


Lecture 2 - Introduction to VMs

DSE 511

Drew Schmidt
2022-08-30

Announcements

- No class THIS THURSDAY on 9/1 
- UTKDSE slack org
 - Everyone should have an invitation
 - Use channel `#dse511-fall2022` for public chat
- Homework 1 graded

Homework 1 Comments

- **Very** diverse student backgrounds
- Lots of interest in git and the shell!
- Most know some R and Python (or equivalent) already
- Almost everyone going native (not a VM)
- This semester: git, bash, ...
- Next semester: HPC, the cloud, performance optimization, ...

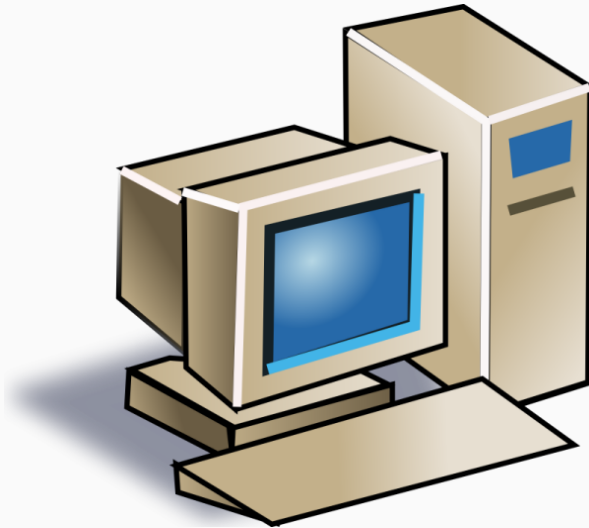
Today's Lecture

- VM Basics
- Setting Up a VM
- Installing Linux Software
- Wrapup

VM Basics

What Is a VM?

A VM is an entire OS living inside your OS.



What Is a VM?

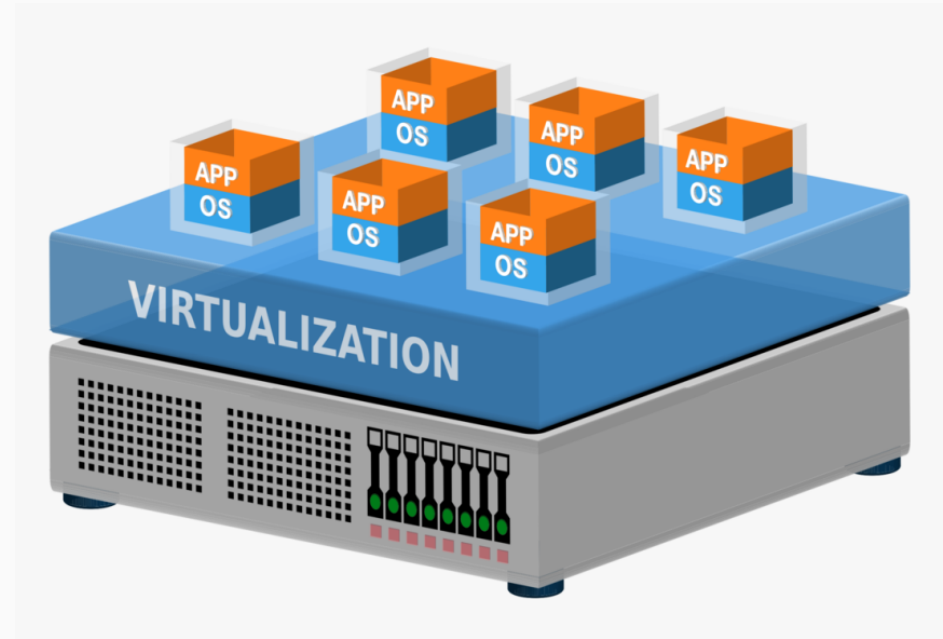
- Virtualization tool
- An OS inside your OS
- Now broadly lumped under "containerization" umbrella

History of Containerization

- 1980's: chroot
- 1990's: VM's
- 2000's: BSD Jails
- 2013: Docker
- 2016: Singularity
- 2016--Present: Kubernetes, OpenVZ, snap, flatpak, OpenShift, AND
MANY MORE

What Is a VM?

A Virtual Machine (VM) is a compute resource that uses **software** instead of a **physical computer** to run programs and deploy apps. One or more virtual "guest" machines run on a physical "host" machine. Each virtual machine runs its own operating system and functions separately from the other VMs, even when they are all running on the same host.



From <https://www.vmware.com/topics/glossary/content/virtual-machine.html>

Why Though?

Benefits

- Isolation
- Reproducibility
- Distribution

Common Uses

- Web services
- Dev environment
- CI builds
- Batch runs

"Portability"



Randy Zwitch

@randyzwitch



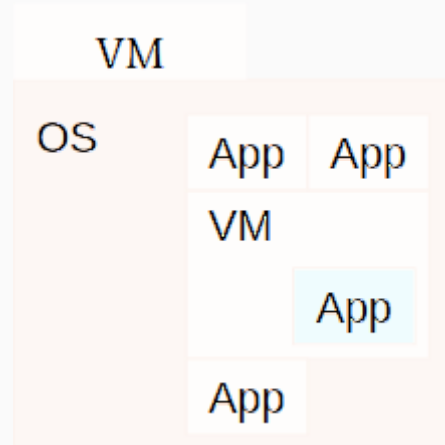
The only solution for python packaging is to mail your working computer to whomever wants to use your package

11:58 AM · Jan 3, 2019 · [TweetDeck](#)

50 Retweets **306** Likes

How A Program Runs in a VM

- Full OS installs on your hdd
- Has to boot!
- Shallow integration with host OS



VM Uses

- *The cloud*
- Running non-native arch binaries
- Distributing software (less common these days)

Hypervisors


- Runs the VM
- Native vs hosted...
- Common hypervisors
 - QEMU
 - VirtualBox
 - VMWare
 - Parallels (Mac)
 - KVM

Setting Up a VM

Installing a VM

- VM thinks it's a computer
- We have to install the OS
- This is a bit time consuming
- For most modern applications, Linux containers are a better solution
- We'll use VirtualBox for demonstration

Virtual Box Demo



Name and operating system

Please choose a descriptive name and destination folder for the new virtual machine and select the type of operating system you intend to install on it. The name you choose will be used throughout VirtualBox to identify this machine.


Name:

Machine Folder:

Type:

Version:

Virtual Box Demo



Memory size

Select the amount of memory (RAM) in megabytes to be allocated to the virtual machine.

The recommended memory size is **1024** MB.

4 MB

64512 MB

4096 MB

< Back

Next >

Cancel



Hard disk

If you wish you can add a virtual hard disk to the new machine. You can either create a new hard disk file or select one from the list or from another location using the folder icon.

If you need a more complex storage set-up you can skip this step and make the changes to the machine settings once the machine is created.

The recommended size of the hard disk is **10.00 GB**.

☐ Do not add a virtual hard disk

☒ Create a virtual hard disk now

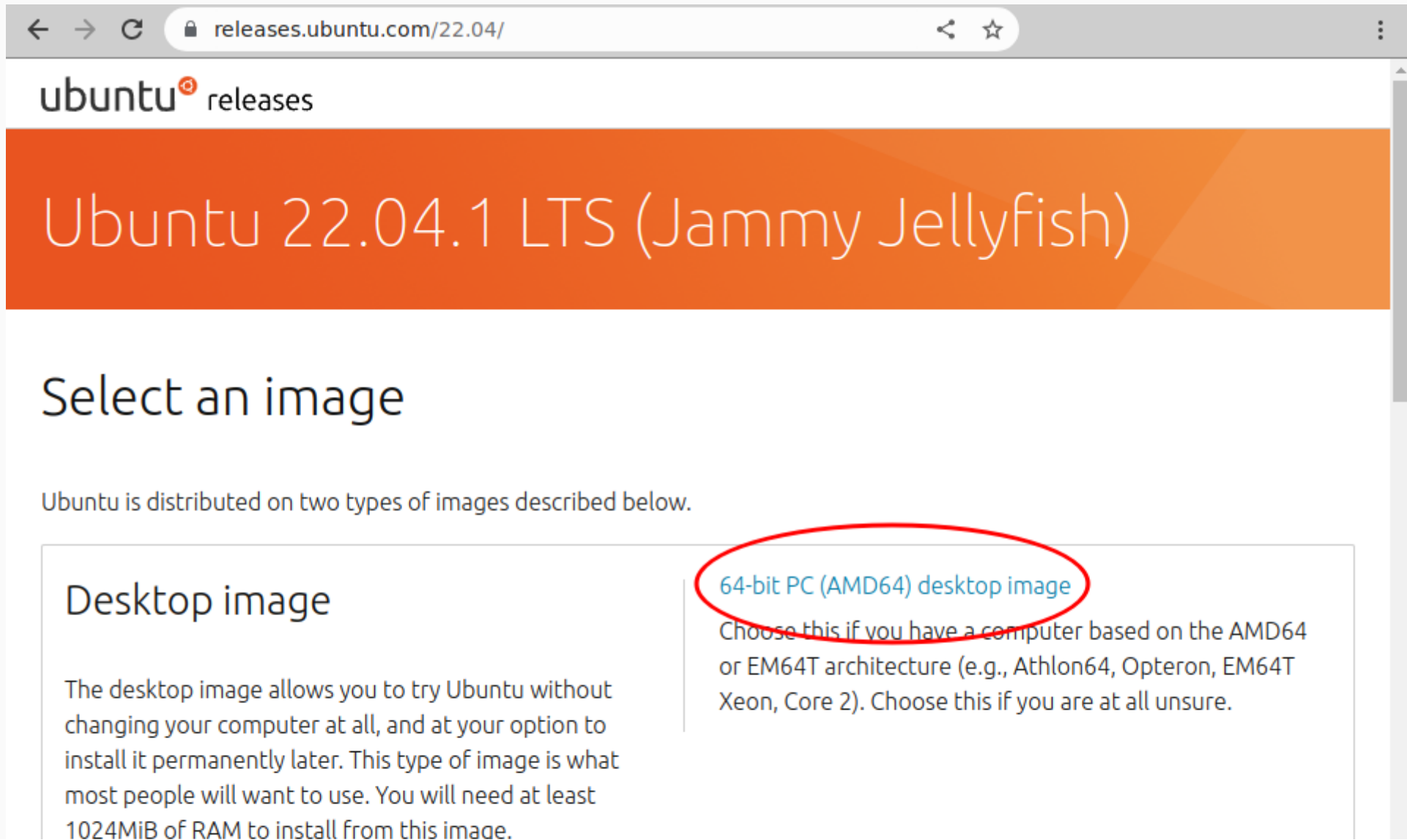
☐ Use an existing virtual hard disk file



< Back

Create

Cancel



← → ↻ releases.ubuntu.com/22.04/ 🔒 ⌵ ☆ ⋮

ubuntu⁺ releases

Ubuntu 22.04.1 LTS (Jammy Jellyfish)

Select an image

Ubuntu is distributed on two types of images described below.

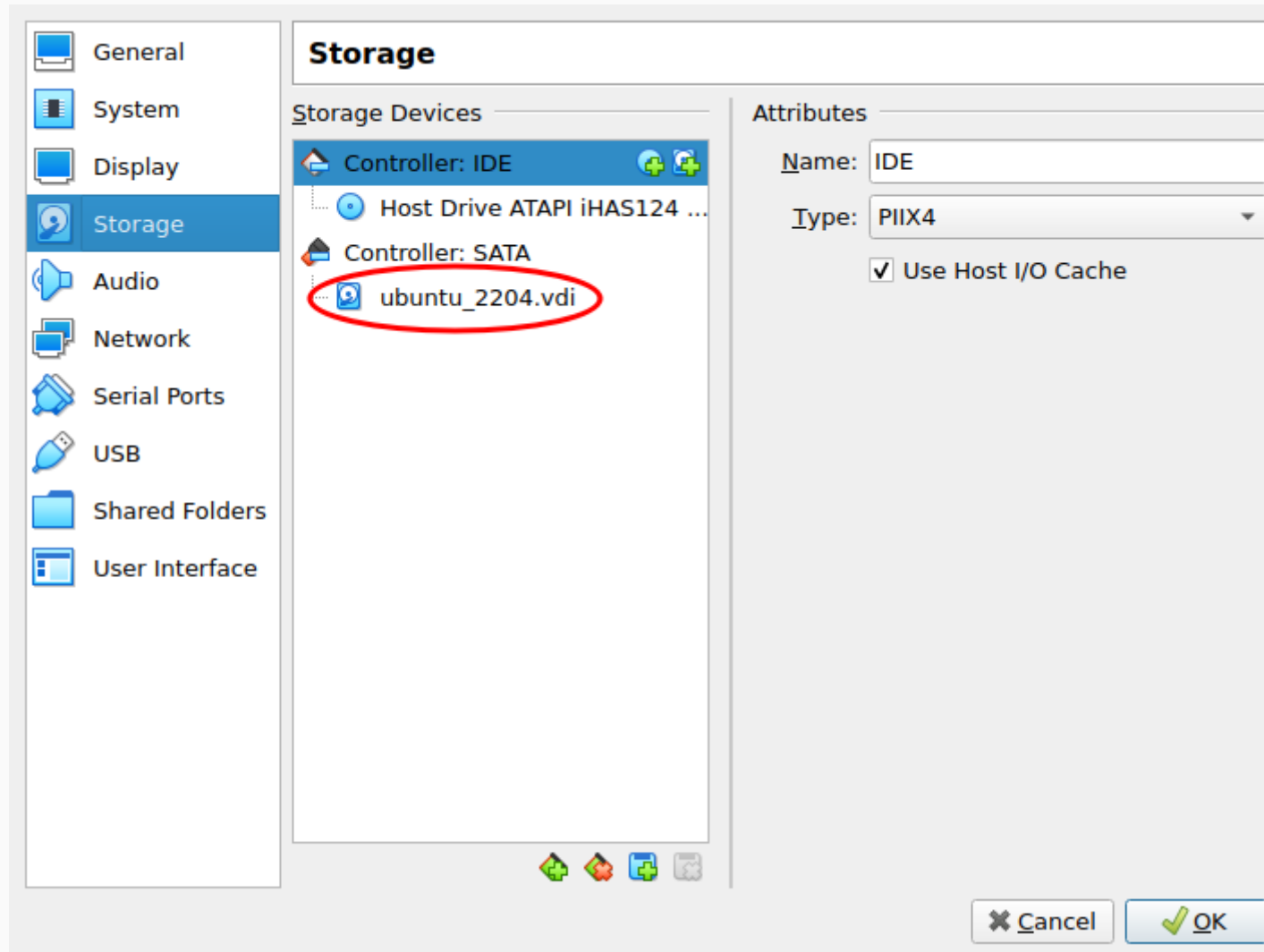
Desktop image

The desktop image allows you to try Ubuntu without changing your computer at all, and at your option to install it permanently later. This type of image is what most people will want to use. You will need at least 1024MiB of RAM to install from this image.

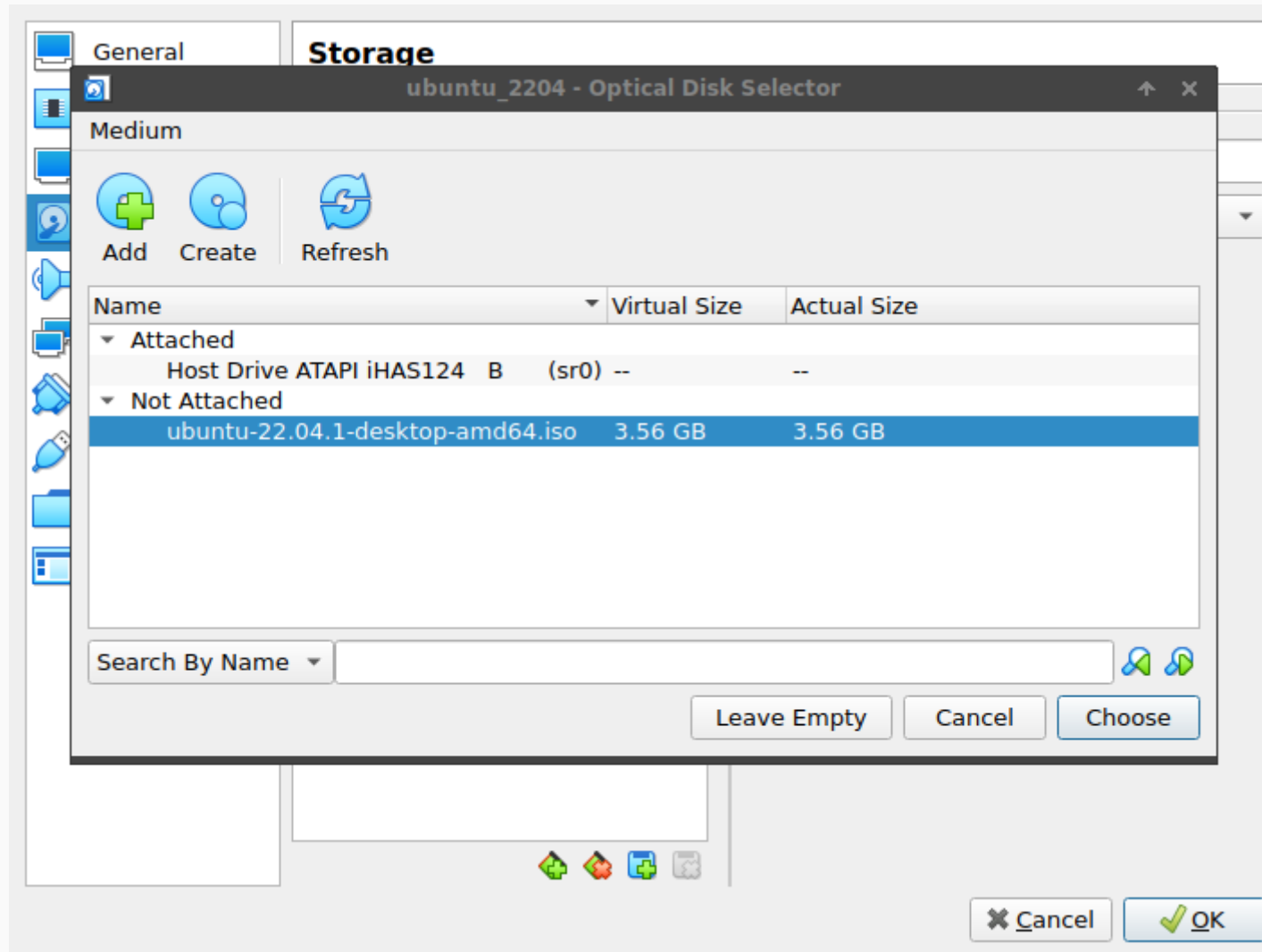
[64-bit PC \(AMD64\) desktop image](#)

Choose this if you have a computer based on the AMD64 or EM64T architecture (e.g., Athlon64, Opteron, EM64T Xeon, Core 2). Choose this if you are at all unsure.

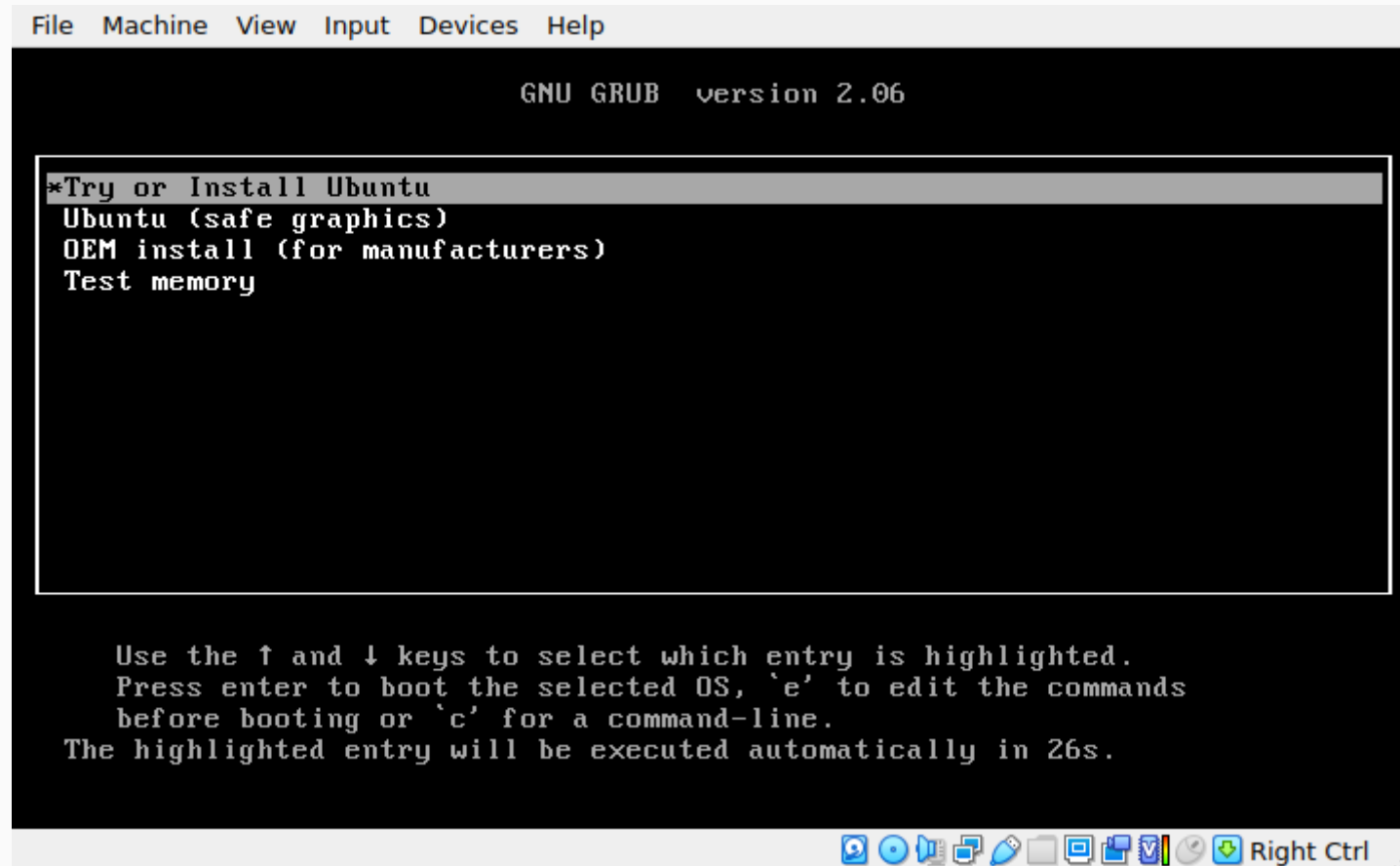
Virtual Box Demo



Virtual Box Demo



Virtual Box Demo



Virtual Box Demo

Virtual Box Demo

Installing Linux Software

Installing Software

- So you set up your VM
- Now what?



Installing Software

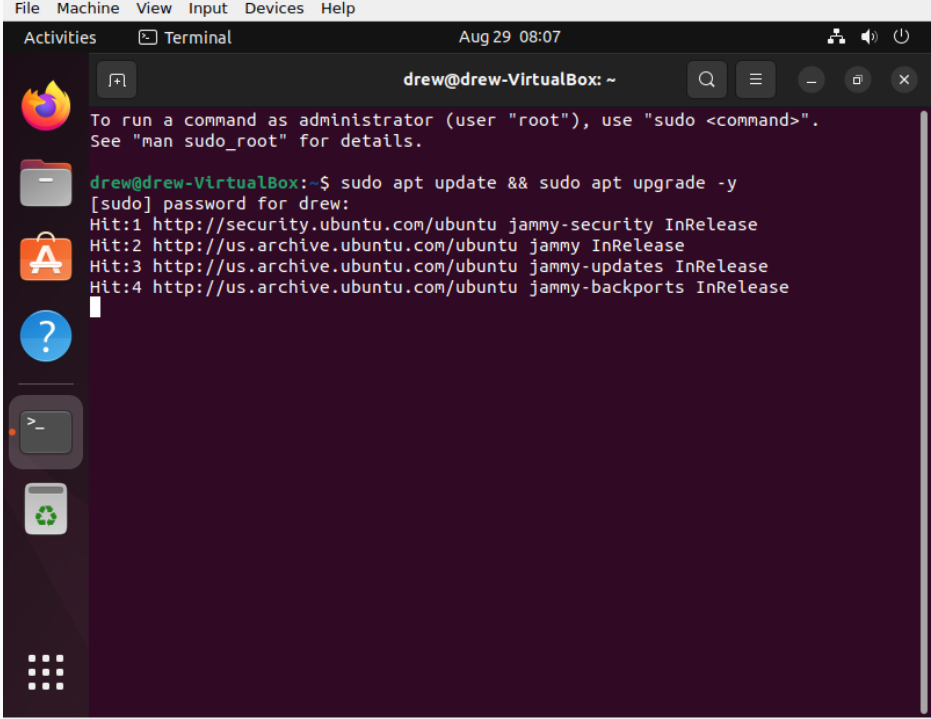
- On Windows: click click click click ...
- On Mac: click click click click ...
- On Linux: use the package manager

Installing Linux Software

- Various package managers exist
- Each "distro" has one
- We'll be using Ubuntu
 - It's basically the standard
 - If you have strong opinions: use whatever you want I don't care

Updating Your System

```
sudo apt update && sudo apt upgrade -y
```



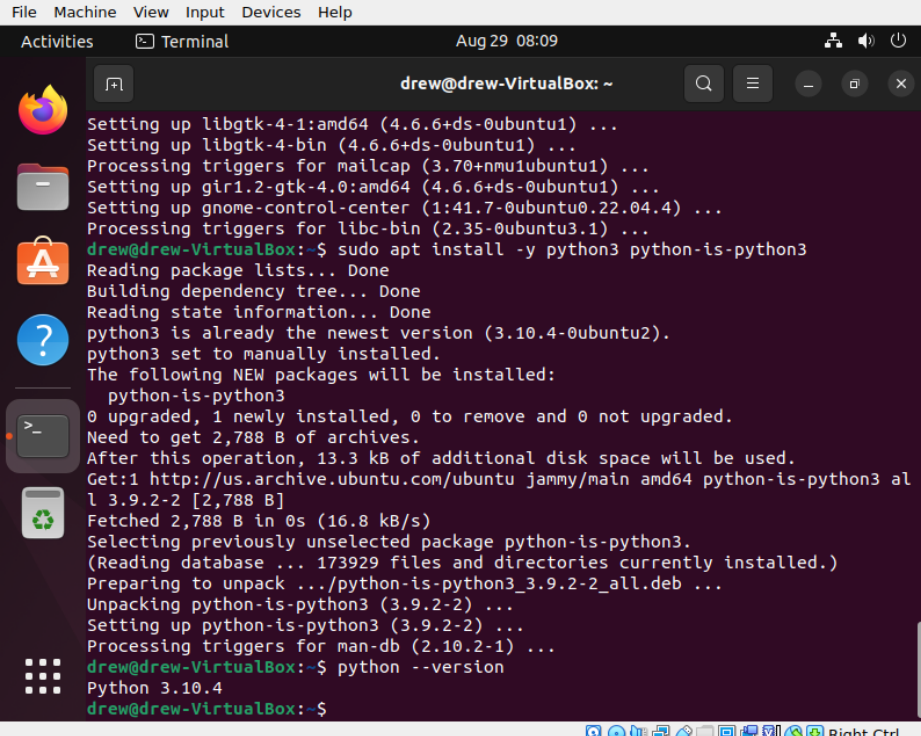
The screenshot shows a terminal window titled "drew@drew-VirtualBox: ~" with a search bar and window controls. The terminal output is as follows:

```
To run a command as administrator (user "root"), use "sudo <command>".  
See "man sudo_root" for details.  
  
drew@drew-VirtualBox:~$ sudo apt update && sudo apt upgrade -y  
[sudo] password for drew:  
Hit:1 http://security.ubuntu.com/ubuntu jammy-security InRelease  
Hit:2 http://us.archive.ubuntu.com/ubuntu jammy InRelease  
Hit:3 http://us.archive.ubuntu.com/ubuntu jammy-updates InRelease  
Hit:4 http://us.archive.ubuntu.com/ubuntu jammy-backports InRelease
```

The terminal window is part of a desktop environment with a sidebar on the left containing icons for the Dash, Home, Applications, and Dash to Dock. The top of the window has a menu bar with "File", "Machine", "View", "Input", "Devices", and "Help". The bottom of the window has a taskbar with various application icons and a "Right Ctrl" button.

Installing Python

```
sudo apt install -y \
python3 python-is-python3
```

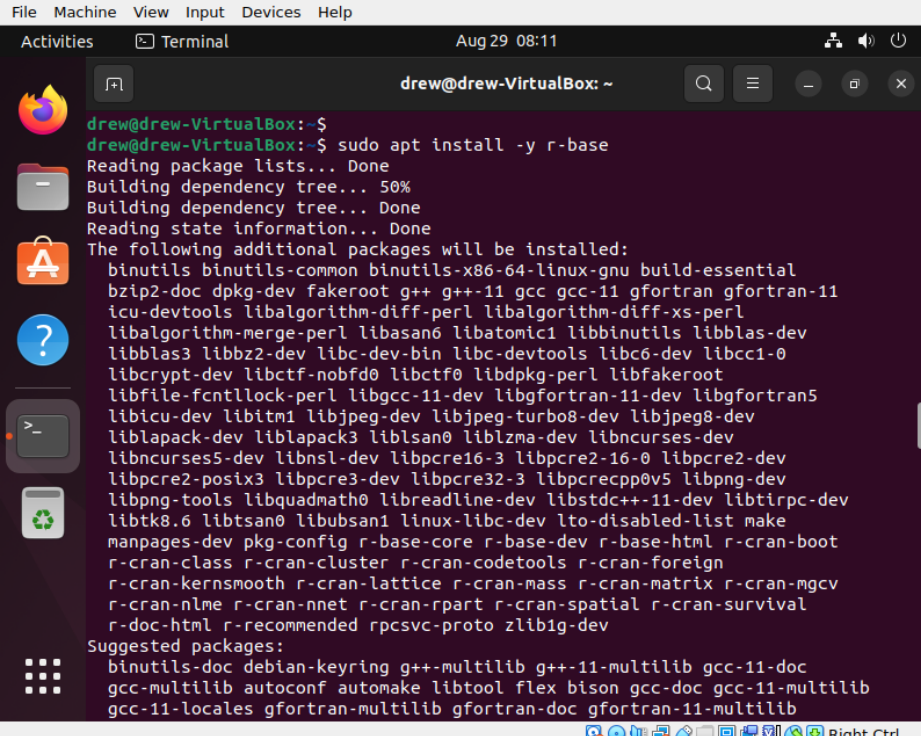


The screenshot shows a terminal window titled "drew@drew-VirtualBox: ~" with a search icon, a menu icon, and window control buttons. The terminal output shows the execution of the command `sudo apt install -y python3 python-is-python3`. The output indicates that `python3` is already the newest version (3.10.4-0ubuntu2) and is set to manually installed. The following NEW packages will be installed: `python-is-python3`. The terminal shows the process of building the dependency tree, reading state information, and fetching the package. The output also shows the disk space requirements and the download of the package from the Ubuntu archive. Finally, the terminal shows the unpacking of the package and the processing of triggers. The terminal ends with the command `python --version` which outputs `Python 3.10.4`.

```
File Machine View Input Devices Help
Activities Terminal Aug 29 08:09
drew@drew-VirtualBox: ~
Setting up libgtk-4-1:amd64 (4.6.6+ds-0ubuntu1) ...
Setting up libgtk-4-bin (4.6.6+ds-0ubuntu1) ...
Processing triggers for mailcap (3.70+nmu1ubuntu1) ...
Setting up gir1.2-gtk-4.0:amd64 (4.6.6+ds-0ubuntu1) ...
Setting up gnome-control-center (1:41.7-0ubuntu0.22.04.4) ...
Processing triggers for libc-bin (2.35-0ubuntu3.1) ...
drew@drew-VirtualBox:~$ sudo apt install -y python3 python-is-python3
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
python3 is already the newest version (3.10.4-0ubuntu2).
python3 set to manually installed.
The following NEW packages will be installed:
  python-is-python3
0 upgraded, 1 newly installed, 0 to remove and 0 not upgraded.
Need to get 2,788 B of archives.
After this operation, 13.3 kB of additional disk space will be used.
Get:1 http://us.archive.ubuntu.com/ubuntu jammy/main amd64 python-is-python3 al
l 3.9.2-2 [2,788 B]
Fetched 2,788 B in 0s (16.8 kB/s)
Selecting previously unselected package python-is-python3.
(Reading database ... 173929 files and directories currently installed.)
Preparing to unpack .../python-is-python3_3.9.2-2_all.deb ...
Unpacking python-is-python3 (3.9.2-2) ...
Setting up python-is-python3 (3.9.2-2) ...
Processing triggers for man-db (2.10.2-1) ...
drew@drew-VirtualBox:~$ python --version
Python 3.10.4
drew@drew-VirtualBox:~$
```

Installing R

```
sudo apt install -y r-base
```

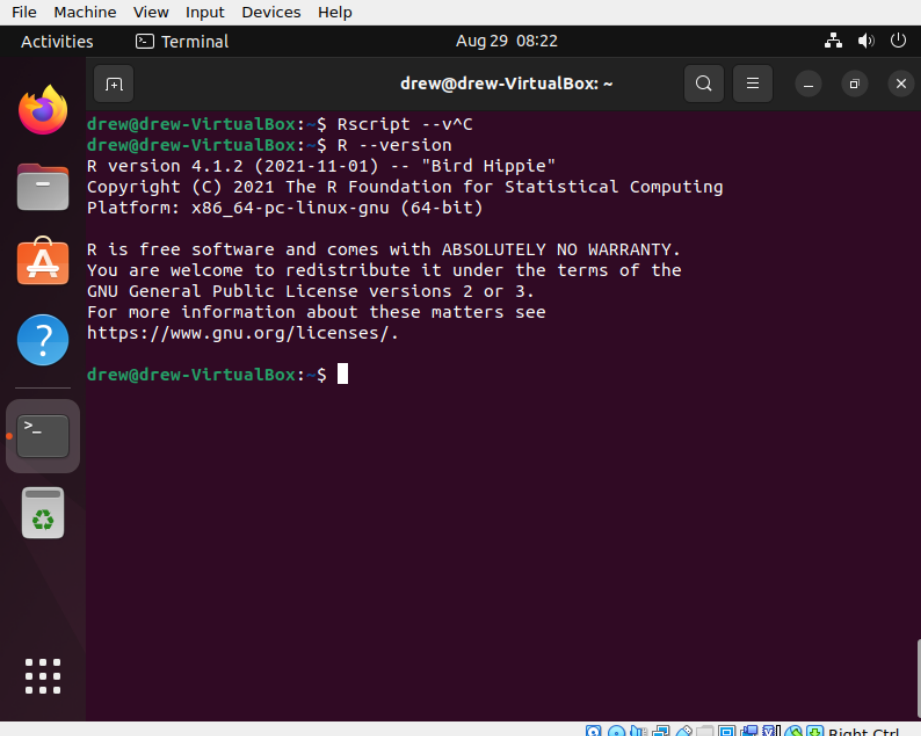


The screenshot shows a terminal window titled "drew@drew-VirtualBox: ~" with a search icon, a menu icon, and window control buttons. The terminal output shows the command `sudo apt install -y r-base` being executed. The output includes status messages like "Reading package lists... Done", "Building dependency tree... 50%", and "Building dependency tree... Done". It then lists additional packages to be installed, such as `binutils`, `binutils-common`, `binutils-x86-64-linux-gnu`, `build-essential`, `bzip2-doc`, `dpkg-dev`, `fakeroot`, `g++`, `g++-11`, `gcc`, `gcc-11`, `gfortran`, `gfortran-11`, `icu-devtools`, `libalgorithm-diff-perl`, `libalgorithm-diff-xs-perl`, `libalgorithm-merge-perl`, `libasan6`, `libatomic1`, `libbinutils`, `libblas-dev`, `libblas3`, `libbz2-dev`, `libc-dev-bin`, `libc-devtools`, `libc6-dev`, `libcc1-0`, `libcrypt-dev`, `libctf-nobfd0`, `libctf0`, `libdpkg-perl`, `libfakeroot`, `libfile-fcntllock-perl`, `libgcc-11-dev`, `libgfortran-11-dev`, `libgfortran5`, `libcxx-dev`, `libitm1`, `libjpeg-dev`, `libjpeg-turbo8-dev`, `libjpeg8-dev`, `liblapack-dev`, `liblapack3`, `liblsan0`, `liblzma-dev`, `libncurses-dev`, `libncurses5-dev`, `libnsl-dev`, `libpcre16-3`, `libpcre2-16-0`, `libpcre2-dev`, `libpcre2-posix3`, `libpcre3-dev`, `libpcre32-3`, `libpcrecpp0v5`, `libpng-dev`, `libpng-tools`, `libquadmath0`, `libreadline-dev`, `libstdc++-11-dev`, `libtirpc-dev`, `libtk8.6`, `libtsan0`, `libubsan1`, `linux-libc-dev`, `lto-disabled-list`, `make`, `manpages-dev`, `pkg-config`, `r-base-core`, `r-base-dev`, `r-base-html`, `r-cran-boot`, `r-cran-class`, `r-cran-cluster`, `r-cran-codetools`, `r-cran-foreign`, `r-cran-kernsmooth`, `r-cran-lattice`, `r-cran-mass`, `r-cran-matrix`, `r-cran-mgcv`, `r-cran-nlme`, `r-cran-nnet`, `r-cran-rpart`, `r-cran-spatial`, `r-cran-survival`, `r-doc-html`, `r-recommended`, `rpcsvc-proto`, and `zlib1g-dev`. It also lists suggested packages like `binutils-doc`, `debian-keyring`, `g++-multilib`, `g++-11-multilib`, `gcc-11-doc`, `gcc-multilib`, `autoconf`, `automake`, `libtool`, `flex`, `bison`, `gcc-doc`, `gcc-11-multilib`, `gcc-11-locale`, `gfortran-multilib`, and `gfortran-11-multilib`. The terminal window has a sidebar with icons for Activities, Terminal, and other applications. The top bar shows the date and time as "Aug 29 08:11".

```
drew@drew-VirtualBox:~$ sudo apt install -y r-base
Reading package lists... Done
Building dependency tree... 50%
Building dependency tree... Done
Reading state information... Done
The following additional packages will be installed:
  binutils binutils-common binutils-x86-64-linux-gnu build-essential
  bzip2-doc dpkg-dev fakeroot g++ g++-11 gcc gcc-11 gfortran gfortran-11
  icu-devtools libalgorithm-diff-perl libalgorithm-diff-xs-perl
  libalgorithm-merge-perl libasan6 libatomic1 libbinutils libblas-dev
  libblas3 libbz2-dev libc-dev-bin libc-devtools libc6-dev libcc1-0
  libcrypt-dev libctf-nobfd0 libctf0 libdpkg-perl libfakeroot
  libfile-fcntllock-perl libgcc-11-dev libgfortran-11-dev libgfortran5
  libcxx-dev libitm1 libjpeg-dev libjpeg-turbo8-dev libjpeg8-dev
  liblapack-dev liblapack3 liblsan0 liblzma-dev libncurses-dev
  libncurses5-dev libnsl-dev libpcre16-3 libpcre2-16-0 libpcre2-dev
  libpcre2-posix3 libpcre3-dev libpcre32-3 libpcrecpp0v5 libpng-dev
  libpng-tools libquadmath0 libreadline-dev libstdc++-11-dev libtirpc-dev
  libtk8.6 libtsan0 libubsan1 linux-libc-dev lto-disabled-list make
  manpages-dev pkg-config r-base-core r-base-dev r-base-html r-cran-boot
  r-cran-class r-cran-cluster r-cran-codetools r-cran-foreign
  r-cran-kernsmooth r-cran-lattice r-cran-mass r-cran-matrix r-cran-mgcv
  r-cran-nlme r-cran-nnet r-cran-rpart r-cran-spatial r-cran-survival
  r-doc-html r-recommended rpcsvc-proto zlib1g-dev
Suggested packages:
  binutils-doc debian-keyring g++-multilib g++-11-multilib gcc-11-doc
  gcc-multilib autoconf automake libtool flex bison gcc-doc gcc-11-multilib
  gcc-11-locale gfortran-multilib gfortran-11-multilib
```


Installing R

```
R --version
```



The screenshot shows a terminal window titled "drew@drew-VirtualBox: ~" with a search bar and window controls. The terminal output is as follows:

```
drew@drew-VirtualBox:~$ Rscript --v^C
drew@drew-VirtualBox:~$ R --version
R version 4.1.2 (2021-11-01) -- "Bird Hippie"
Copyright (C) 2021 The R Foundation for Statistical Computing
Platform: x86_64-pc-linux-gnu (64-bit)

R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under the terms of the
GNU General Public License versions 2 or 3.
For more information about these matters see
https://www.gnu.org/licenses/.

drew@drew-VirtualBox:~$
```

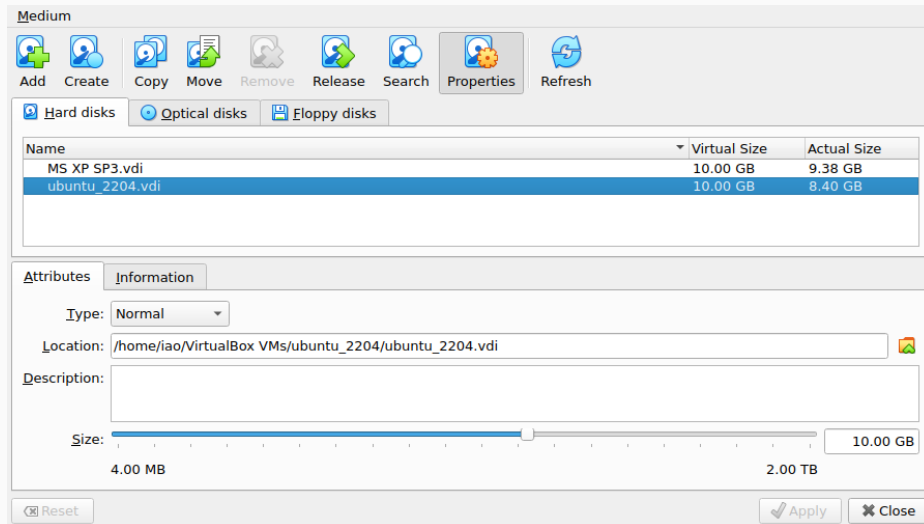
The terminal window has a menu bar with "File", "Machine", "View", "Input", "Devices", and "Help". The status bar at the bottom shows system icons and the text "Right Ctrl".

Uh-Oh!

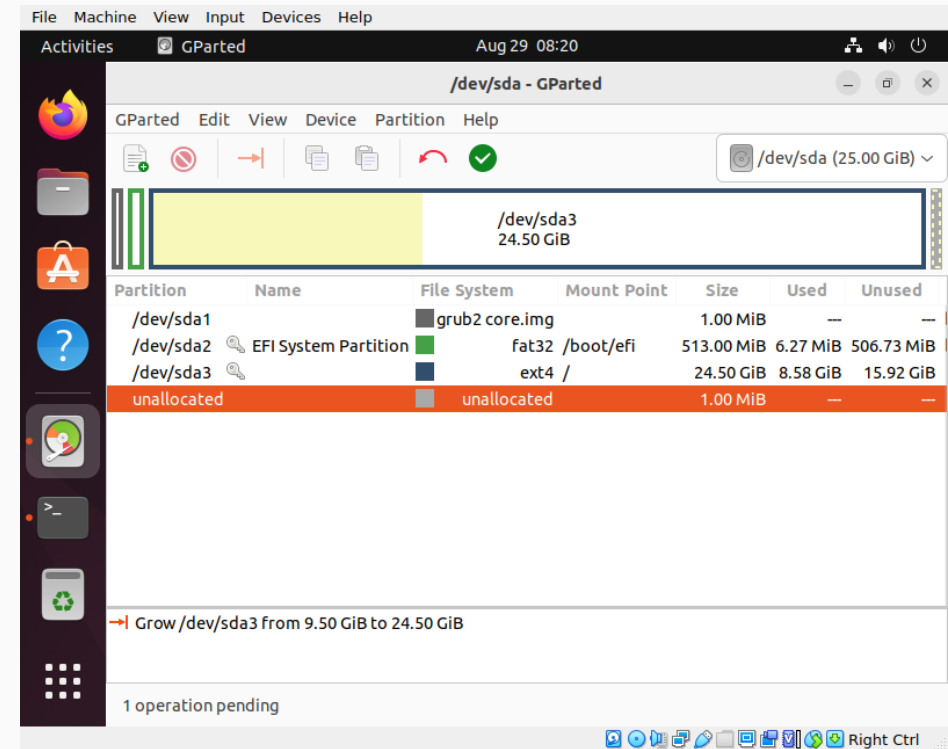
We ran out of storage space!

Resizing Your VM

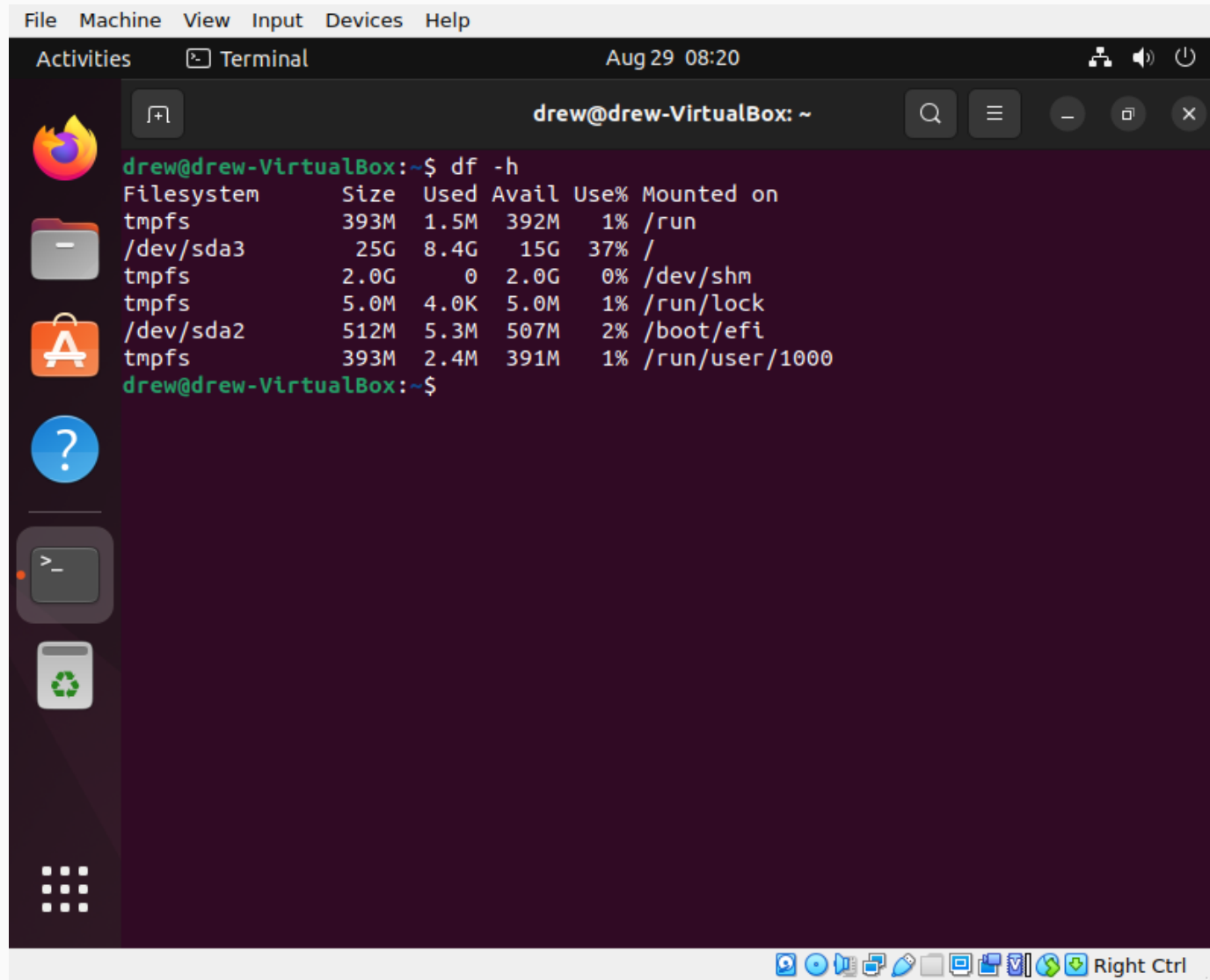
Hypervisor



VM



Resizing Your VM



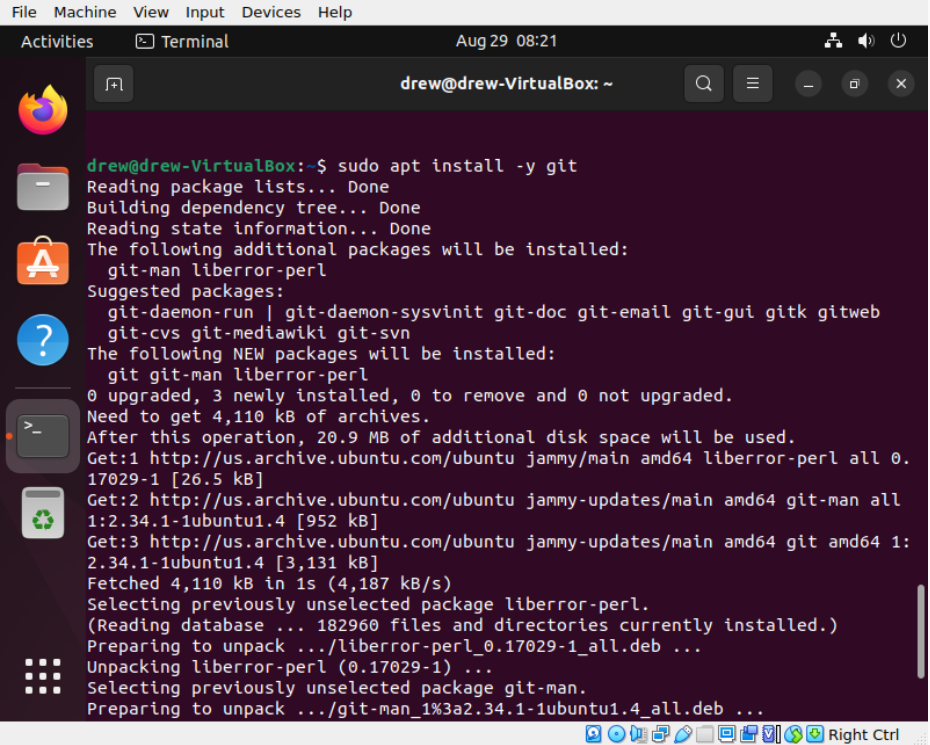
The screenshot shows a terminal window titled "drew@drew-VirtualBox: ~" with a menu bar (File, Machine, View, Input, Devices, Help) and a status bar (Aug 29 08:20). The terminal displays the output of the command `df -h`, which shows disk usage for various filesystems. The output is as follows:

Filesystem	Size	Used	Avail	Use%	Mounted on
tmpfs	393M	1.5M	392M	1%	/run
/dev/sda3	25G	8.4G	15G	37%	/
tmpfs	2.0G	0	2.0G	0%	/dev/shm
tmpfs	5.0M	4.0K	5.0M	1%	/run/lock
/dev/sda2	512M	5.3M	507M	2%	/boot/efi
tmpfs	393M	2.4M	391M	1%	/run/user/1000

The terminal window also features a sidebar with application icons (Firefox, Files, App Store, Help, Terminal, Recycle Bin) and a dock at the bottom with various system icons and a "Right Ctrl" label.

Installing git

```
sudo apt install -y git
```

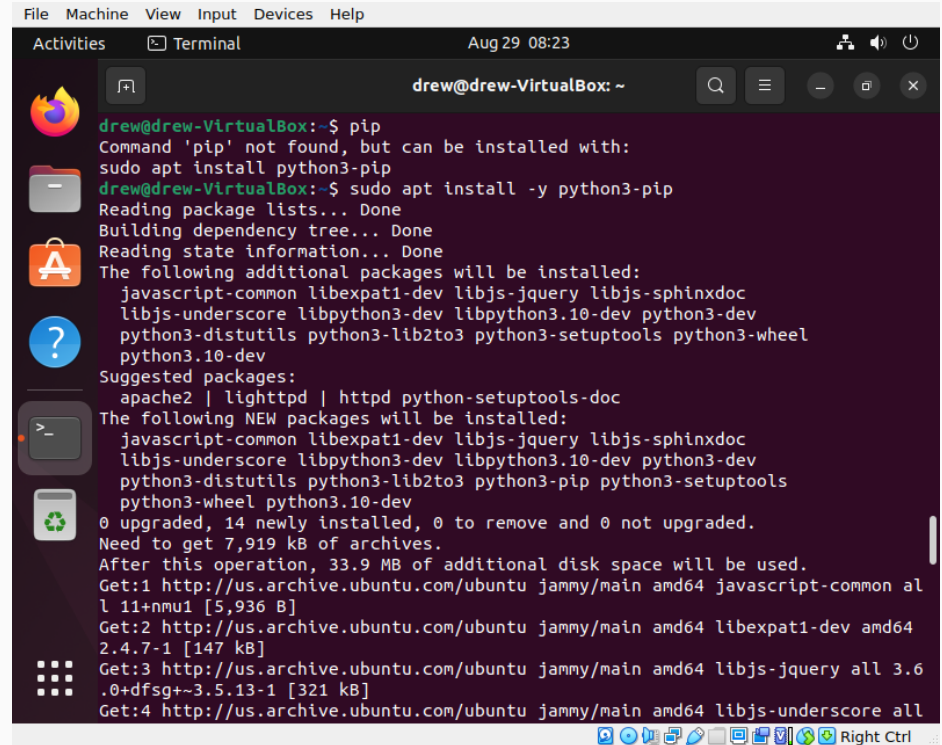


The screenshot shows a terminal window titled "drew@drew-VirtualBox: ~" with a search bar and window controls. The terminal output shows the command `sudo apt install -y git` being executed. The output includes package list reading, dependency tree building, and state information reading. It lists additional packages to be installed (`git-man`, `liberror-perl`) and suggested packages (`git-daemon-run`, `git-daemon-sysvinit`, `git-doc`, `git-email`, `git-gui`, `gitk`, `gitweb`, `git-cvs`, `git-mediawiki`, `git-svn`). It then lists the new packages to be installed (`git`, `git-man`, `liberror-perl`) and shows the disk space requirements and download progress for these packages. The installation of `liberror-perl` and `git-man` is shown as completed.

```
drew@drew-VirtualBox:~$ sudo apt install -y git
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following additional packages will be installed:
  git-man liberror-perl
Suggested packages:
  git-daemon-run | git-daemon-sysvinit git-doc git-email git-gui gitk gitweb
  git-cvs git-mediawiki git-svn
The following NEW packages will be installed:
  git git-man liberror-perl
0 upgraded, 3 newly installed, 0 to remove and 0 not upgraded.
Need to get 4,110 kB of archives.
After this operation, 20.9 MB of additional disk space will be used.
Get:1 http://us.archive.ubuntu.com/ubuntu jammy/main amd64 liberror-perl all 0.17029-1 [26.5 kB]
Get:2 http://us.archive.ubuntu.com/ubuntu jammy-updates/main amd64 git-man all 1:2.34.1-1ubuntu1.4 [952 kB]
Get:3 http://us.archive.ubuntu.com/ubuntu jammy-updates/main amd64 git amd64 1:2.34.1-1ubuntu1.4 [3,131 kB]
Fetched 4,110 kB in 1s (4,187 kB/s)
Selecting previously unselected package liberror-perl.
(Reading database ... 182960 files and directories currently installed.)
Preparing to unpack .../liberror-perl_0.17029-1_all.deb ...
Unpacking liberror-perl (0.17029-1) ...
Selecting previously unselected package git-man.
Preparing to unpack .../git-man_1%3a2.34.1-1ubuntu1.4_all.deb ...
```

Installing pip

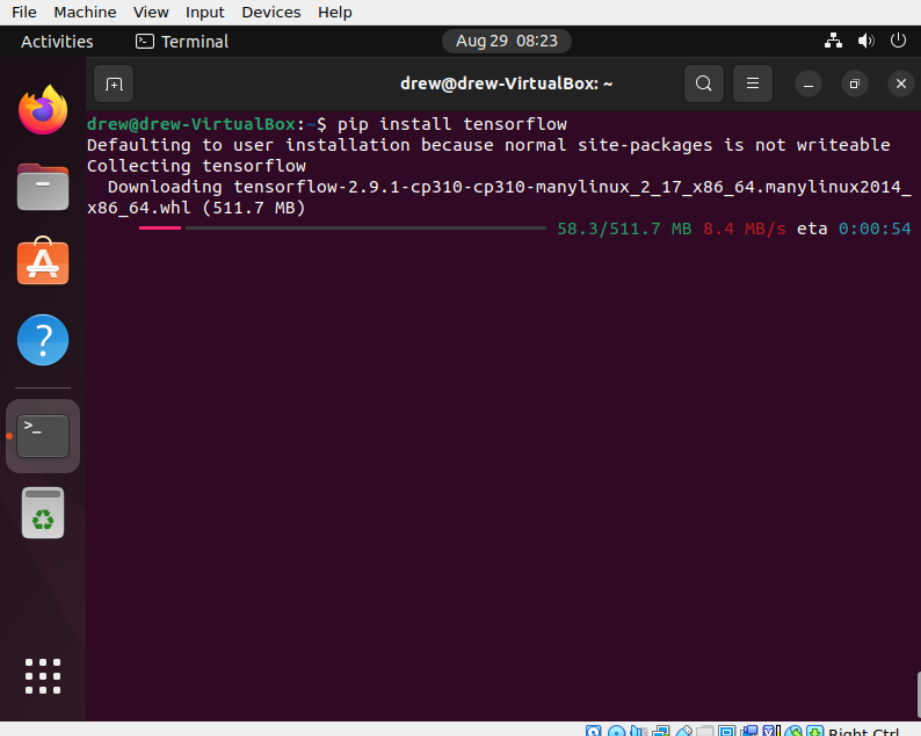
```
sudo apt install -y python3-pip
```



```
File Machine View Input Devices Help
Activities Terminal Aug 29 08:23
drew@drew-VirtualBox: ~
drew@drew-VirtualBox:~$ pip
Command 'pip' not found, but can be installed with:
sudo apt install python3-pip
drew@drew-VirtualBox:~$ sudo apt install -y python3-pip
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
The following additional packages will be installed:
  javascript-common libexpat1-dev libjs-jquery libjs-sphinxdoc
  libjs-underscore libpython3-dev libpython3.10-dev python3-dev
  python3-distutils python3-lib2to3 python3-setuptools python3-wheel
  python3.10-dev
Suggested packages:
  apache2 | lighttpd | httpd python-setuptools-doc
The following NEW packages will be installed:
  javascript-common libexpat1-dev libjs-jquery libjs-sphinxdoc
  libjs-underscore libpython3-dev libpython3.10-dev python3-dev
  python3-distutils python3-lib2to3 python3-pip python3-setuptools
  python3-wheel python3.10-dev
0 upgraded, 14 newly installed, 0 to remove and 0 not upgraded.
Need to get 7,919 kB of archives.
After this operation, 33.9 MB of additional disk space will be used.
Get:1 http://us.archive.ubuntu.com/ubuntu jammy/main amd64 javascript-common all 11+nmu1 [5,936 B]
Get:2 http://us.archive.ubuntu.com/ubuntu jammy/main amd64 libexpat1-dev amd64 2.4.7-1 [147 kB]
Get:3 http://us.archive.ubuntu.com/ubuntu jammy/main amd64 libjs-jquery all 3.6.0+dfsg+~3.5.13-1 [321 kB]
Get:4 http://us.archive.ubuntu.com/ubuntu jammy/main amd64 libjs-underscore all
```

Installing tensorflow

```
pip install tensorflow
```



The screenshot shows a terminal window titled "drew@drew-VirtualBox: ~" with a search bar and window controls. The terminal output is as follows:

```
drew@drew-VirtualBox:~$ pip install tensorflow
Defaulting to user installation because normal site-packages is not writeable
Collecting tensorflow
  Downloading tensorflow-2.9.1-cp310-cp310-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (511.7 MB)
    58.3/511.7 MB 8.4 MB/s eta 0:00:54
```

The terminal window has a sidebar on the left with icons for Activities, Terminal, and other applications. The bottom status bar shows system icons and the text "Right Ctrl".

What About Windows/Mac?

- WSL uses Ubuntu
 - Step 1: Install WSL
 - Step 2: `sudo apt install ...`
- There are "similar" things for Mac (homebrew, ports)

How "Ubuntu" Is This?

- Short answer: kinda
- `apt`: Debian, Ubuntu, ...
- `yum`: Fedora, CentOS, RedHat, ...
- Others exist; largely irrelevant



Wrapup

Wrapup

- A VM is a virtualized OS + apps
- Advantages of a VM
 - Isolation
 - Reproducibility
 - Distribution
- Install Linux software via the software repo

Ungraded (aka optional) Homework

- VM
 - Install an Ubuntu 22.04 VM with VirtualBox
 - Install the VirtualBox guest additions
 - I/O
 - Mount a folder from your host OS in your VM
 - Put a text file in the folder (from host OS)
 - From terminal: `cat` the file
 - Set up sshd in your VM and ssh to it (Windows users will need Putty or WSL for ssh)
- Native
 - On Windows (WSL): install git, R, and Python using `apt`
 - On Mac: experiment with homebrew

Questions?