Cloud Deployment: Infrastructure Automation

Infrastructure-as-Code, Containerization

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The Days before Infrastructure Automation

Manual Provisioning for Deployment

“Old School” Server Configuration and Deployment

Order hardware to set up (virtual) servers

Manual execution of steps to achieve server state

Patches are applied to the running server

Error prone, Slow / Time consuming

Requires heavy process (in large organizations)

Further Reading: https://speakerdeck.com/garethr/infrastructure-as-code

Manual Provisioning for Deployment

Infrastructure Knowledge Management

Knowledge about existing infrastructure in manual provisioning is usually not documented in any formal manner:

> In operator's head
(internal knowledge, worst case)

> Documentation in internal wikis
(textual representation, still not great)

Developing Software for the Cloud (Quick Recap)

Scalability / API-driven Infrastructure at Scale

> New resources (cloud instances) can be spawned at scale over an API

Ephemeral Infrastructure / Cloud Instance Volatility

> Cloud Instances terminate frequently (scale down, faults)

Jürgen Cito, Philipp Leitner, Thomas Fritz, and Harald C. Gall. 2015. **The making of cloud applications: an empirical study on software development for the cloud**. In Proceedings of the 2015 10th Joint Meeting on Foundations of Software Engineering (ESEC/FSE 2015). ACM, New York, NY, USA, 393-403. DOI=http://dx.doi.org/10.1145/2786805.2786826

The Need for Infrastructure Automation for Server Provisioning in the Cloud

Scalability / API-driven Infrastructure at Scale

Not feasible to manually configure every new instance

Ephemeral Infrastructure / Cloud Instance Volatility

Manual changes on cloud instances get lost

Jürgen Cito, Philipp Leitner, Thomas Fritz, and Harald C. Gall. 2015. **The making of cloud applications: an empirical study on software development for the cloud**. In Proceedings of the 2015 10th Joint Meeting on Foundations of Software Engineering (ESEC/FSE 2015). ACM, New York, NY, USA, 393-403. DOI=http://dx.doi.org/10.1145/2786805.2786826

Infrastructure Transparency

Infrastructure **provisioning** and application **deployment** in the cloud largely **automated**

Servers are **not** seen as **durable entities**

Any **changes** in infrastructure are **defined in code**

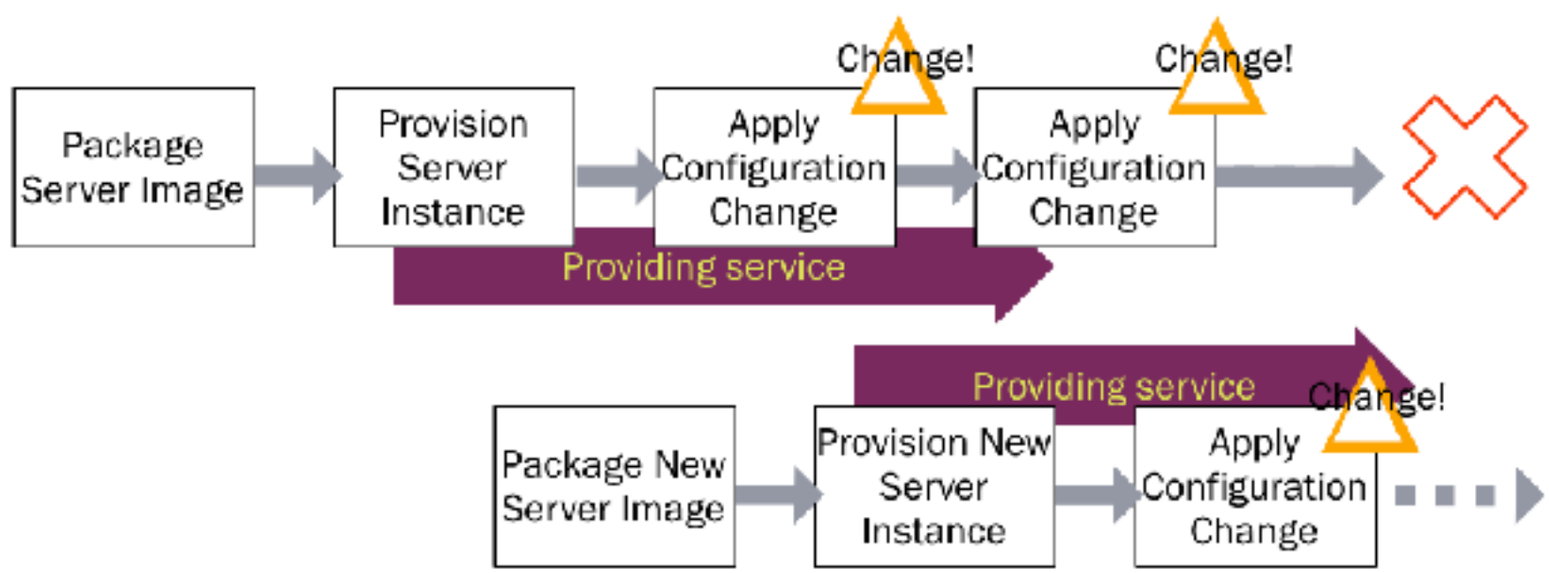
"What happens in our infrastructure is a lot more obvious. Everything we do on that level [infrastructure] is over code (...) So, I don't need ask my colleague what he did to get that process running - I just look at the code and maybe the commit history"

Jürgen Cito, Philipp Leitner, Thomas Fritz, and Harald C. Gall. 2015. **The making of cloud applications: an empirical study on software development for the cloud**. In Proceedings of the 2015 10th Joint Meeting on Foundations of Software Engineering (ESEC/FSE 2015). ACM, New York, NY, USA, 393-403. DOI=http://dx.doi.org/10.1145/2786805.2786826

Immutable Infrastructure

Existing instances that have already been deployed are never modified but rather replaced with a new (tested) updated instance

Manual Provisioning

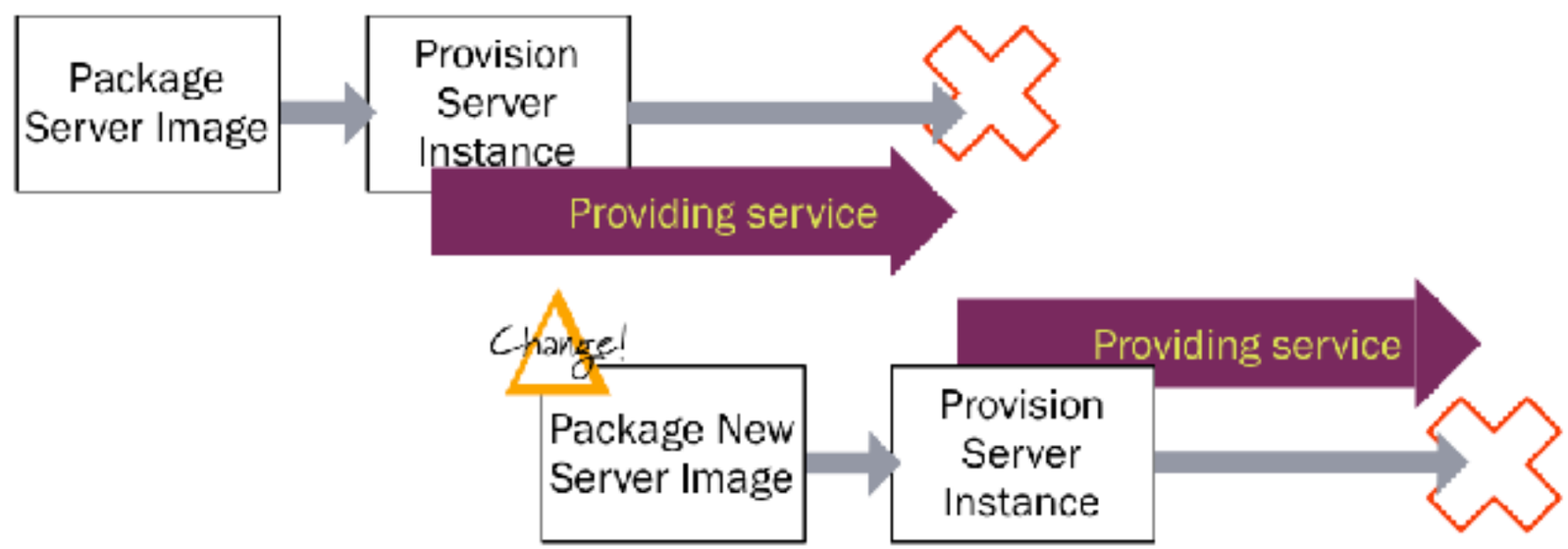


Further Reading: https://martinfowler.com/bliki/ImmutableServer.html

Immutable Infrastructure

Existing instances that have already been deployed are never modified but rather replaced with a new (tested) updated instance

Immutable Infrastructure



Further Reading: https://martinfowler.com/bliki/ImmutableServer.html

Immutable Infrastructure: Data

If instances are ephemeral, so is the data stored on the instance.

Cloud services generally offer mountable storage and database services.

Further Reading: https://martinfowler.com/bliki/ImmutableServer.html

Infrastructure as Code

Declarative (or sometimes imperative) definition of infrastructure in program code files to manage configuration and automate provisioning.

Sometimes also called *“programmable infrastructure”*

Allows to leverage software engineering best practices

“Infrastructure as Code (IaC) is the process of managing and provisioning computing infrastructure (processes, bare-metal servers, virtual servers, etc.) and their configuration through machine-processable definition files, rather than physical hardware configuration or the use of interactive configuration tools.”

https://en.wikipedia.org/wiki/Infrastructure_as_Code

Infrastructure as Code

Different Abstractions, Different Tools (for IaaS)

Cloud Environment Orchestration

- Openstack Heat
- CloudFormation
- Terraform
- …

Creates networks, instances, storage, etc.

Configuration Management

- Chef
- Puppet
- Ansible
- …

Provisions an existing server instance

Infrastructure as Code

Example: Chef

```
service "tomcat" do
  service_name "tomcat6"
  case node["platform"]
  when "centos","redhat","fedora"
    supports :restart => true, :status => true
  when "debian","ubuntu"
    supports :restart => true, :reload => true, :status => true
  end
  action [:enable, :start]
end
```

Infrastructure as Code

Example: Puppet

```
# execute 'apt-get update'
exec { 'apt-update':
  command => '/usr/bin/apt-get update'
}

# install apache2 package
package { 'apache2':
  require => Exec['apt-update'],
  ensure => installed,
}

# install mysql-server package
package { 'mysql-server':
  require => Exec['apt-update'],
  ensure => installed,
}
```

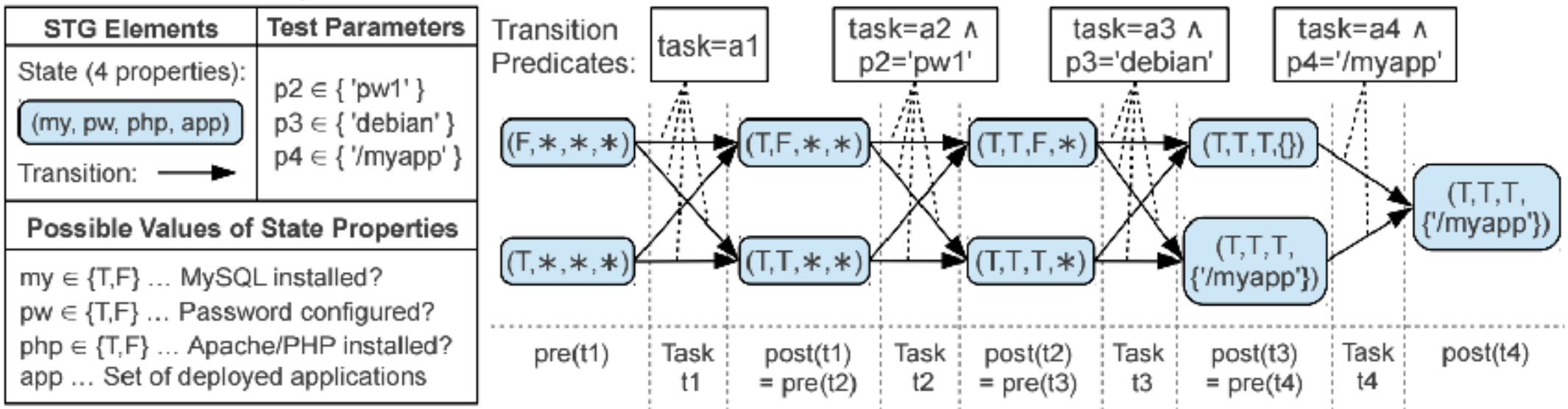
Infrastructure as Code

Goal: Reach certain system state through executed actions

Example Tasks

#	Task	Parameters
a_1	Install MySQL	-
a_2	Set MySQL password	$p2$ = root password
a_3	Install Apache & PHP	$p3$ = operating system distribution (e.g., 'debian')
a_4	Deploy Application	$p4$ = application context path (e.g., '/myapp')

State Graph



Waldemar Hummer, Florian Rosenberg, Fabio Oliveira, Tamar Eilam. 2013. **Testing Idempotence for Infrastructure as Code.** In Proceedings of the 2013 ACM/IFIP/USENIX Middleware Conference

Infrastructure as Code

Software Engineering Best Practices

Version Control

> Track infrastructure evolution

Testing & Continuous Integration

> Validation of infrastructure with unit- and integration tests

Code Review

> Infrastructure code inspection reduces potential of errors in configuration

Reuse

> Existing definitions of infrastructure can be used in different contexts

Infrastructure as Code

Testing: Linter (Example: Puppet Lint)

"Puppet Lint will test modules and manifests against the recommended Puppet style guidelines"

```
$ puppet-lint /etc/puppet/modules
foo/manifests/bar.pp - ERROR: trailing whitespace found on line 1
apache/manifests/server.pp - WARNING: variable not enclosed in {} on line 56
...
```

http://puppet-lint.com/

Infrastructure as Code

Testing: Unit Tests (Example: rspec-puppet)

Assert expectations of actions defined in infrastructure code file — by testing resulting resources

```
it do
  is_expected.to contain_user('luke').only_with(
    'ensure' => 'present',
    'uid'    => '501'
  )
end
…
it { is_expected.to contain_service('keystone').without(
  ['restart', 'status']
)}
```

Infrastructure as Code

Testing: Unit Tests (Example: serverspec)

Assert expectations of actions defined in infrastructure code file — by testing server's **actual state**

```
describe service('apache2') do
  it { should be_enabled }
  it { should be_running }
end
…
describe port(80) do
  it { should be_listening }
end
```

Different Approaches to Infrastructure Automation

“Baking” Images

> Amazon Machine Images (AMI), Packer/Vagrant

> Speeds up provisioning

PaaS Deployment

> Previously packaged in specific format. Has to adhere to guildelines, less overall freedom (Buildpacks in Heroku, CloudFoundry)

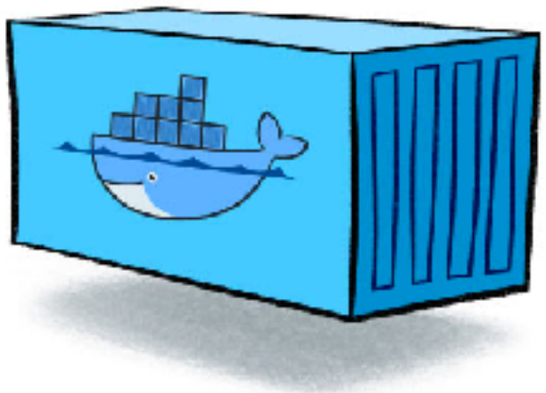
> Container Cloud Deployment on the rise

LXC

Containers:

Mix of packaging and means for infrastructure automation

Docker Containers



What is Docker?

Docker allows you to package an application with all of its dependencies into a standardized unit for software development

Containers consist of everything that enables software to run:

> Code

> Runtime

> System Tools

> System Libraries

* https://www.docker.com/what-docker

Technical Overview / Virtual Machines vs Containers

“Lightweight” VM

> Container is an isolated process

(*“chroot on steroids”*)

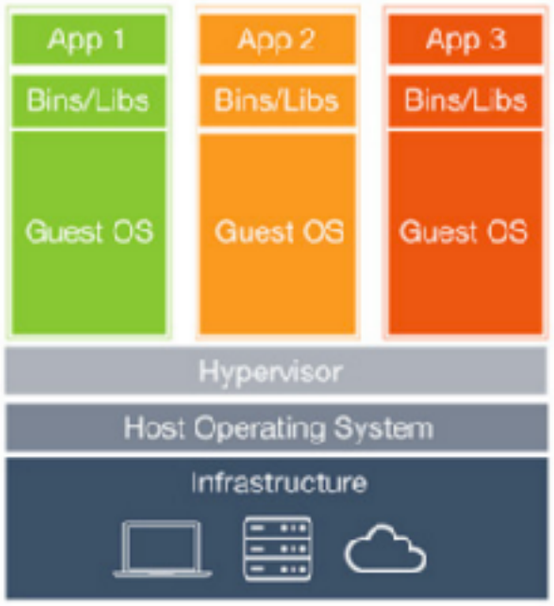
> Own process space

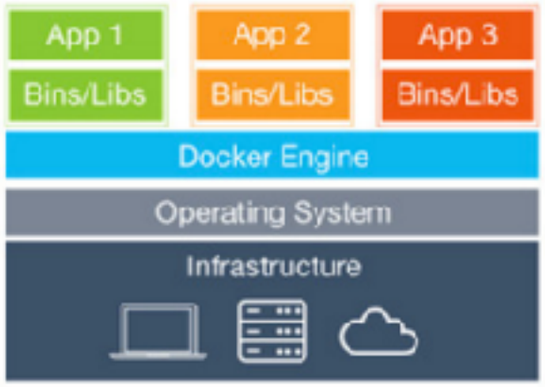
> Own network interface

> Feels like a VM

> Share kernel with the host

> Isolation through cgroups/namespaces





https://www.docker.com/what-is-docker

https://blog.docker.com/2016/03/containers-are-not-vms/

Docker Engine

Centralized runtime environment for containers

Enables portability

Sole dependency for Docker

No Emulation layer (almost no performance impact)

https://www.docker.com/products/docker-engine

Benefits of Docker Containers

Fast instantiation (~1-3 seconds)

Almost native performance

Transparent build process

Smaller Images

Easy to build, share, and publish

also compared to
other container technology

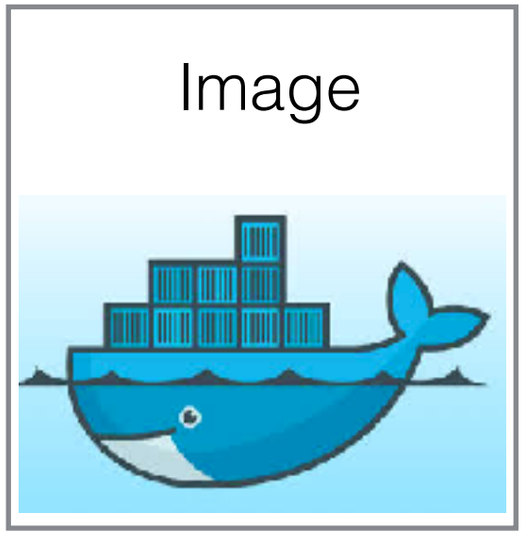
* https://www.docker.com/what-docker

Local Docker Workflow

```
# Build redis from source
# Make sure you have the redis source code
checked out in
# the same directory as this Dockerfile

FROM ubuntu:12.04
MAINTAINER dockerfiles http://
dockerfiles.github.io

RUN echo "deb http://archive.ubuntu.com/
ubuntu precise main universe" > /etc/apt/
sources.list
RUN apt-get update
RUN apt-get upgrade -y

RUN apt-get install -y gcc make g++ build-
essential libc6-dev tcl wget

RUN wget http://download.redis.io/redis-
stable.tar.gz -O - | tar -xvz

# RUN tar -zvzf /redis/redis-stable.tar.gz
RUN (cd /redis-stable && make)
RUN (cd /redis-stable && make test)

RUN mkdir -p /redis-data
VOLUME ["/redis-data"]
EXPOSE 6379

ENTRYPOINT ["/redis-stable/src/redis-
server"]
CMD ["--dir", "/redis-data"]
```

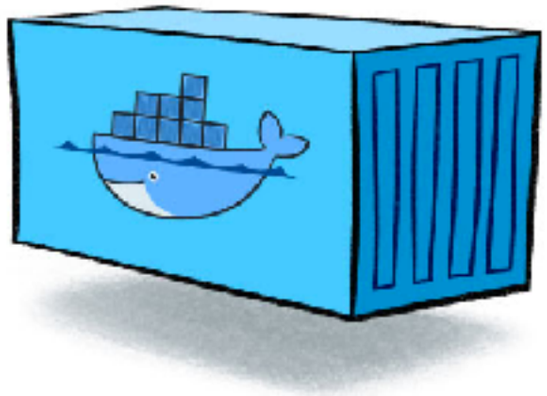
Dockerfile

build



Docker Image

run



Docker Container

Terminology

Dockerfile

Declarative definition of an environment for producing an image

Docker Image

Immutable artifact built from a Dockerfile, has one to many layers.

Docker Container

Execution environment - Instantiation/running version of an image (can be parameterized)

Docker Registry

Public or private repository that stores allows for distribution of images

(Docker Hub - https://hub.docker.com/ or CoreOS Quay - https://quay.io/)

Local Docker Workflow

```
# Build redis from source
# Make sure you have the redis source code
checked out in
# the same directory as this Dockerfile

FROM ubuntu:12.04
MAINTAINER dockerfiles http://
dockerfiles.github.io

RUN echo "deb http://archive.ubuntu.com/
ubuntu precise main universe" > /etc/apt/
sources.list
RUN apt-get update
RUN apt-get upgrade -y

RUN apt-get install -y gcc make g++ build-
essential libc6-dev tcl wget

RUN wget http://download.redis.io/redis-
stable.tar.gz -O - | tar -xvz

# RUN tar -zvzf /redis/redis-stable.tar.gz
RUN (cd /redis-stable && make)
RUN (cd /redis-stable && make test)

RUN mkdir -p /redis-data
VOLUME ["/redis-data"]
EXPOSE 6379

ENTRYPOINT ["/redis-stable/src/redis-
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CMD ["--dir", "/redis-data"]
```
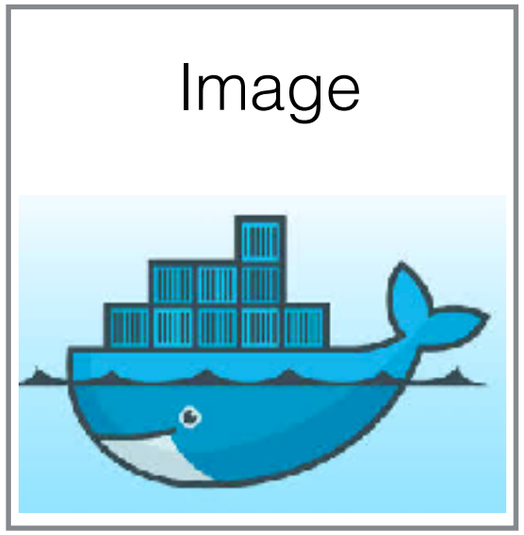
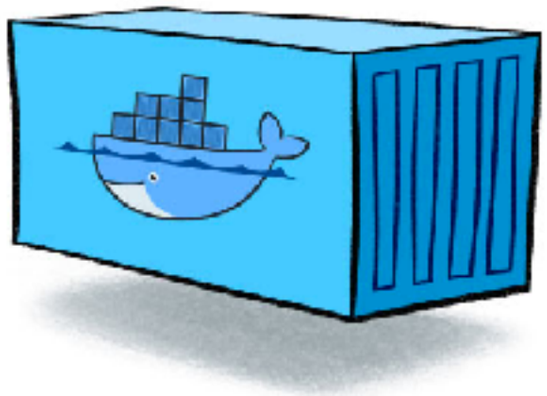

Dockerfile

build



Docker Image

run



Docker Container

Dockerfile

Definition of infrastructure and dependencies of a container through instructions

```
# Build redis from source
# Make sure you have the redis source code checked out in
# the same directory as this Dockerfile

FROM ubuntu:12.04
MAINTAINER dockerfiles

RUN echo "deb http://archive.ubuntu.com/ubuntu precise main universe" > /etc/apt/
sources.list
RUN apt-get update
RUN apt-get upgrade -y

RUN apt-get install -y gcc make g++ build-essential libc6-dev tcl wget
RUN wget http://download.redis.io/redis-stable.tar.gz -O - | tar -xvz

# RUN tar -zvzf /redis/redis-stable.tar.gz
RUN (cd /redis-stable && make)
RUN (cd /redis-stable && make test)

COPY redis.conf /var/www/redis.conf

RUN mkdir -p /redis-data
VOLUME ["/redis-data"]
EXPOSE 6379

ENTRYPOINT ["/redis-stable/src/redis-server"]
CMD ["--dir", "/redis-data"]
```

Base Image can be an OS (Ubuntu) or a different, existing image

Runs commands as if you were typing them in the command line

Dependencies

Install

Copies local files from build context into container

Volume
Open Port

Start Server

Data Volumes

A specially-designated directory within one or more containers that bypasses the Union File System*

Volumes allow you to manage data within containers

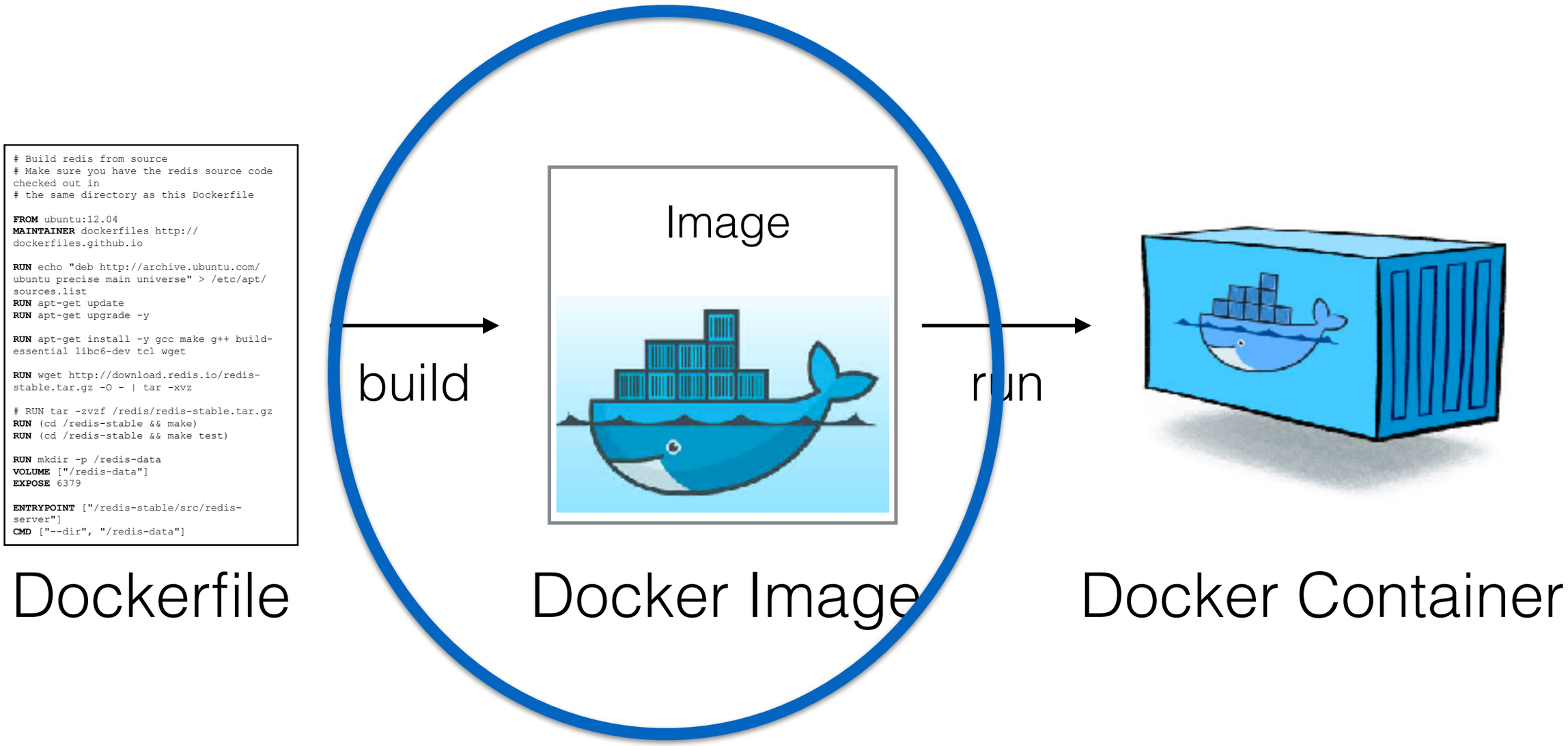
> Mount a host directory (dependency to the host filesystem)

> Mount a data volume container (dependency to another container)

> Mount a shared-storage volume (NFS, iSCSI, etc.)

* https://docs.docker.com/engine/userguide/containers/dockervolumes/

Local Docker Workflow



Dockerfile —> Image

Definition of infrastructure and dependencies of a container through instructions

```
docker build -t <imagename> .
```

Build Context

containing all local dependencies and Dockerfile

Docker Images

Lists all previously built images

```
# docker images
REPOSITORY          TAG     IMAGE ID      CREATED          SIZE
mhart/alpine-node   latest  2a15d8568f75  1 week ago       36.76 MB
hakyll              latest  d575da1e730c  2 weeks ago      1.487 GB
redis               alpine  50405530a7e5  4 weeks ago      15.95 MB
```

```
# docker rmi hakyll
Untagged: hakyll:latest
Deleted: sha256:3240943c9ea3f72db51…
Deleted: sha256:a3aeefae0d4b8f61…
Deleted: sha256:16a7ebd378002f1261…
```

Removes image 'hakyll' and all its layers from disk

Local Docker Workflow

```
# Build redis from source
# Make sure you have the redis source code
checked out in
# the same directory as this Dockerfile

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MAINTAINER dockerfiles http://
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RUN echo "deb http://archive.ubuntu.com/
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sources.list
RUN apt-get update
RUN apt-get upgrade -y

RUN apt-get install -y gcc make g++ build-
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EXPOSE 6379

ENTRYPOINT ["/redis-stable/src/redis-
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CMD ["--dir", "/redis-data"]
```
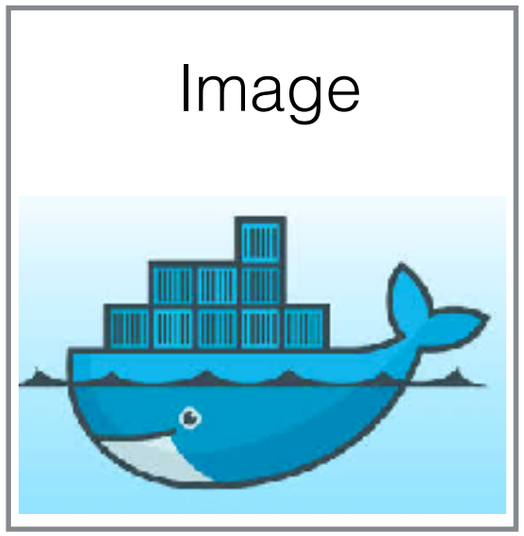
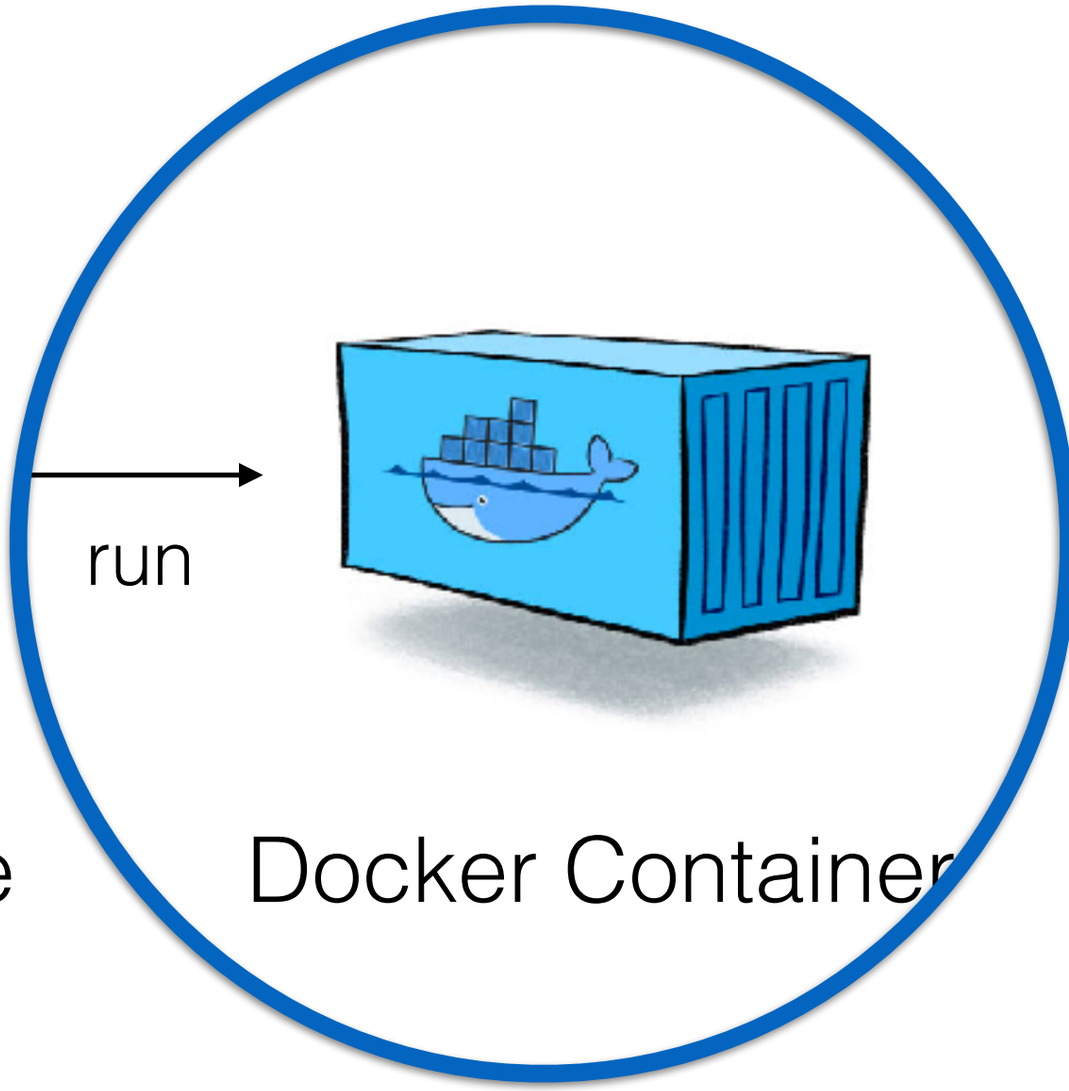

Dockerfile

build



Docker Image

run



Docker Container

Image —> Container

(A typical example)

```
docker run -d --name <containername> -p 80:5000 <imagename>
```

Give the container
a unique name

Run container
in the background
(d for daemon)

Port mapping

First the exposed port (80)

Second the port within the container (5000)

Many more possibilities to run containers, see full reference here:

https://docs.docker.com/engine/reference/run/

Container Management

```
docker ps
```

List all running containers

```
docker ps -a
```

List all containers (also stopped)

```
docker stop <container>
```

Stop a running container

```
docker rm <container>
```

Remove a stopped container

Container Debugging

```
# docker inspect <container>
```

Low-level information on a container or image

```
# docker exec -ti <container> bash
```

Start an interactive shell into a running container

```
# docker run -ti --entrypoint=bash <imagename>
```

Start image with a different entrypoint

Docker Hub: Public Registry

Explore Help nginx Sign up Log In

OFFICIAL REPOSITORY

nginx ☆

Last pushed: 4 days ago

Repo Info Tags

Short Description

Official build of Nginx.

Docker Pull Command

```
docker pull nginx
```

Full Description

Supported tags and respective `Dockerfile` links

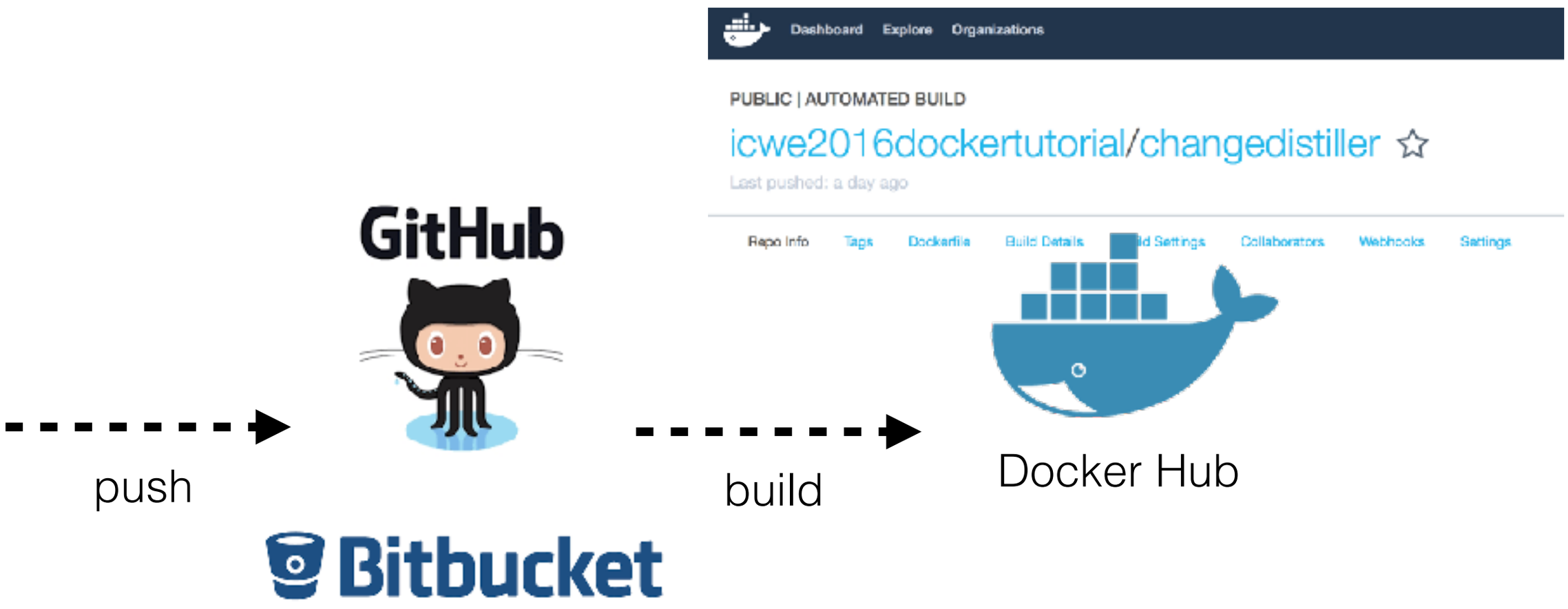
- `latest`, `1`, `1.9`, `1.9.15` (*mainline/jessie/Dockerfile*)
- `stable`, `1.10`, `1.10.0` (*stable/jessie/Dockerfile*)
- `mainline-alpine`, `alpine`, `1-alpine`, `1.9-alpine`, `1.9.15-alpine` (*mainline/alpine/Dockerfile*)
- `stable-alpine`, `1.10-alpine`, `1.10.0-alpine` (*stable/alpine/Dockerfile*)

ImageLayers.io 183 MB / 8 Layers

For more information about this image and its history, please see the relevant manifest file (`library/nginx`). This image is updated via pull requests to the `docker-library/official-images`

Docker Hub: Automated/Trusted Build

Improves transparency



https://docs.docker.com/docker-hub/builds/

Cloud Deployment

Infrastructure as Code, Containerization
Summary

Means of automating infrastructure provisioning

Provides formal definition and documentation of infrastructure and configuration

Enables use of software engineering best practices

Encourages reuse of infrastructure code even beyond organisational boundaries (Dockerhub, Chef Recipes, etc.)

Containers also allow a way of packaging application into a standardized unit for deployment in different stages