Introduction to Docker

...and a bit of Vagrant

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What is Docker exactly?

*"Docker provides a way to **run applications securely isolated** in a **container**, packaged with all its dependencies and libraries."*[1]

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Container

Containerization = **Operating-system-level virtualization**

- an isolated layer of file system (and software)
- relies on the host OS's kernel -> host and guest kernel must be the same
- shared hardware ressources between host and guest

Runs applications

- install an application in a container and run it in there
- communicate with the host via port-binding or SSH

[1] https://docs.docker.com/

[2] https://en.wikipedia.org/wiki/Operating-system-level_virtualization

Runs applications

- install an application in a container and run it in there
- communicate with the host via port-binding or SSH

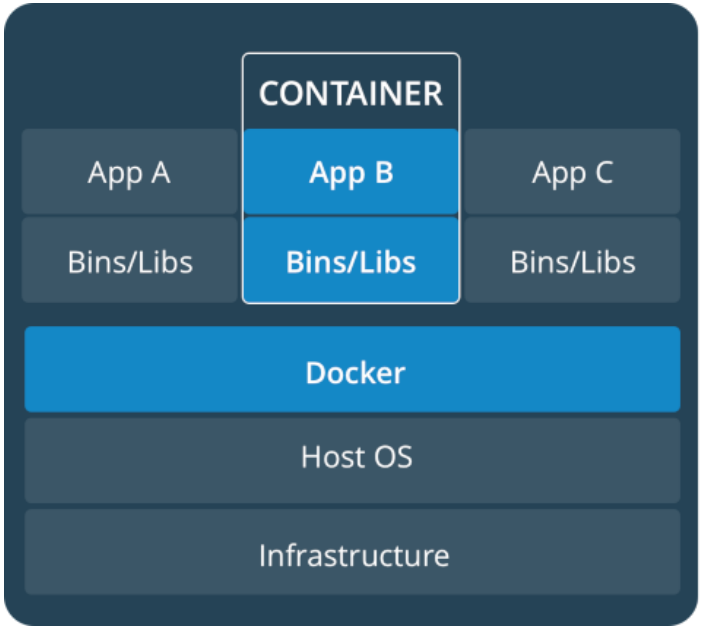
Securely isolated

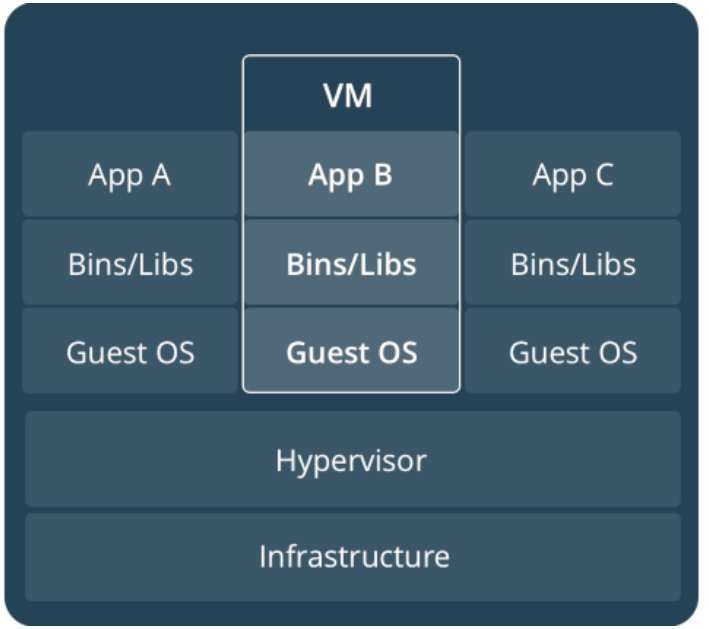
- simply running an application in a container doesn't guarantee security per se
- **root** user in the container is **root** on the host -> can possibly access ressources on the host

[1] https://docs.docker.com/

[2] https://en.wikipedia.org/wiki/Operating-system-level_virtualization

Docker and Virtual Machines





- docker shares the ressources, a VM is isolated
- preferably one application per container, a whole dev. env. in a VM

[1] https://docs.docker.com/get-started/#images-and-containers

So when use Docker and when a VM?

In general, both Docker (left) and VMs (right) provide modularity and isolation. With Vagrant VMs are also easily reproducible, just like Docker containers. Both of them guarantee that you can have the same setup running on someone elses computer that you are running on your own.

- virtualize the OS
- shared ressources
- a container management that can consistently run software as long as a containerization system exists
- preferably one application per container

- virtualize the hardware
- dedicated ressources (eg. 2GB RAM, 2 CPU from the host)
- a consistent development environment workflow across multiple operation systems

Docker on Mac, Windows, Linux

For **Linux**: no problemo

For **Mac**: read the docs

For **Windows**: read the docs

- starting with Windows Server 2016 and Windows 10
- no integration between containers and the Windows UI -> can't use Docker to run a client app but can use it to build your apps

Windows Server: containers are run directly directly on the server, no layer between host and guest

Windows 10: each container is run in a ligth VM (Hyper-V), running Windows Server kernel

Windows is *licensed* on the host level, not the container level -> one licence per host with arbitrary many containers

(while each VM needs its own licence...)

Docker quickstart

Goal: build the 3dgeo notes locally

! the same container is used on GitLab to build the book

1. We need a GitBook image from Docker Hub

```
docker pull billryan/gitbook
```

Docker quickstart

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! the same container is used on GitLab to build the book

1. We need a GitBook image from Docker Hub

```
docker pull billryan/gitbook
```

2. Then "simply" build the book in the repository and serve it on port `4000`

```
docker run \
    --rm \
    -v "$PWD:/gitbook" \
    -p 4000:4000 \
    billryan/gitbook \
    gitbook build
```

Docker quickstart explained

```
docker pull billryan/gitbook
```

Download the pre-built image from Docker Hub

```
docker run <image> <command>
docker run billryan/gitbook gitbook build
```

1. Create a container with the `billryan/gitbook` image
2. Start the container
3. Run the build process in the container with `gitbook build`

Docker quickstart explained

```
docker pull billryan/gitbook
```

Download the pre-built image from Docker Hub

```
docker run <image> <command>
docker run billryan/gitbook gitbook build
```

1. Create a container with the `billryan/gitbook` image
2. Start the container
3. Run the build process in the container with `gitbook build`

```
--rm
```

Remove the container after the process has finished

Docker quickstart explained

```
-p, --publish <host port>:<container port>
```

Map the port `4000` from the host into the container's port `4000`

Docker quickstart explained

```
-p, --publish <host port>:<container port>
```

Map the port `4000` from the host into the container's port `4000`

```
-v, --volume <host dir>:<container dir>
```

Mount the contents of the current working directory into the container's `/gitbook` directory, so that the build process can use the files

Building an image — The Dockerfile

Describes all the steps that are required to create an image

Usually in root directory of the project

Images are built from the Dockerfile. Give a name to the image with `-t <name>:<tag>`.

```
docker build -t gitbook:latest <path to Dockerfile>
```

Building an image — The Dockerfile

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Images are built from the Dockerfile. Give a name to the image with `-t <name>:<tag>`.

```
docker build -t gitbook:latest <path to Dockerfile>
```

```
FROM mdillon/postgis:10 # build on an exising image

EXPOSE 5432 # expose the port

ENV POSTGRES_USER postgres
ENV POSTGRES_DB postgres
ENV POSTGRES_PASSWORD=test_admin

RUN apt-get install -y p7zip # run any command

COPY ./docker_provision/init_db.sh /docker-entrypoint-initdb.d/
COPY ./example_data/batch3dfier_db.sql .
```

Building an image — The Dockerfile

Layers of filesystem and chaching

- only re-build what has changed (tip: `--no-cache`)

Every `RUN` command adds a new layer to the image and increases its size

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- only re-build what has changed (tip: `--no-cache`)

Every `RUN` command adds a new layer to the image and increases its size

Container references the layered filesystem image + some metadata

creating a container takes minimal space

- create them for running single commands (eg building a gitbook)

```
balazs@balazs-laptop:~$ docker ps -as
CONTAINER ID        IMAGE                  COMMAND                  CRE
9fae10cb3c5c        fzinfz/anaconda3       "/usr/bin/tini -- ju…"   2 c
fcec76004288        strhawk/graph_tool     "/usr/bin/tini -- ju…"   2 c
7a83fd39c97f        ucalgary/gitbook       "node"                   6 c
```

Use data from the host in a container

bind-mount: file or directory on the host is mounted into a container, so the filesystem in the host must be compatible with the guest

```
docker run -v <host dir>:<container dir> my_image
```

volume: new directory is created within Docker's storage directory on the host, and Docker manages that directory's contents

Volumes can be named and they exist independently of containers. For example create a volume for a database data directory and connect any containers to it.

```
docker create volume my_volume
docker run -v my_volume:<container dir> my_image
```

Networking basics

Drivers:

- *bridge*: (default) application running in standalone mode and containers need to communicate
- *host*: no isolation between host and container and use the host's network directly

Networking basics

There is a common network bridge that both the host and Docker connect to. First create a user-defined bridge

```
$ docker network create docker-bridge
```

Then connect a container to the bridge on creation

```
$ docker create --name geoserver \
  --network docker-bridge \
  --publish 8080:8080 \
  kartoza/geoserver
```

The `ip addr` on the host will show on which IP is the host accessible from the bridge. The same is true for the container

But don't forget to set up the aproppriate firewall rules (and allow the IP addresses for Postgres for example)

Docker security 101

*Don't forget that **root** user in the container is **root** on the host -> can possibly access ressources on the host*

Create a non-priviledged user and run processes in a container with it. Read more about it here

The same networking security rules apply as normally

To run a container as a specific user (eg `root`):

```
docker run -u root <image> <command>
```

Use case #1 — Compute on Godzilla

I need to generate a graph with 100k nodes, using the Erdős-Rényi model. I cannot do it on my laptop, because there is not enough memory.

```
#! /usr/bin/python2.7
import sys
import igraph
n = int(sys.argv[1])
g = igraph.Graph.Erdos_Renyi(n, 0.5, directed=True, loops=True)
g.write_graphml(sys.argv[2])
```

On Godzilla:

```
docker pull ntamas/python-igraph
```

```
docker run \
    --rm \
    -v "$(pwd):/tmp" \
    ntamas/python-igraph:latest \
    /tmp/generate_er-graph.py 10000 /tmp/er_n100k.graphml
```

It generates the graph in 1 minute and saves `er_n100k.graphml` into the current directory.

Use case #2 — 3dfier in a container

Multi-stage build: Compile the dependencies in the first image, build 3dfier in the second

On code change, rebuild only the 3dfier image

Still just one dockerfile, and a single final image

Multiple build configurations possible (per OS, per dependency)

See the complete Dockerfile

The multi-stage Dockerfile

The `FROM` instruction marks a stage.

```
FROM ubuntu:xenial as builder
RUN ... # build dependencies

FROM builder as build3dfier
ENV LIBDIR "/opt"
COPY . $LIBDIR/3dfier/ # copy source code
                       # from the host into the image
RUN ... # build 3dfier
    mv $LIBDIR/3dfier/build/3dfier /bin/

ENTRYPOINT /bin/3dfier
```

The multi-stage Dockerfile

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RUN ... # build 3dfier
    mv $LIBDIR/3dfier/build/3dfier /bin/

ENTRYPOINT /bin/3dfier
```

```
docker build -t 3dfier:app <Dockerfile>
docker run --rm 3dfier:app testarea_config.yml \
                           --OBJ output/testarea.obj
```

The multi-stage Dockerfile

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```
FROM ubuntu:xenial as builder
RUN ... # build dependencies

FROM builder as build3dfier
ENV LIBDIR "/opt"
COPY . $LIBDIR/3dfier/ # copy source code
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RUN ... # build 3dfier
    mv $LIBDIR/3dfier/build/3dfier /bin/

ENTRYPOINT /bin/3dfier
```

```
docker build -t 3dfier:app <Dockerfile>
docker run --rm 3dfier:app testarea_config.yml \
                           --OBJ output/testarea.obj
```

However, ubuntu + all dependencies yield an image >1GB

Its a monolithic image, not the "best practice". But otherwise statically linked executables need to be copied from one image to the next.

Use case #3 — A pyCSW server

Web services are probably the most common use of Docker

```
docker run \
    --name pycsw \
    --detach \
    --volume "$(pwd)"/pycsw_pg.cfg:/etc/pycsw/pycsw.cfg \
    --network pycsw \
    --publish 8000:8000 \
    --add-host=godzilla:172.19.0.1 \
    geopython/pycsw
```

Use case #3 explained

The command `docker run` will download the image `geopython/pycsw` from Docker Hub if necessary

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```
--name pycsw
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```
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Give a name to the container

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--detach
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Run as a background process

Use case #3 explained

The command `docker run` will download the image `geopython/pycsw` from Docker Hub if necessary

```
--name pycsw
```

Give a name to the container

```
--detach
```

Run as a background process

```
--volume "$(pwd)"/pycsw_pg.cfg:/etc/pycsw/pycsw.cfg
```

Mount the `pycsw` config file into the container

Use case #3 explained

The command `docker run` will download the image `geopython/pycsw` from Docker Hub if necessary

```
--name pycsw
```

Give a name to the container

```
--detach
```

Run as a background process

```
--volume "$(pwd)"/pycsw_pg.cfg:/etc/pycsw/pycsw.cfg
```

Mount the `pycsw` config file into the container

```
--add-host=<host name>:<host IP>
```

Map a host name to an IP. This is a portable way to define hosts in a container, because the host is reachable as `godzilla` from the container, even if the IP changes.

So what about Vagrant?

- Create a reproducible / discardable development environment
- Set up the whole dev. env. in minutes by just issuing `vagrant up`, **provided that**
  - virtualization is enabled on your computer
  - there is VirtualBox / VMware / Parallels on your computer
  - Vagrant is installed :-)
- Very useful when you need to migrate your setup onto anoter machine

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- Very useful when you need to migrate your setup onto anoter machine

When you issue `vagrant up` the first time, the VM is **provisioned**. It reads the config from a `Vagrantfile` (familiar?).

The `Vagrantfile` configures the VM itself (networking, ressource allocation etc.) and references a **provisioner**. The provisioner takes care of the contents of the VM (software etc.). It can be a shell script, but also Docker.

Vagrant use case

Web development in the REPAiR project

It needs Ubuntu, Python 3.6, SQLite, Node, Yarn and many many python and JS libraries

Developers use Windows, Mac, Linux

The source code is on the host, and it is synced into the VM

-> edit the code with any editor on the host, execute it in the VM

See the project's Vagrant README for more

References

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