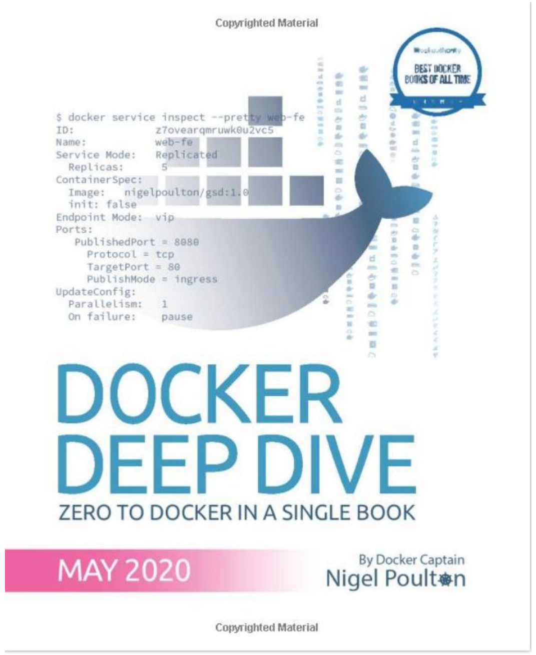
UMD DATA605 - Big Data Systems

DevOps with Docker

Docker - Resources

- Concepts in the slides
- Tutorial: tutorial_docker, tutorial_docker_compose
- We will use Docker during the project
- Web resources
  - A Beginner-Friendly Introduction to Containers, VMs and Docker
  - Official Docker Getting Started Tutorial
- Mastery:
  - Poulton, Docker Deep Dive: Zero to Docker in a single book, 2020
  - Google SRE book TODO



```
$ docker service inspect --pretty web-fe
ID:             z7ovearqmruwk0u2vc5
Name:           web-fe
Service Mode:   Replicated
  Replicas:     5
ContainerSpec:
  Image:    nigelpoulton/gsd:1.0
  init: false
Endpoint Mode:  vip
Ports:
   PublishedPort = 8080
    Protocol = tcp
    TargetPort = 80
    PublishMode = ingress
UpdateConfig:
  Parallelism:    1
  On failure:     pause
```

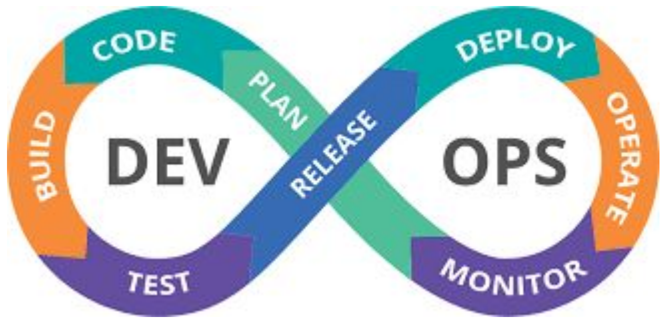
Application Deployment

- For (almost all) Internet companies, the application **is** the business
  - If the application breaks, the business stops working
  - E.g., Amazon, Google, Facebook, on-line banks, travel sites (e.g., Expedia)
- **Problem**:
  - How to release / manage / deploy / monitor applications?
- **Solutions**:
  - Before 2000s: “bare-metal era”
  - 2000s-2010s: “virtual machine era”
  - > ~2013: “container era”

DevOps

- **DevOps** = set of practices that combines software development (dev) and IT operations (ops)

- **Container technology revolutionized DevOps**
  - Enable true independence between applications and IT ops
    - Teams create applications
    - Teams deploy and manage applications
  - Create a model for better collaboration (fewer conflicts) and innovation
    - IT: “It doesn’t work!”
    - Devs: “What? It works for me”



Before Virtualization

- < 2000s
- “Run on the bare metal”
- Running one or few applications on each server
- **Pros**:
  - No virtualization overhead
- **Cons**:
  - Not safe / not secure
  - Expensive
- IT would buy a new server for each application
  - Difficult to spec out the machine -> buy “big and fast servers”
    - Overpowered servers operating at 5-10% of capacity
    - Tons of money in the 2000 DotCom boom was spent on machines (Sun Servers) and networks (Cisco)

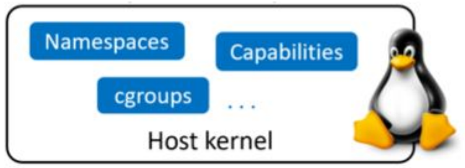
Virtual Machine Era

- Circa 2000-2010
- Virtual machine technology = run multiple copies of OSes on the same hardware
- **Pros:**
  - VM ran safely and securely multiple applications on a single server
  - IT could run apps on existing servers with spare capacity
- **Cons:**
  - Every VM requires an OS (waste of CPU, RAM, and disk)
  - Monitor and patch each OS
  - Buy an OS license
  - VMs are slow to boot

Containers Era

- Circa 2013: Docker becomes ubiquitous
- **Pros:**
  - Containers don't require full-blown OS
  - All containers run on a single host
  - Reduce OS licencing cost
  - Reduce overhead of OS patching and maintenance
  - Containers are fast and portable
- **Cons:**
  - CPU overhead
  - Toolchain to learn / use

- Docker
  - Didn't invent containers
  - Made containers simple and mainstream
- Linux supported containers for some time
  - Kernel namespaces
  - Control groups
  - Union filesystems



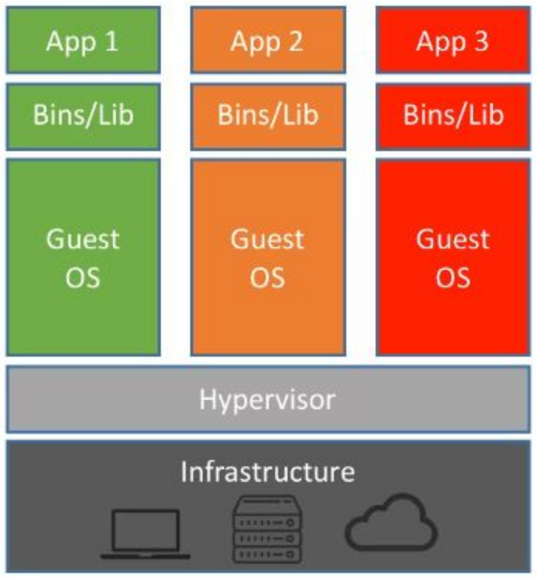
Serverless Computing

- Containers run in an OS which runs on a **host**
  - **Where is the host**
    - Local (your laptop)
    - On premise (your own computers in a rack)
    - Cloud instance (e.g., EC2)
  - **What is the host**
    - Bare-metal server
    - On a virtual machine
    - On a virtual machine running a virtual machine
- **Serverless computing**
  - As long your application runs somewhere, you don’t care “how” or “where”

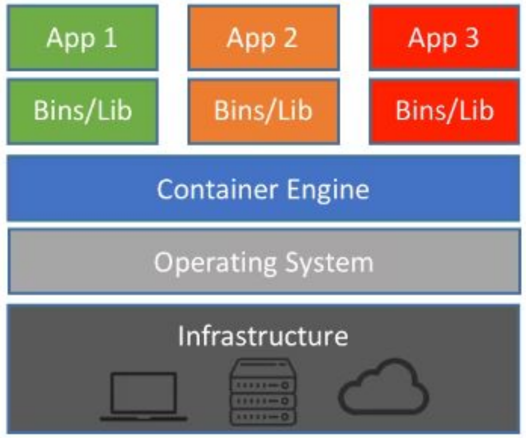
OS vs Container Virtualization

- Hypervisor boots and performs HW virtualization
  - Carves out physical hardware resources into VMs
  - Resources (CPUs, RAM, storage) are allocated to a VM
- "Virtual machine tax"
  - To run 3 apps, need 3 VMs and 3 OSes
  - Each VM requires time to start
  - Consume CPU, RAM, storage
  - Need a license
  - Need admins

- Containers
  - Docker performs OS virtualization



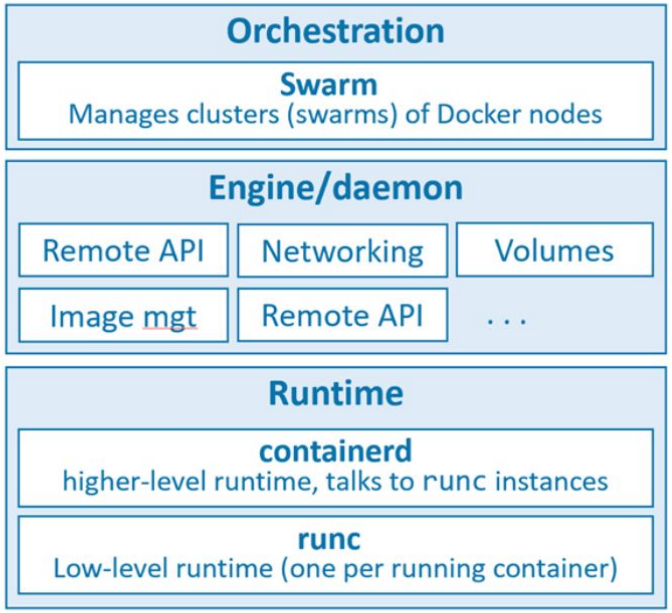
Machine Virtualization



Containers

Docker Architecture

- Docker run-time
  - `runc`: start and stop containers
  - `containerd`:
    - Pull images
    - Create volumes, network interfaces
- Docker engine
  - `dockerd`:
    - Expose remote API
    - Manage images, volumes, networks
- Docker orchestration
  - `docker swarm`
  - Manage clusters of nodes
  - Replaced by Kubernetes

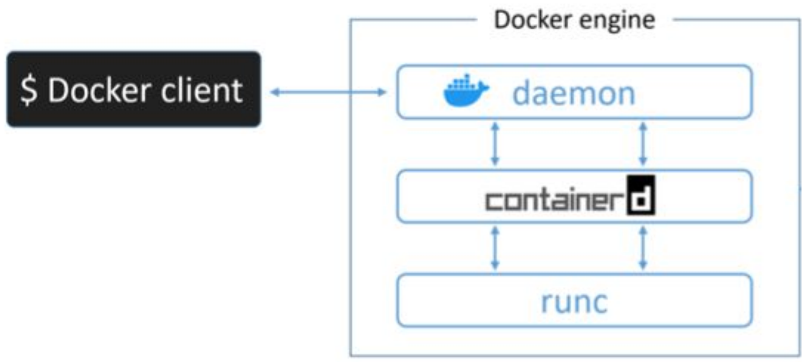

Orchestration
Swarm
Manages clusters (swarms) of Docker nodes
Engine/daemon
Remote API
Networking
Volumes
Image mgt
Remote API
. . .
Runtime
containerd
higher-level runtime, talks to runc instances
runc
Low-level runtime (one per running container)

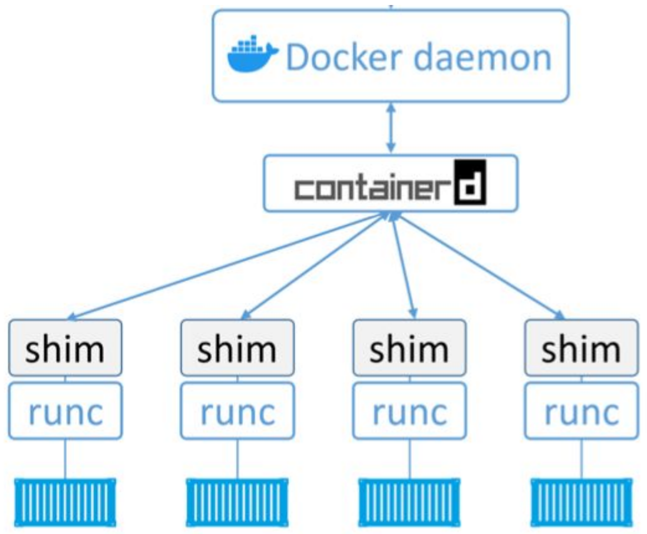
- Open Container Initiative (OCI)
  - Standardize low-level components of container infrastructure
  - E.g., image format, run-time API
  - "Death" of Docker

Docker: Server-Client

- Server-client architecture

- **Docker client**
  - Command line interface
  - Communicate with the server through IPC socket (e.g., `/var/run/docker.sock`) or IP port
- **Docker engine**
  - Run and manage containers
  - Modular and built from several OCI-compliant sub-systems
    - E.g., Docker daemon, **`containerd`**, **`runc`**, plug-ins for networking and storage

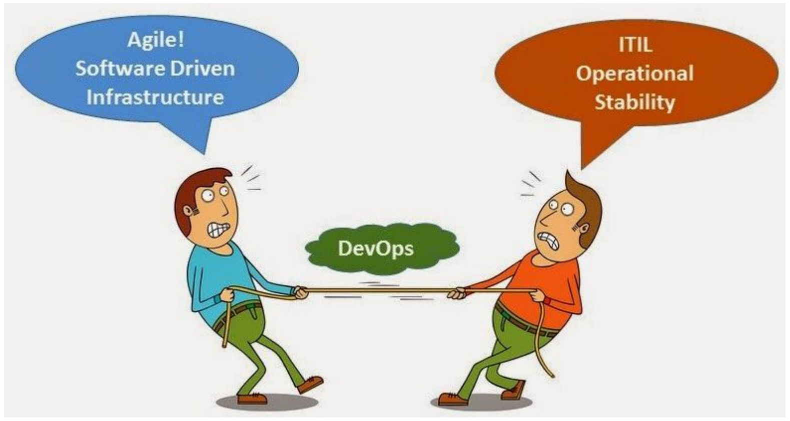




Devops = Devs + Ops

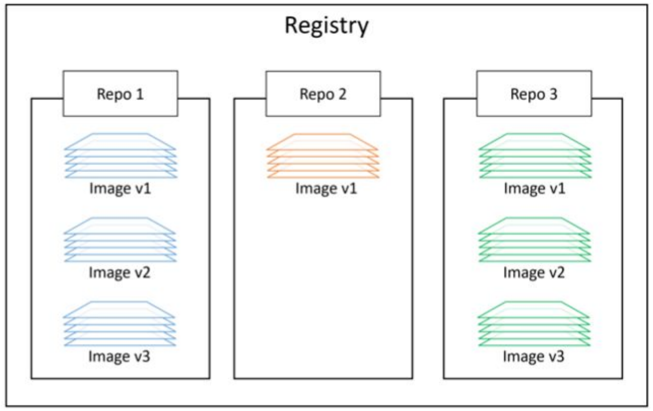
- **Devs**
- Implement the app (e.g., Python, virtual env)
- Containerize the app
  - Create Dockerfile
  - Contain the instruction on how to build an image
- Build image
- Run the app as a container
- Test "locally"

- **Ops**
- Download images
  - Contain filesystem, application, app dependencies
- Start containers
- Destroy container
- In case of issues, it's easy to repro the problem
  - Here is the log
  - Run command line
  - Deploy on a test system and debug


Agile! Software Driven Infrastructure
DevOps
ITIL Operational Stability

Docker Containers

- **Docker Containers**
  - Lightweight, stand-alone, executable software package
  - Includes everything needed to run
    - E.g., code, runtime / system libraries, settings
  - Run-time objects
    - vs Docker images are built-time objects
- **Docker repos**
  - Store Docker images
    - `<registry>/<repo>:<tag>`
    - `alpine:latest`
    - E.g., DockerHub, AWS ECR
  - Some repos are vetted by Docker
  - Unofficial repos shouldn't be trusted

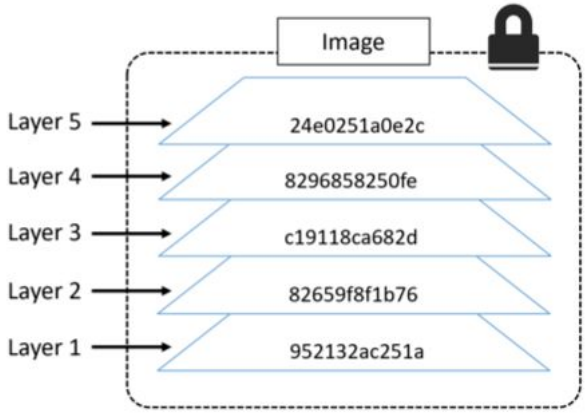


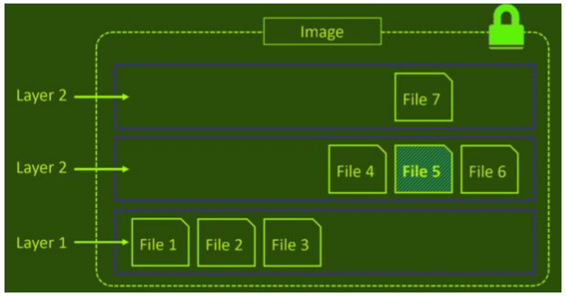
Docker Image

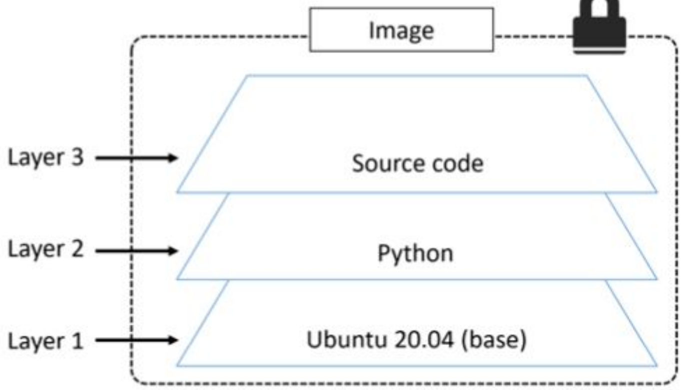
- Unit of deployment
- Contain everything needed by an application to run
  - Application code
  - Application dependencies
  - Minimal OS support
- Can build images from Dockerfiles
- Can pull pre-built image s from registry
- Multiple layers stacked on top of each other
- Typically few 100s MBs

Docker Image Layers

- A docker image is a configuration file that lists the layers and some metadata
  - It is composed of read-only layers
  - Each layer comprising of many files
  - Each layer is independent from each other
- **Docker driver**
  - Stacks these layers representing them as a unified filesystem
  - Files from the top layers can obscure the files from the bottom layers
  - Implements a copy-on-write behavior
- **Layer hash**
  - Each layer has an hash based on its content
  - Layers are pulled and pushed compressed the hash of a compressed layer is different
    - A "distribution hash" is used
- **Image hash**
  - Each image has an hash
  - The hash is function of the config file and of the layers
  - When an image changes, a new hash is generated







Docker: Container Data

- **Container storage is ephemeral**
  - Data inside of containers is persisted as long as the container is not killed
  - If you stop or pause a container data is not lost
  - Containers are designed to be immutable
    - It's not good practice to write “persistent” data into containers
- **Bind-mount**
  - Bind-mounting a local dir
  - A local dir is mounted to a dir inside a container
- **Docker volumes**
  - E.g., to store the content of a Postgres DB
  - Docker provides volumes that exist separately from the container
  - State is permanent across container invocations
  - Can be shared across containers

Containerizing an App

- Develop your application code using the needed dependencies
  - Install dependencies
    - Directly inside a container
    - Inside a virtual env
- Create a Dockerfile describing:
  - your app
  - its dependencies
  - how to run it
- Build image with `docker image build`
- (Optional) Push image to a Docker image registry
- Run container from image

Building a Container

- **Dockerfile**
  - Describe how to create a container
- **Build context**
  - `> docker build -t web:latest .`
  - Sent to Docker engine to build the application
  - Directory containing the application and its dependencies
  - Typically the Dockerfile is in the root directory of the build context

Dockerfile Example

```
FROM python:3.8-slim-buster
LABEL maintainer="gsaggese@umd.edu"

WORKDIR /app

COPY requirements.txt requirements.txt
RUN pip3 install -r requirements.txt

COPY . .

CMD ["python3","-m", "flask", "run", "--host=0.0.0.0"]
```

Docker Tutorial

- tutorial_docker.md

Docker Compose

- Deploy and manage multi-container applications running on a single node
  - Describe the app in a single declarative configuration YAML file
    - Instead of scripts with long Docker commands
  - Compose talks to Docker API to achieve what you requested
  - E.g., you need a client app and Postgres DB
  - E.g., microservices
    - Web front-end
    - Ordering
    - Back-end DB
- In 2020 Docker Compose has become an open standard for "code-to-cloud" process

- To run on multiple hosts
  - Docker Stacks / Swarm
  - Kubernetes

Docker Compose: Commands

```
> docker compose --help

Usage:  docker compose [OPTIONS] COMMAND

Options:
      --env-file string           Specify an alternate environment file.
  -f, --file stringArray          Compose configuration files
  -p, --project-name string       Project name

Commands:
  build       Build or rebuild services
  convert     Converts the compose file to platform's canonical format
  cp          Copy files/folders between a service container and the local filesystem
  create      Creates containers for a service.
  down        Stop and remove containers, networks
  events      Receive real time events from containers.
  exec        Execute a command in a running container.
  images      List images used by the created containers
  kill        Force stop service containers.
  logs        View output from containers
  ls          List running compose projects
  pause       Pause services
  port        Print the public port for a port binding.
  ps          List containers
  pull        Pull service images
  push        Push service images
  restart     Restart containers
  rm          Removes stopped service containers
  run         Run a one-off command on a service.
  start       Start services
  stop        Stop services
  top         Display the running processes
  unpause     Unpause services
  up          Create and start containers
  version     Show the Docker Compose version information
```

Docker Compose: Tutorial Example

- The default name for a Compose file is \`docker-compose.yml\`
  - You can specify \`-f\` for custom filenames
- **Top-level keys** are:
  - \`version\`:
    - Mandatory first line to specify API version
    - Ideally always use the latest version
    - Typically 3 or higher
  - \`services\`:
    - Define the different microservices
  - \`networks\`:
    - Creates new networks
    - By default it creates a \`bridge\` network to connect multiple containers on the same Docker host
  - \`volumes\`:
    - Creates new volumes
- **Key in services** describe a different “service” in terms of container
  - **Inner keys** specify the params of Docker run command

```
version: "3.8"

services:
  web-fe:
    build: .
    command: python app.py
    ports:
      - target: 5000
        published: 5000
    networks:
      - counter-net
    volumes:
      - type: volume
        source: counter-vol
        target: /code

  redis:
    image: "redis:alpine"
    networks:
      counter-net:

networks:
  counter-net:

volumes:
  counter-vol:
```

Docker Compose: Tutorial

- Example taken from https://github.com/nigelpoulton/counter-app

  - tutorial_docker_compose

```
> cd tutorials/tutorial_docker_compose
> vi tutorial_docker_compose.md
```