Introduction to OS-Level Virtualization on Linux

Pedro Bruel
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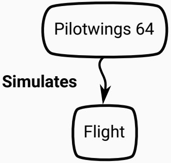
May 25th, 2020

What are Simulation, Emulation, Virtualization?



Pilotwings 64

Simulates

Flight

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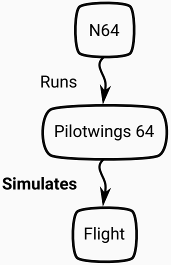

N64

Runs

Pilotwings 64

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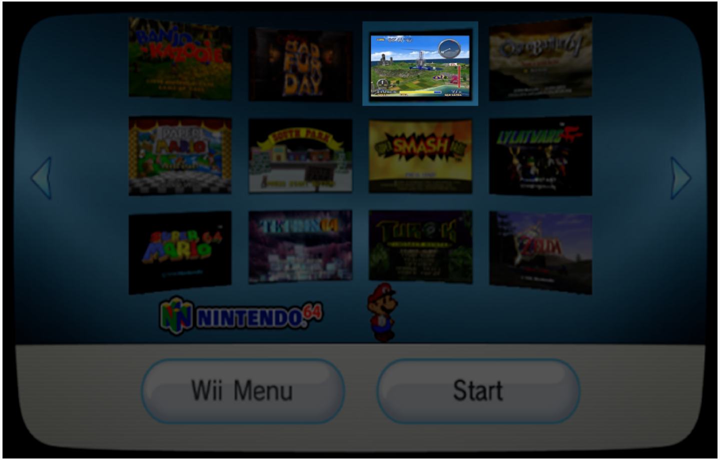

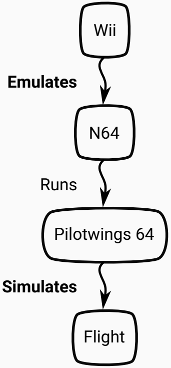
Wii

Emulates

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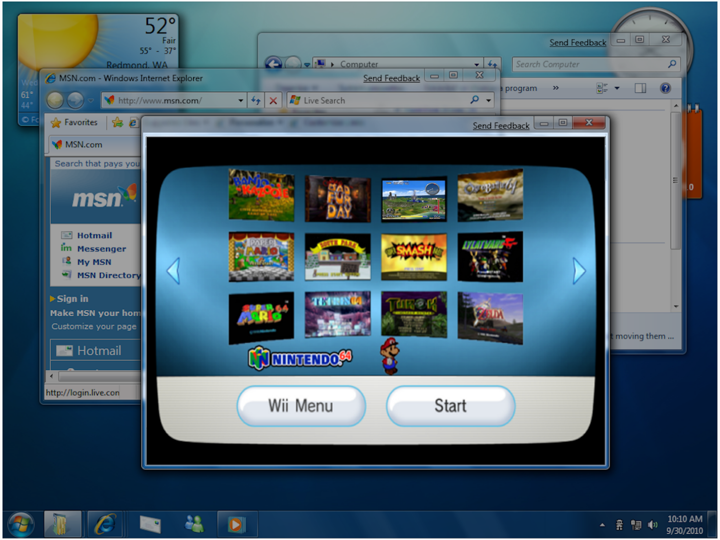

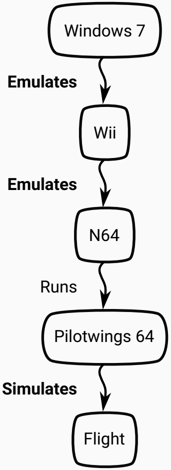
Windows 7

Emulates

Wii

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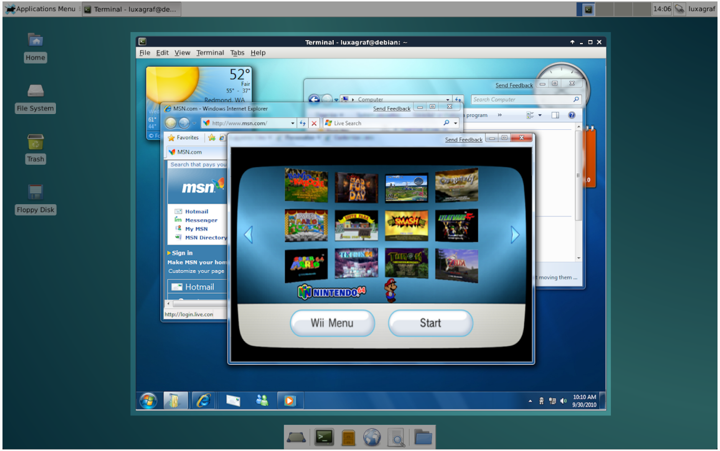

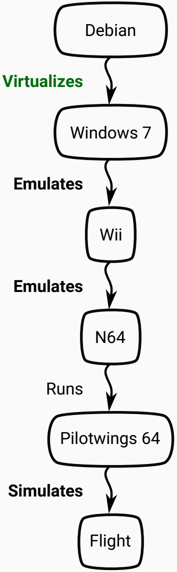

Debian

Virtualizes

Windows 7

Emulates

Wii

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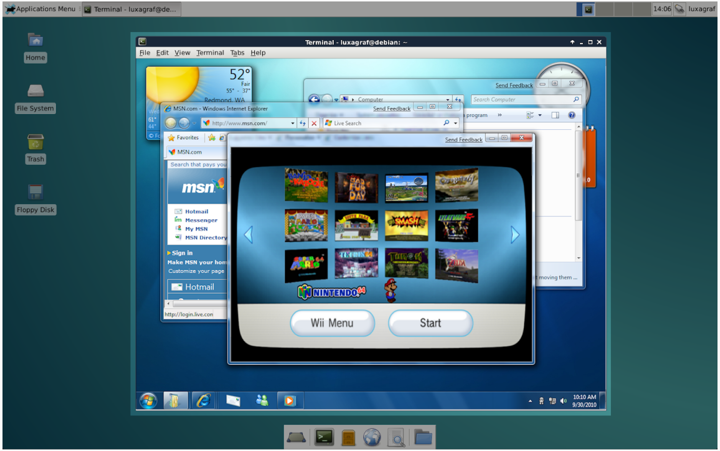

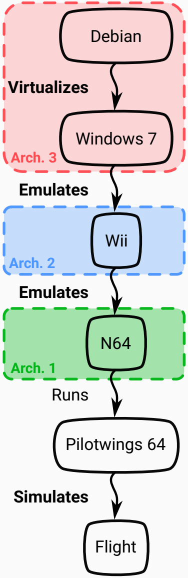
Debian

Virtualizes

Windows 7

Arch. 3

Emulates

Wii

Arch. 2

Emulates

N64

Arch. 1

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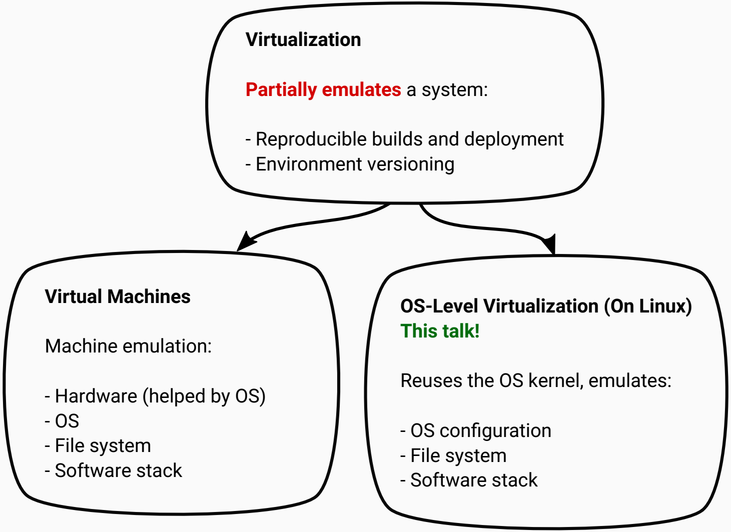
OS-Level Virtualization



Virtualization

Partially emulates a system:

- Reproducible builds and deployment
- Environment versioning

Virtual Machines

Machine emulation:

- Hardware (helped by OS)
- OS
- File system
- Software stack

OS-Level Virtualization (On Linux)
This talk!

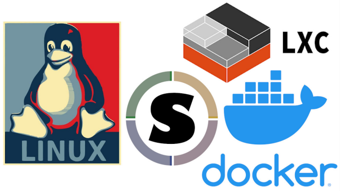
Reuses the OS kernel, emulates:

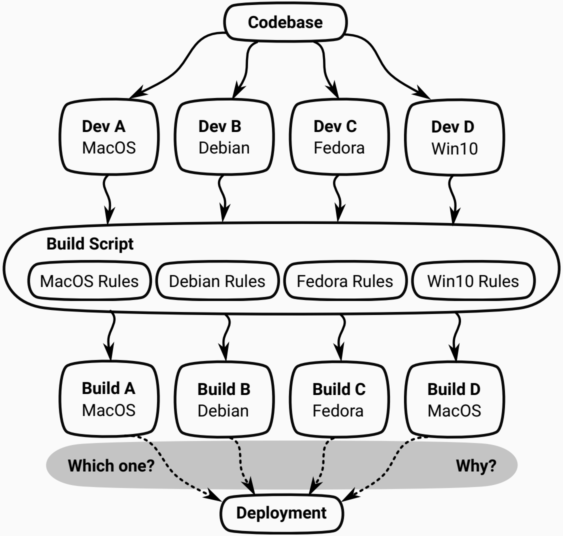
- OS configuration
- File system
- Software stack

OS-Level Virtualization: Scope of this Talk

Scope

- Why should you use containers?
    - Reproducible builds
    - Environment versioning
    - It's also easier
- How do containers work?
- What tools are available?





OS-Level Virtualization: Scope of this Talk

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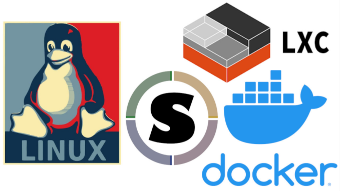
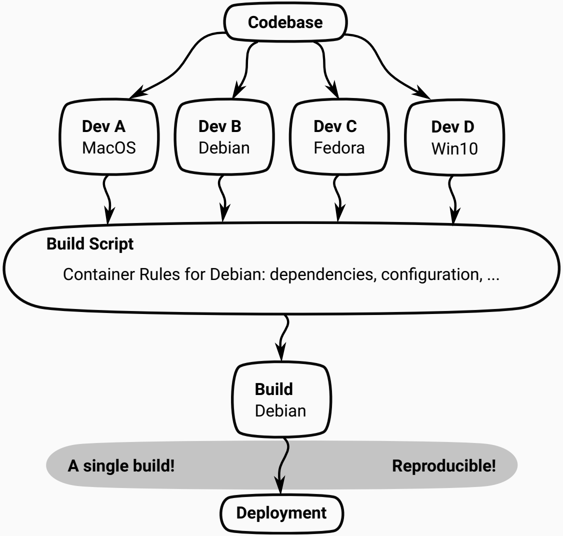
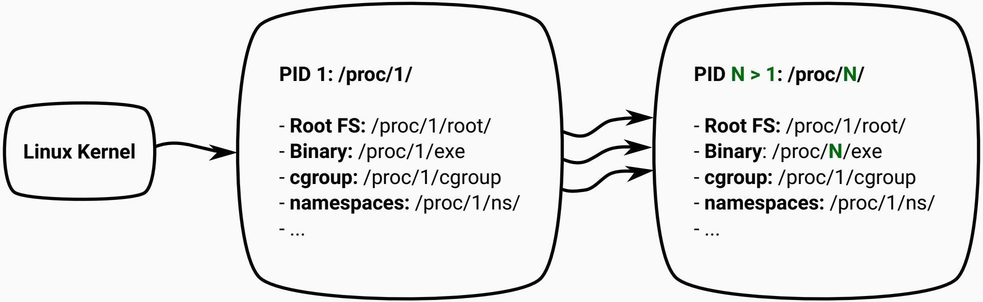




OS-Level Virtualization on Linux



Linux Kernel

PID 1: /proc/1/

- **Root FS:** /proc/1/root/
- **Binary:** /proc/1/exe
- **cgroup:** /proc/1/cgroup
- **namespaces:** /proc/1/ns/
- ...

PID N > 1: /proc/N/

- **Root FS:** /proc/1/root/
- **Binary**: /proc/N/exe
- **cgroup:** /proc/1/cgroup
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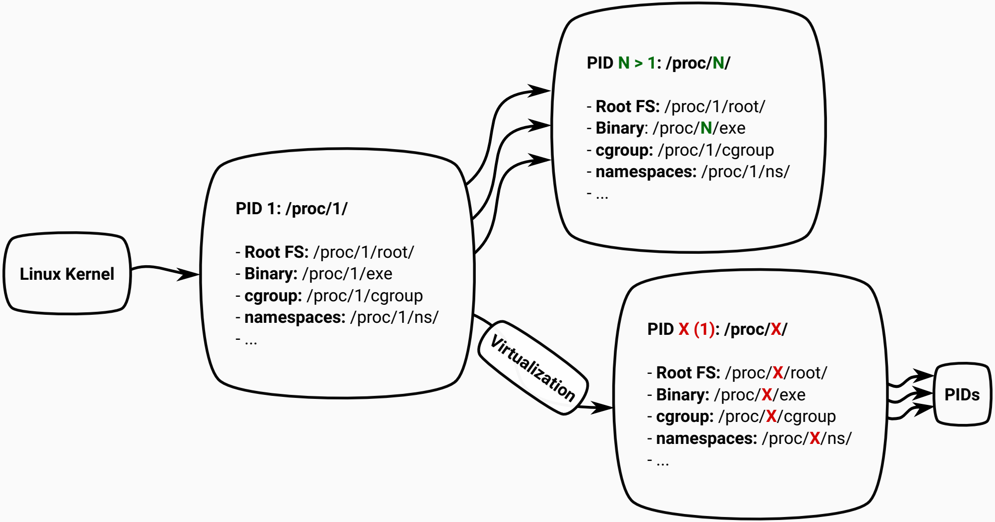
- ...

OS-Level Virtualization on Linux



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Virtualization

PID X (1): /proc/X/

- **Root FS:** /proc/**X**/root/
- **Binary:** /proc/**X**/exe
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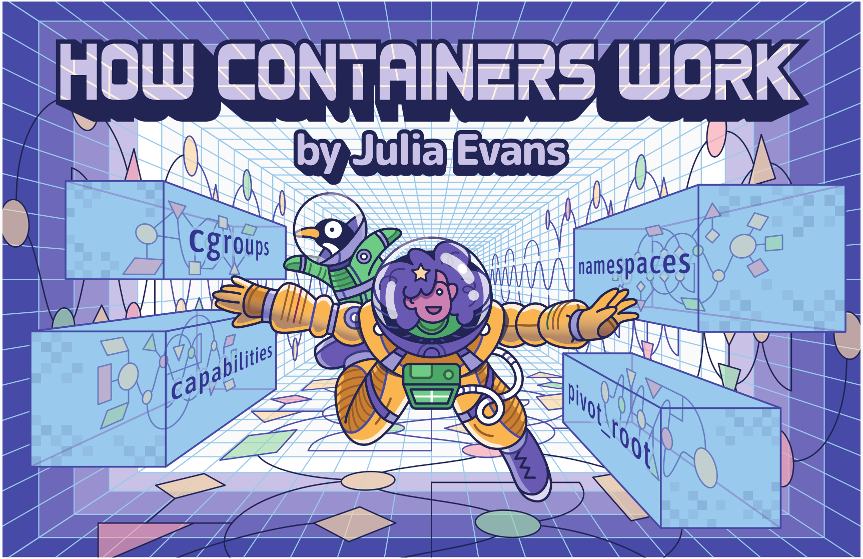
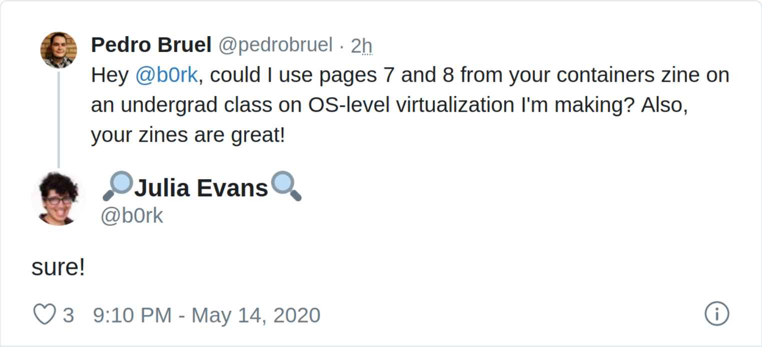
PIDs

How do Containers Work?



How do Containers Work?

Images used with permission:



Pedro Bruel @pedrobruel · 2h

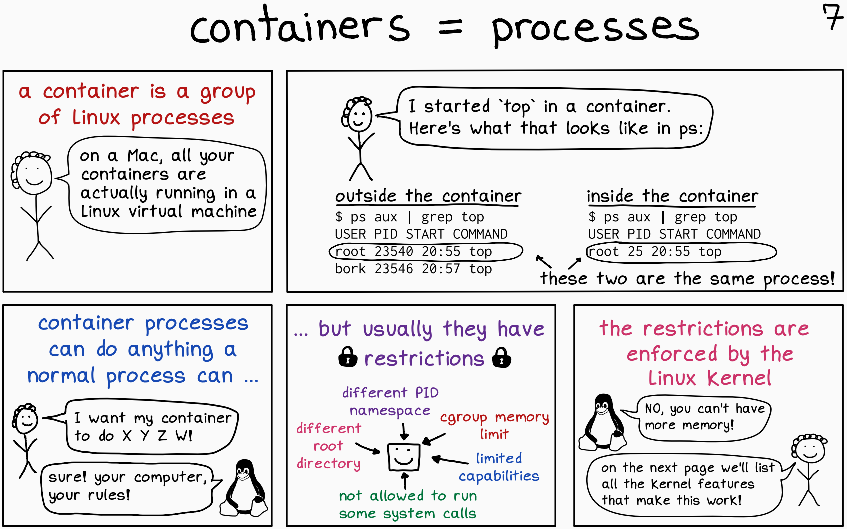
Hey @b0rk, could I use pages 7 and 8 from your containers zine on an undergrad class on OS-level virtualization I'm making? Also, your zines are great!

🔎**Julia Evans**🔍
@b0rk

sure!

♡ 3 9:10 PM - May 14, 2020

Containers on Linux are Just Processes



containers = processes

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a container is a group of Linux processes

on a Mac, all your containers are actually running in a Linux virtual machine
I started `top` in a container. Here's what that looks like in ps:

outside the container

```
$ ps aux | grep top
USER PID START COMMAND
root 23540 20:55 top
bork 23546 20:57 top
```

inside the container

```
$ ps aux | grep top
USER PID START COMMAND
root 25 20:55 top
```

these two are the same process!

container processes can do anything a normal process can ...

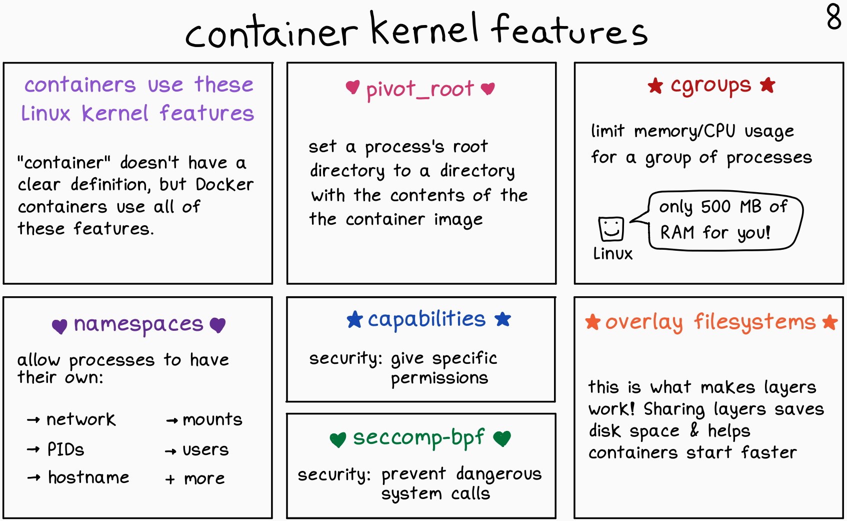
I want my container to do X Y Z W!
sure! your computer, your rules!

... but usually they have 🔒 restrictions 🔒

the restrictions are enforced by the Linux kernel

NO, you can't have more memory!
on the next page we'll list all the kernel features that make this work!

Containers on Linux use Some Kernel Features



container kernel features

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containers use these Linux kernel features

"container" doesn't have a clear definition, but Docker containers use all of these features.

♥ pivot_root ♥

set a process's root directory to a directory with the contents of the the container image

★ cgroups ★

limit memory/CPU usage for a group of processes

Linux
only 500 MB of RAM for you!

♥ namespaces ♥

allow processes to have their own:

- → network
- → PIDs
- → hostname
- → mounts
- → users
- + more

★ capabilities ★

security: give specific permissions

♥ seccomp-bpf ♥

security: prevent dangerous system calls

★ overlay filesystems ★

this is what makes layers work! Sharing layers saves disk space & helps containers start faster

Containers from Scratch: Obtaing an Image

An image usually means:

- A root file system, and
- Some metadata

We will use the Alpine distribution:

- It's root FS has only 2.4MB
- No need for metadata

Bash Script

```
#!/usr/bin/bash

IMG_DIR="alpine_img"
IMG_REPO="https://us.images.linuxcontainers.org/images"
IMG_URL="$IMG_REPO/alpine/3.11/amd64/default/20200521_13:00/rootfs.tar.xz"
[ ! -d $IMG_DIR ] && \
    mkdir -p $IMG_DIR && \
    curl $IMG_URL | tar xJ -C $IMG_DIR
```

Containers from Scratch: Creating cgroups and Setting Limits

We will create a cgroup allowing up to:

- 50% CPU usage: 512/1024 shares
- 10GB of RAM

Script

```
CGROUP_ID="MAC0475-145"
sudo cgcreate -g "cpu,cpuacct,memory:$CGROUP_ID"
sudo cgset -r cpu.shares=512 "$CGROUP_ID"
sudo cgset -r memory.limit_in_bytes=10000000000 "$CGROUP_ID"
```

Containers from Scratch: Launching our Alpine Container

- cgexec: Runs using a cgroup
- unshare: Runs with new namespaces
- chroot: Changes root of the file system
- mount: Here, mounts a new proc directory
- sh: Starts a shell on the container
- We could install depencies now

Script

```
HOSTNAME="alpine-container"
sudo cgexec -g "cpu,cpuacct,memory:$CGROUP_ID" \
     unshare -fmuipn --mount-proc \
     chroot "$IMG_DIR/" \
     /bin/sh -c "PATH=/bin && mount -t proc proc /proc && hostname $HOSTNAME && sh"
```

And some cleanup after:

```
sudo cgdelete cpu,cpuacct,memory:/$CGROUP_ID
```