DOCKER

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Introduction to Containerization

According to IBM,
Containerization involves encapsulating or packaging up software code and all its dependencies so that it can run uniformly and consistently on any infrastructure.

How to avoid *"but, it runs on my machine"*?

1. Develop and run the application inside an isolated environment (known as a container) that matches your final deployment environment.
2. Put the application inside a single file (known as an image) along with all its dependencies and necessary deployment configurations.
3. And share that image through a central server (known as a registry) that is accessible by anyone with proper authorization.

What role does Docker play ?

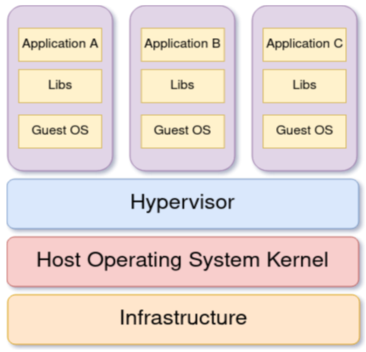
Docker is an implementation of containerization idea. It's an open-source platform that allows to containerize applications, share them using public or private registries, and also to orchestrate them.

Docker Container

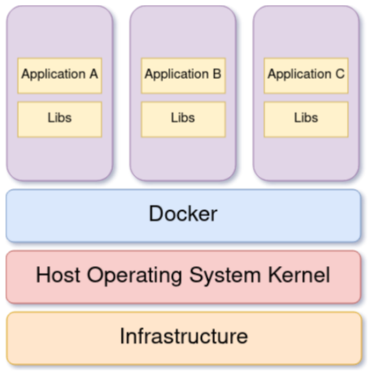
A container is an abstraction at the application layer that packages code and dependencies together. Instead of virtualizing the entire physical machine, containers virtualize the host operating system only.

Containers vs Virtual Machines

Containers and virtual machines are actually different ways of virtualizing your physical hardware. The main difference between these two is the method of virtualization. Virtual machines are usually created and managed by a program known as a hypervisor, like Oracle VM VirtualBox, VMware Workstation, KVM, Microsoft Hyper-V and so on. This hypervisor program usually sits between the host operating system and the virtual machines to act as a medium of communication.



Each virtual machine comes with its own guest operating system which is just as heavy as the host operating system.
The application running inside a virtual machine communicates with the guest operating system, which talks to the hypervisor, which then in turn talks to the host operating system to allocate necessary resources from the physical infrastructure to the running application.
As you can see, there is a long chain of communication between applications running inside virtual machines and the physical infrastructure. The application running inside the virtual machine may take only a small amount of resources, but the guest operating system adds a noticeable overhead.
Unlike a virtual machine, a container does the job of virtualization in a smarter way. Instead of having a complete guest operating system inside a container, it just utilizes the host operating system via the container runtime while maintaining isolation – just like a traditional virtual machine.



The container runtime, that is Docker, sits between the containers and the host operating system instead of a hypervisor. The containers then communicate with the container runtime which then communicates with the host operating system to get necessary resources from the physical infrastructure.
As a result of eliminating the entire guest operating system layer, containers are much lighter and less resource-hogging than traditional virtual machines. *Containers virtualize the host operating system instead of having an operating system of their own.*

Docker Image

Images are multi-layered self-contained files that act as the template for creating containers. They are like a frozen, read-only copy of a container. Images can be exchanged through registries. In the past, different container engines had different image formats. But later on, the Open Container Initiative (OCI) defined a standard specification for container images which is complied by the major containerization engines out there. This means that an image built with Docker can be used with another runtime like Podman without any additional hassle.
Containers are just images in running state. When you obtain an image from the internet and run a container using that image, you essentially create another temporary writable layer on top of the previous read-only ones.

Docker Registry

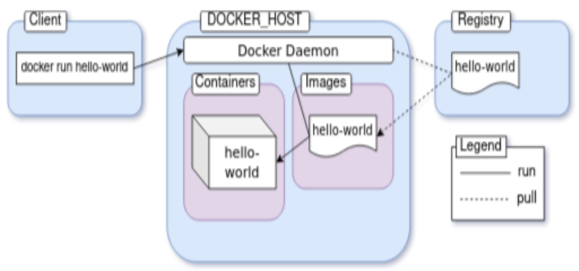
An image registry is a centralized place where you can upload your images and can also download images created by others. Docker Hub is the default public registry for Docker. Another very popular image registry is Quay by Red Hat. Apart from Docker Hub or Quay, you can also create your own image registry for hosting private images. There is also a local registry that runs within your computer that caches images pulled from remote registries.

Docker Architecture

1. Docker Daemon: The daemon (dockerd) is a process that keeps running in the background and waits for commands from the client. The daemon is capable of managing various Docker objects.
2. Docker Client: The client (docker) is a command-line interface program mostly responsible for transporting commands issued by users.
3. REST API: The REST API acts as a bridge between the daemon and the client. Any command issued using the client passes through the API to finally reach the daemon.

According to the official docs,
"Docker uses a client-server architecture. The Docker client talks to the Docker daemon, which does the heavy lifting of building, running, and distributing your Docker containers".

Demonstration



1. You execute *docker run hello-world* command where *hello-world* is the name of an image.
2. Docker client reaches out to the daemon, tells it to get the *hello-world* image and run a container from that.
3. Docker daemon looks for the image within your local repository and realizes that it's not there, resulting in the *Unable to find image 'hello-world:latest' locally* that's printed on your terminal.
4. The daemon then reaches out to the default public registry which is Docker Hub and pulls in the latest copy of the *hello-world* image, indicated by the *latest: Pulling from library/hello-world* line in your terminal.
5. Docker daemon then creates a new container from the freshly pulled image.
6. Finally Docker daemon runs the container created using the *hello-world* image outputting the wall of text on your terminal.

Docker Container Manipulation

Run a Container

```
    docker <object> <command> <options>
```

In this syntax:

- *object* indicates the type of Docker object you'll be manipulating. This can be a container, image, network or volume object.
- *command* indicates the task to be carried out by the daemon, that is the run command.
- *options* can be any valid parameter that can override the default behavior of the command, like the –publish option for port mapping.

Publish Port

Containers are isolated environments. Your host system doesn't know anything about what's going on inside a container. Hence, applications running inside a container remain inaccessible from the outside.
To allow access from outside of a container, you must publish the appropriate port inside the container to a port on your local network.

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

8080:80 means any request sent to port 8080 of your host system will be forwarded to port 80 inside the container.

Use Detached Mode

Closing the terminal window also stopped the running container.
This is because, by default, containers run in the foreground and attach themselves to the terminal like any other normal program invoked from the terminal.
In order to override this behavior and keep a container running in background, you can include the –detach option with the run command.

```
    docker container run --detach --publish
<local Network port>:<Container port> <image name>
```

List Containers

```
    docker container ls -all
```

Name or Rename a Container

By default, every container has two identifiers. They are as follows:

- CONTAINER ID - a random 64 character-long string.
- NAME - combination of two random words, joined with an underscore.

```
docker container run --detach --publish <local Network port>:
<Container port> --name <name> <image name>
docker container rename <container identifier> <new name>
```

Stop or Kill a Container

The stop command shuts down a container gracefully by sending a *SIGTERM* signal. If the container doesn't stop within a certain period, a *SIGKILL* signal is sent which shuts down the container immediately.
In cases where you want to send a *SIGKILL* signal instead of a *SIGTERM* signal, you may use the container kill

```
    docker container stop <container identifier>
    docker container kill <container identifier>
```

Start or Restart a Container

```
    docker container start <container identifier>
    docker container restart <container identifier>
```

Create a Container Without Running

Container run command which is in reality a combination of two separate commands. These commands are as follows:

- container create command creates a container from a given image.
- container start command starts a container that has been already created.

```
docker container create --publish <local Network port>:
<Container port> --name <name> <image name>
```

Remove Dangling Containers

```
    docker container rm <container identifier>
    docker container prune
```

Run a Container in Interactive Mode

Images can execute simple programs and also can encapsulate an entire application (Linux distribution) inside them. Popular distributions such as Ubuntu, Fedora, and Debian all have official Docker images available in the hub. Programming languages such as python, php, go or run-times like node and deno all have their official images.
These images do not just run some pre-configured program. These are instead configured to run a shell by default. In case of the operating system images it can be something like sh or bash and in case of the programming languages or run-times, it is usually their default language shell. *shell is a computer program which exposes an operating system's services to a human user or other programs. In general, operating system shells use either a command-line interface (CLI) or graphical user interface (GUI), depending on a computer's role and particular operation. It is named a shell because it is the outermost layer around the operating system.*

```
    docker container run --rm -it <docker image>
```

The -it option sets the stage for you to interact with any interactive program inside a container. This option is actually two separate options mashed together.

- The *-i* or *–interactive* option connects you to the input stream of the container, so that you can send inputs to bash.
- The *-t* or *–tty* option makes sure that you get some good formatting and a native terminal-like experience by allocating a pseudo-tty.

Execute Commands Inside a Container

```
    docker container run <image name> <command>
```

What happens here is that, in a container run command, whatever you pass after the image name gets passed to the default entry point of the image.
An entry point is like a gateway to the image. Most of the images except the executable images use shell or sh as the default entry-point. So any valid shell command can be passed to them as arguments.

Work With Executable Images

These images are designed to behave like executable programs.

Bind Mount

A bind mount lets you form a two way data binding between the content of a local file system directory (source) and another directory inside a container (destination). This way any changes made in the destination directory will take effect on the source directory and vise versa.

```
--volume or -v <local file system directory
absolute path>:<container file system directory
absolute path>:<read write access>
```

The difference between a regular image and an executable one is that the entry-point for an executable image is set to a custom program instead of sh.

Docker Image Manipulation

Create a Docker Image

A **Dockerfile** is a collection of instructions that, once processed by the daemon, results in an image.

1. Create a new file named Dockerfile inside that directory
2. Content as follows :

   ```
   FROM <the base image for resultant image>
   EXPOSE <indicate the port needs to be published>
   RUN <executes command inside container shell>
   CMD <sets the default command for the image>
   ```

3. Build the image

   ```
   docker image <command> <options>
   docker image build .
   ```

   (a) docker image build is the command for building the image. The daemon finds any file named Dockerfile within the context.

   (b) The . at the end sets the context for this build. The context means the directory accessible by the daemon during the build process.

Tag Docker Images

```
docker image build --tag <image repository>:<image tag>
docker image tag <im id> <im repository>:<image tag>
```

List and Remove Docker Images

```
docker image ls
docker image rm <image identifier>
docker image prune --force
```

image prune command cleanup all un-tagged dangling images. The –force or -f option skips any confirmation questions.

Understand the Many Layers of a Docker Image

The image comprises of many read-only layers, each recording a new set of changes to the state triggered by certain instructions. When start a container using an image, we get a new writable layer on top of the other layers.
This layering phenomenon that happens every time you work with Docker has been made possible by an amazing technical concept called a union file system. Here, union means union in set theory. *According to Wikipedia -*
It allows files and directories of separate file systems, known as branches, to be transparently overlaid, forming a single coherent file system. Contents of directories which have the same path within the merged branches will be seen together in a single merged directory, within the new, virtual filesystem.
By utilizing this concept, Docker can avoid data duplication and can use previously created layers as a cache for later builds. This results in compact, efficient images that can be used everywhere.