

Run

Docker Container

Kubernetes

Traditional single-platform world

MAKEFILE

EXECUTABLE

PROCESS

OPERATING SYSTEM