

CSCI 4907

Introduction to IoT and Edge Computing Applications

Prof. Kartik Bulusu, CS Dept.

Week 2 [01/26/2023]

- Overview of computing in IoT
- Differences in Cloud and Fog computing
- What is Edge Computing and Edge Compute device
- Setting up the Edge Lab
- Understanding the Python installation on the Raspberry Pi
- Some basic Python programming constructs
- First steps in Raspberry Pi programming [Blinking LEDs]



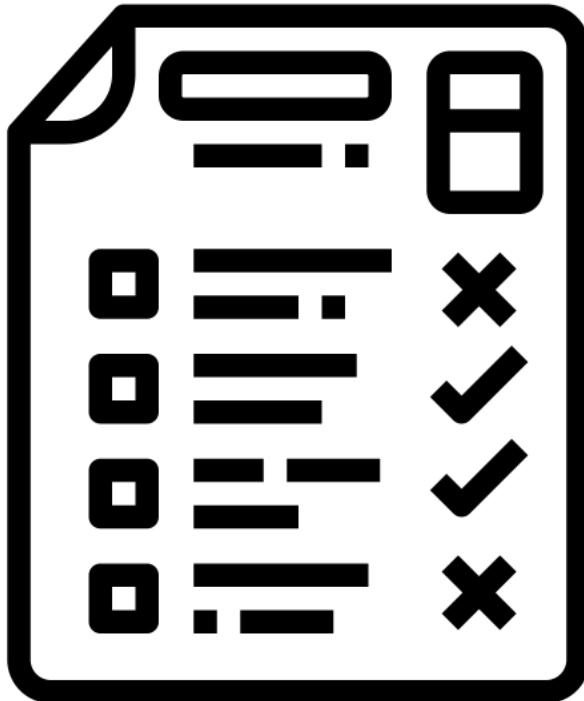
School of Engineering
& Applied Science

Spring 2024

THE GEORGE WASHINGTON UNIVERSITY

Photo: Kartik Bulusu

Democratizing the grading and other course policies



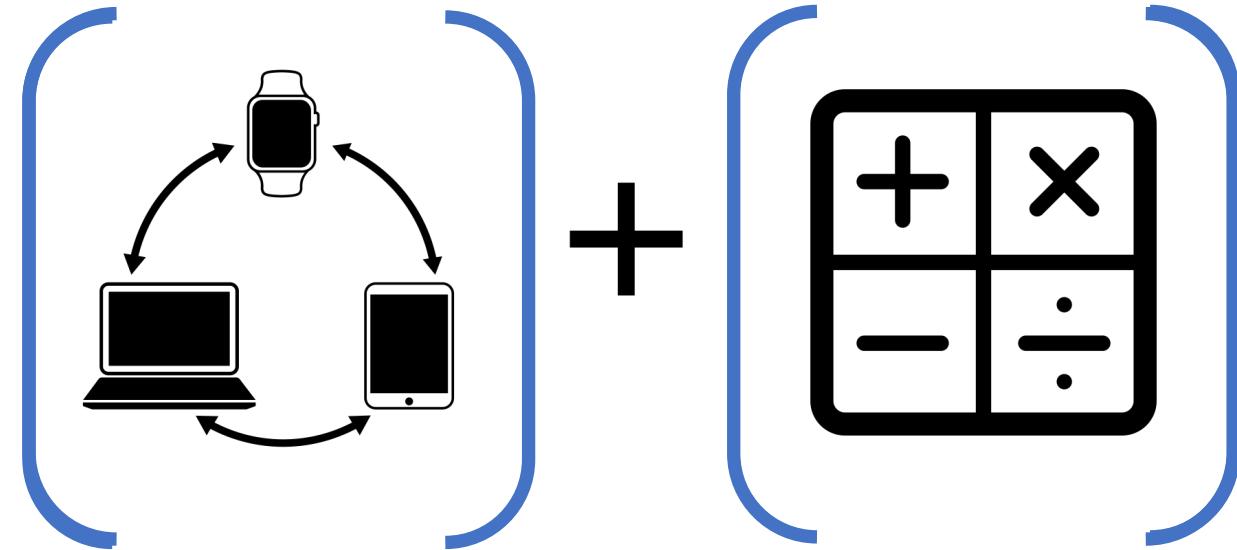
- Attendance and/or peer-to-peer and instructor interactions 10%
- In-class work and/or Weekly Quizzes 10%
- Project reports, paper reviews and in-class presentations 10%
- Python programming and other Homework 20%
- Projects (including code, demo, written report and presentation) 50%
 - 20% Individual midterm project
 - 30% Group final project

What's the “thing”?

Paradigm #1

- A **thing** is self-contained and only operates within the confines of its physical shell.
 - **Thing** carries out only those functions that its designer envisioned when it was fabricated.
- The **thing** contains a powerful computer inside but is completely hidden from the user.
- The **thing** has firmware (not called software).

Paradigm #2



Paradigm #3

“things” with compute

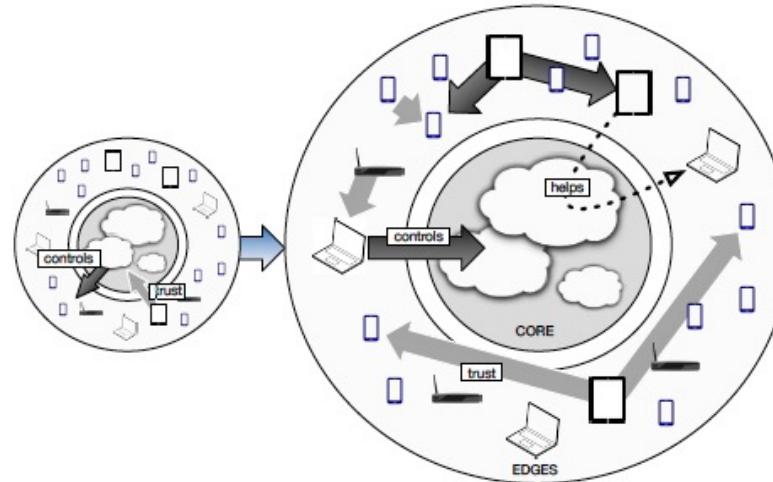
“things” with compute == edge compute

Edge computing is a distributed computing framework that brings enterprise applications closer to data sources such as IoT devices or local edge servers.

This **proximity to data** at its source can deliver strong business benefits, including faster insights, improved response times and better bandwidth availability.



"Edge Computing" was coined around 2002



Content Delivery Networks:

It was mainly associated with the deployment of applications over CDNs, when some large companies announced deals to distribute software through CDN edge servers.

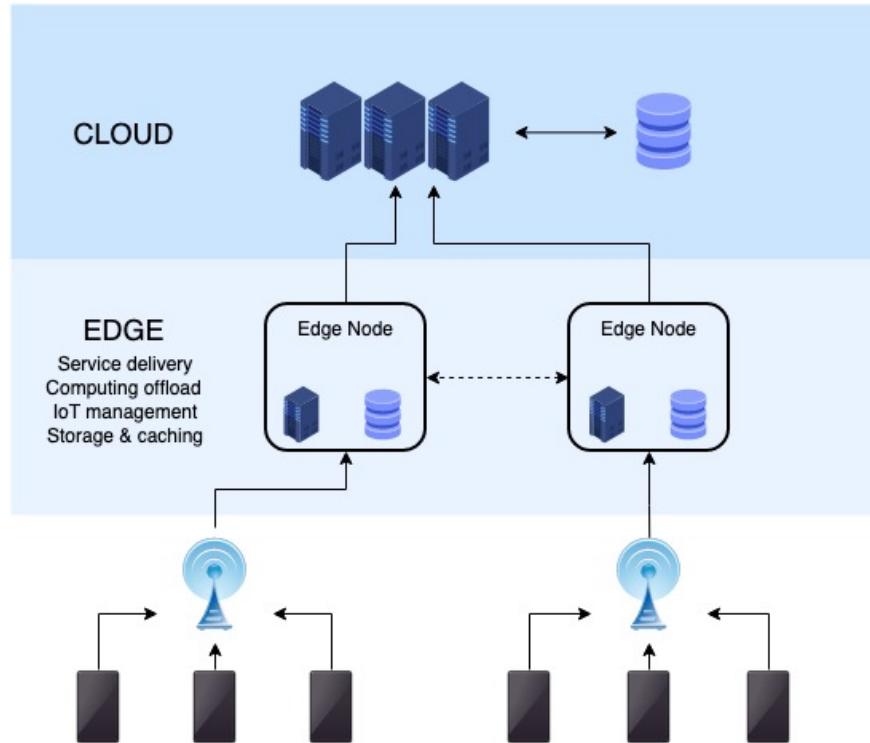
P2P computing:

This is another field closely related to edge computing, it is also its main precursor. The term P2P was first introduced around 2000 with the appearance of popular file-sharing systems such as Napster and Kazaa.

Fog computing:

Fog Computing is a recent research field that has substantial overlap with Edge-centric Computing. Proximity to end-users, dense geographical distribution, and support for mobility are the main distinguishing characteristics of Fog Computing.

Edge computing is a form of distributed computing



Classical Paradigm

- **Distributed computing**

- Covers a broad range of technologies
- Earliest success stories could be considered
 - local area networks and
 - the first internet, ARPANET (1960s).

New Paradigm

- **Decentralized, distributed computing**

- **Proximity to data:** Moving the computer workload closer to the data source
 - reduces latency
 - bandwidth and
 - overhead for the centralized data center

Autonomous Car by Tippawan Sookruay from <https://thenounproject.com/browse/icons/term/autonomous-car/>
 clean energy by Juicy Fish from <https://thenounproject.com/browse/icons/term/clean-energy/>
 Health Care by mynamepong from <https://thenounproject.com/browse/icons/term/health-care/>
 Smart City by dDara from <https://thenounproject.com/browse/icons/term/smart-city/>

Four (near future) Edge computing examples

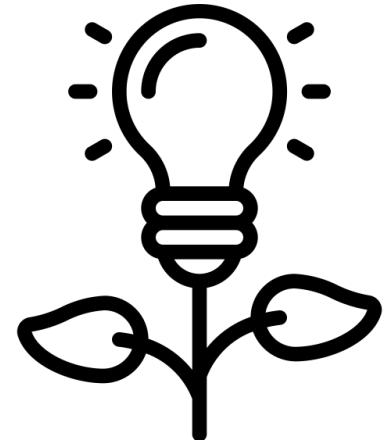


Autonomous Cars

- [Chevrolet](#) collected 4,220 terabytes of data from customer's cars.

McKinsey forecasts that this could grow into a \$450 to 750 billion market by 2030.

Source: <https://www.autoblog.com/2017/02/21/race-for-autonomous-cars-is-over-mcelroy-autoline-opinion/>

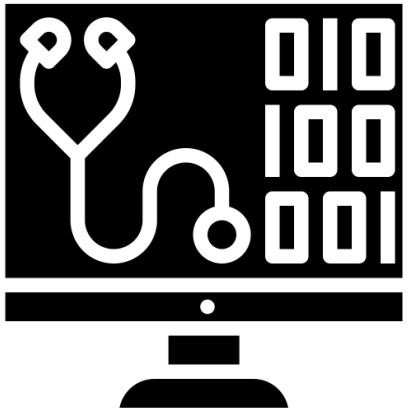


Clean energy technology

- Data centers use an estimated [200 terawatt hours](#) (TWh) of electricity annually
- ~ 50% of all electricity currently used for all global transport.

Edge computing can significantly reduce the amount of time and power, data centers need to use to process data.

Source:
<https://www.forbes.com/sites/forbestechcouncil/2022/03/18/how-machine-learning-and-edge-computing-powers/sustainability/?sh=483ebd025fab>

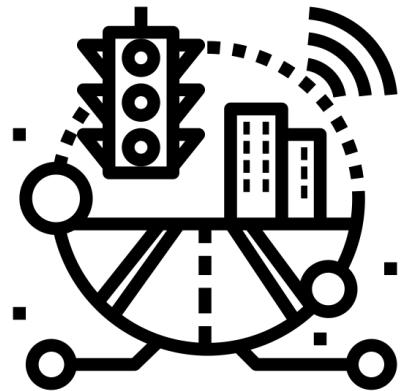


Transforming health care at the edge

- 10 to 15 connected device per US hospital bed
- 3 million data points generated by the average clinical trial
- 30% of all global stored data is from health care

75% of data will be generated at the edge by 2025

Source:
<https://www.technologyreview.com/2021/06/10/1026038/transforming-health-care-at-the-edge/>



Edge AI: Tackling Traffic Management

- A pilot system deployed at Pittsburgh, Pennsylvania, has reportedly
 - reduced travel time by 26%
 - idling time by 41%, and
 - emissions by 21 %.

The INRIX Global Traffic Scorecard: World's 20 most congested cities lost between 164 and 210 hours in congestion per capita through 2018.

Source:
<https://www.iotforall.com/busting-traffic-woes-with-5g-and-edge-ai>



Edge computing, https://en.wikipedia.org/wiki/Edge_computing#/media/File:Edge_computing_infrastructure.png
What is Edge Computing: The Network Edge Explained, <https://www.cloudwards.net/what-is-edge-computing/>
What is IoT Edge computing? <https://www.redhat.com/en/topics/edge-computing/iot-edge-computing-need-to-work-together>
What is edge computing?, <https://azure.microsoft.com/en-us/resources/cloud-computing-dictionary/what-is-edge-computing/>
Secure Edge Computing in IoT Systems: Review and Case Studies , <https://par.nsf.gov/servlets/purl/10097337>

Benefits of Edge computing

- **Reduced latency of communication** between IoT devices and the central IT networks.
- **Faster response times** and increased operational efficiency.
- **Improved network bandwidth.**
- **Continued systems operation offline** when a network connection is lost.
- **Local data processing**, aggregation, and rapid decision making via analytics algorithms and machine learning.

There are concerns!

- **User Privacy** between IoT devices and the central IT networks.
- **Optimization metrics:** There are several layers with various computation abilities in edge computing for choosing an optimal workload allocation.
- **Task-offloading:** Utilizing edge nodes for computation offloading is a concern due to the problem of adequately segmenting computational tasks.
- **Public accessibility of edge nodes:** When an edge device (e.g., a base station, switch, and router) is intended to be used for public access.

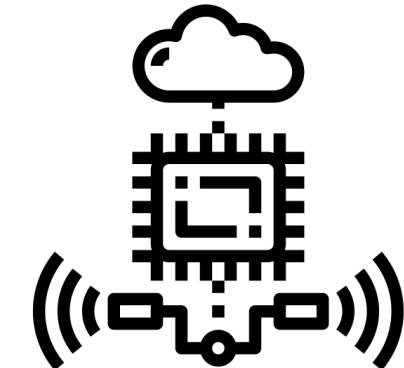
What's an “edge” device?

Paradigm #1

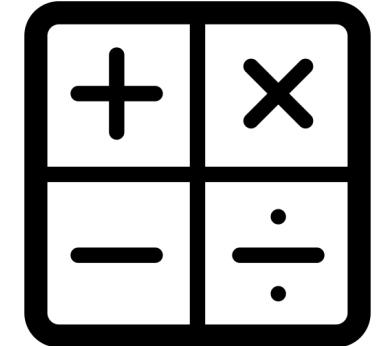
An **edge device** is any piece of hardware that controls data flow at the boundary between two networks.

- Essentially serve as network entry -- or exit -- points.
- Common functions of edge devices are the transmission, routing, processing, monitoring, filtering, translation and storage of data passing between networks.

Paradigm #2



+



Paradigm #3

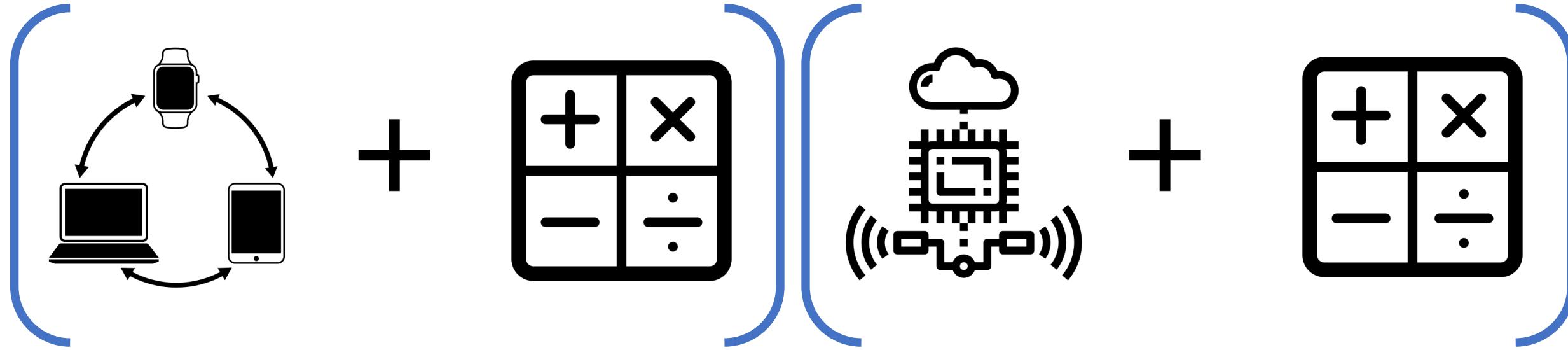
internet of things by Davo Sime from <https://thenounproject.com/browse/icons/term/internet-of-things/>

Calculator by Markus from <https://thenounproject.com/browse/icons/term/calculator/>

industrial transformation by dDara from <https://thenounproject.com/browse/icons/term/industrial-transformation>

What is IoT Edge computing?, <https://www.redhat.com/en/topics/edge-computing/iot-edge-computing-need-to-work-together>

Overview of Computing in IoT



The Internet of Things (IoT) is made up of smart devices connected to a network—sending and receiving large amounts of data to and from other devices—which produces a large amount of data to be processed and analyzed.

Edge computing, a strategy for computing on location where data is collected or used, allows IoT data to be gathered and processed at the edge, rather than sending the data back to a datacenter or cloud.

internet of things by Davo Sime from <https://thenounproject.com/browse/icons/term/internet-of-things/>

Calculator by Markus from <https://thenounproject.com/browse/icons/term/calculator/>

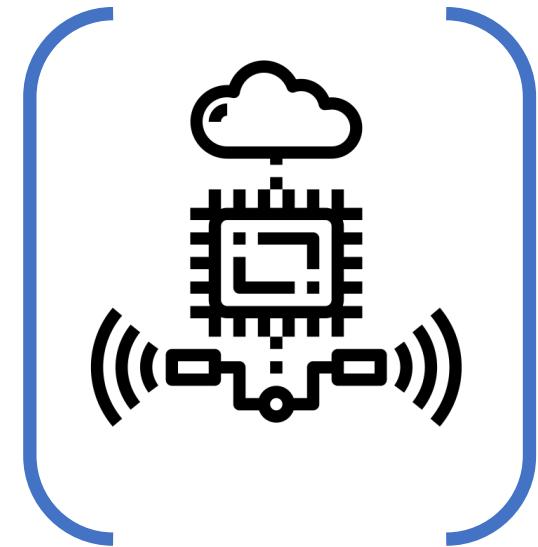
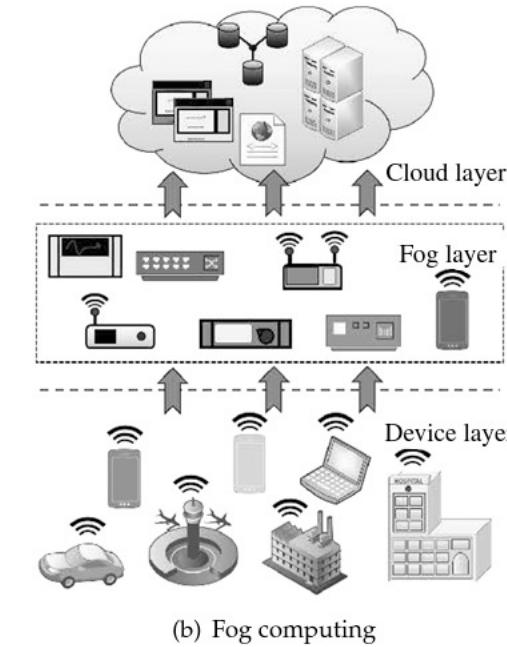
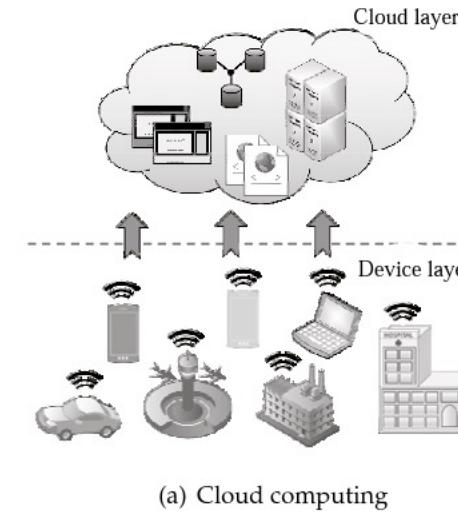
industrial transformation by dDara from <https://thenounproject.com/browse/icons/term/industrial-transformation/>

What is IoT Edge computing?, <https://www.redhat.com/en/topics/edge-computing/iot-edge-computing-need-to-work-together>

Cloud Computing by Slamet Ariyanto from <https://thenounproject.com/browse/icons/term/cloud-computing/>

S. Mishra, A. Mukherjee and A. Roy, Introduction to IoT

Edge, Fog and Cloud Landscape



In a cloud computing model, compute resources and services are often centralized at large datacenters.

- Clouds often provide a portion of the network infrastructure required to connect IoT devices to the internet.

Edge devices require network connectivity to central locations for different purposes:

- To allow remote management,
- To receive automation instructions,
- To forward network telemetry traffic needed for analytics

Summarizing the need for Edge Computing

- IoT devices are low-power and getting smaller in size
- Formidable amount of information to be processed and handled.
- IoT devices need to depend on external platforms
 - Cloud
 - Fog
 - **Edge computing (more recent paradigm)**

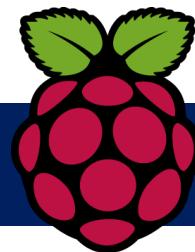
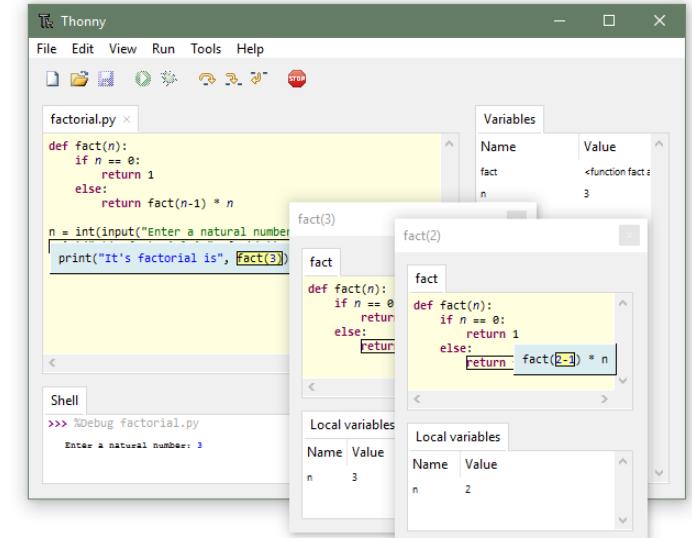
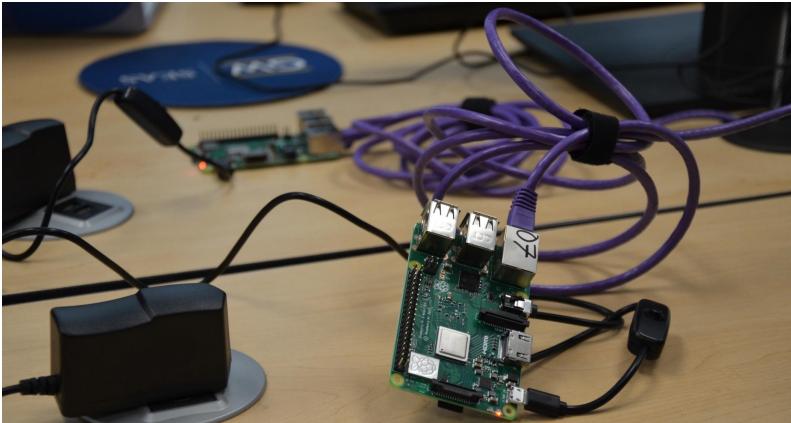


Setting up the Edge-lab each week

Sources:

Thonny (IDE): <https://en.wikipedia.org/wiki/Thonny>

Thonny: <https://thonny.org>



Tompkins 201: Laboratory set up

STEP [-1]:

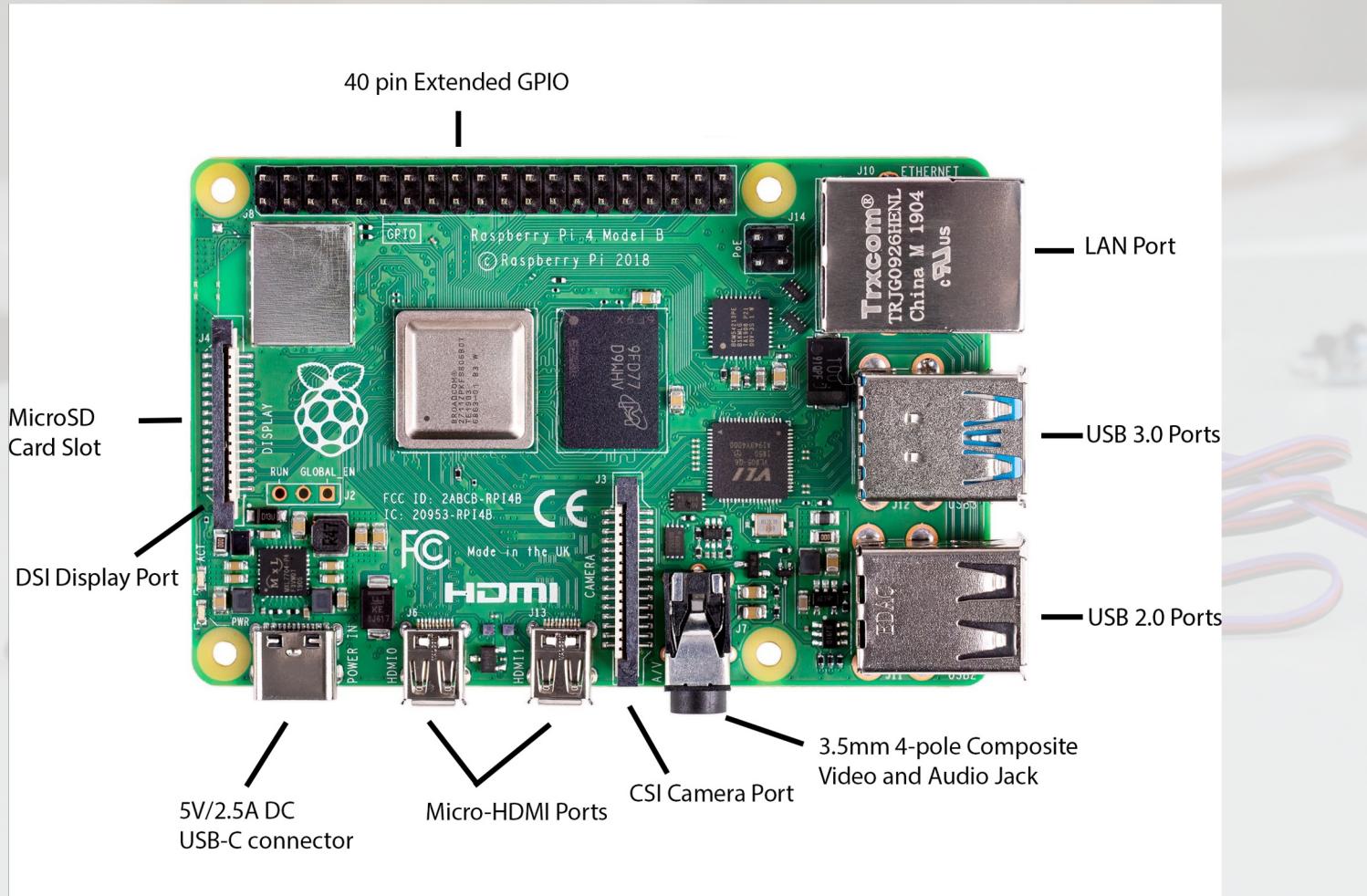
Familiarize yourself with TH201 classroom layout



- 6 clusters of desks
- Each cluster 2-3 laptop power cables (Dell Inspiron)
- Each cluster has 2-3 blue colored ethernet cables specifically connectivity
- Each cluster should have surge protector (on the desk)

STEP [0]:

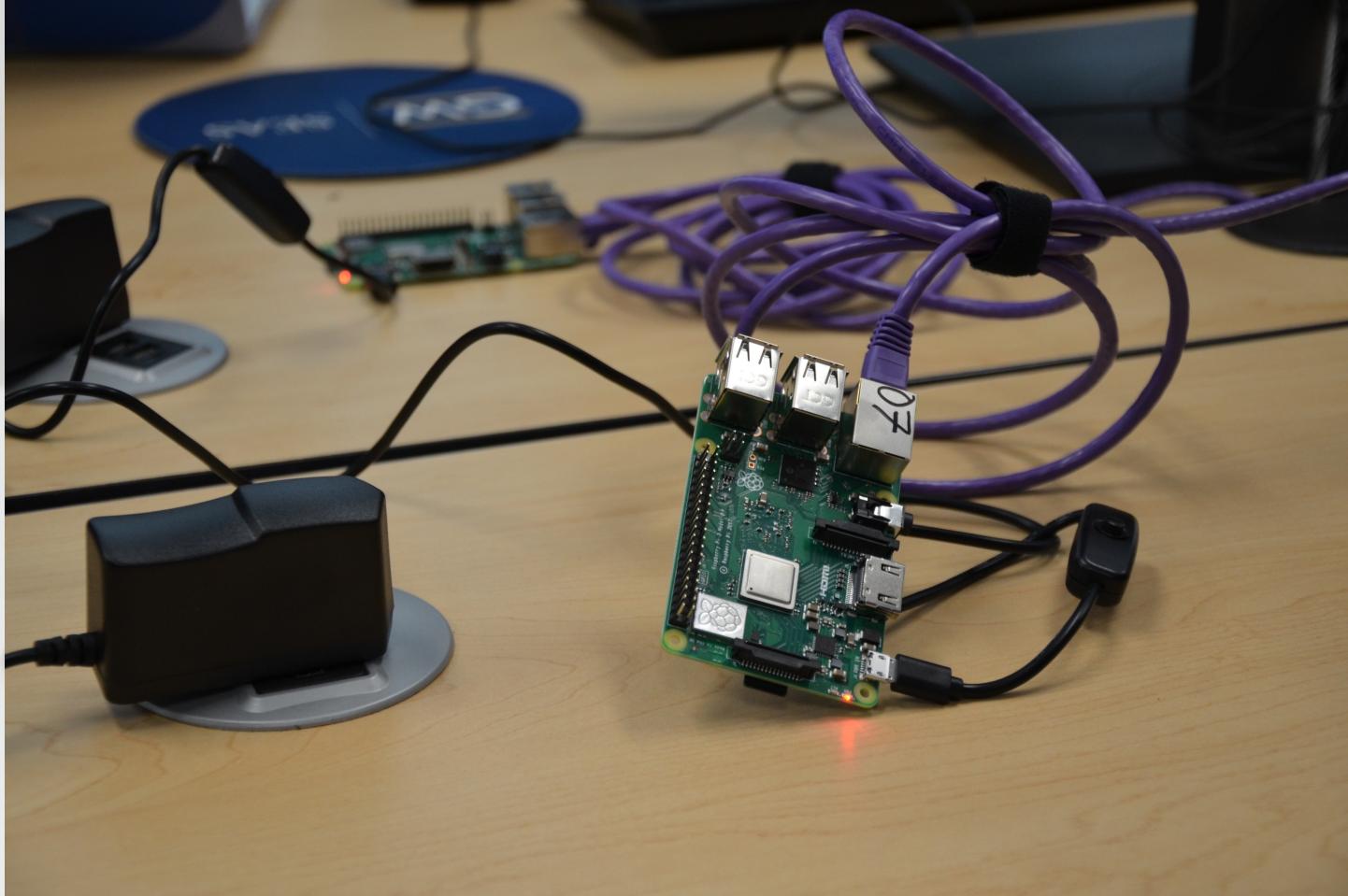
Familiarize yourself with the Raspberry Pi 4B (RPi) layout



- Each RPi will come with a preconfigured OS in a microSD card
- Each RPi will have a microSD card already installed
- Each RPi is assigned a unique alphanumeric name (e.g., Pi07, Pi152 etc)
- To power, boot up and test the RPi you will need
 - USB-C power cord
 - Ethernet cord for 10/100 LAN port
 - IP address
 - Login and password for the RPi
 - Remote desktop feature enabled in your computer

STEP [1]:

Connect the RPis to each desk power outlet as shown



- Make sure there is a microSD card installed in the RPi
- Connect the RPi using the microUSB cable provided
- Connect the purple colored ethernet cables specifically for RPi connections
- LEDs on the RPi will start blinking indicating that it is booting up

STEP [2]:

Access the RPi in the Edge-lab

2.1 Open up remote desktop connection (using the VNC server)

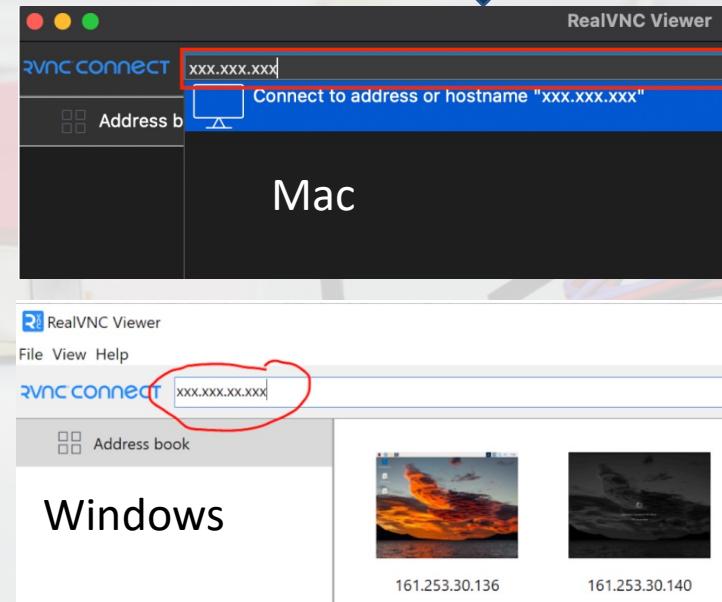
Each RPi has unique alpha-numeric name (e.g., Pi07, Pi152 etc)

- Locate the Pi-name and the IP address on the <128.164.139.xx>

OR

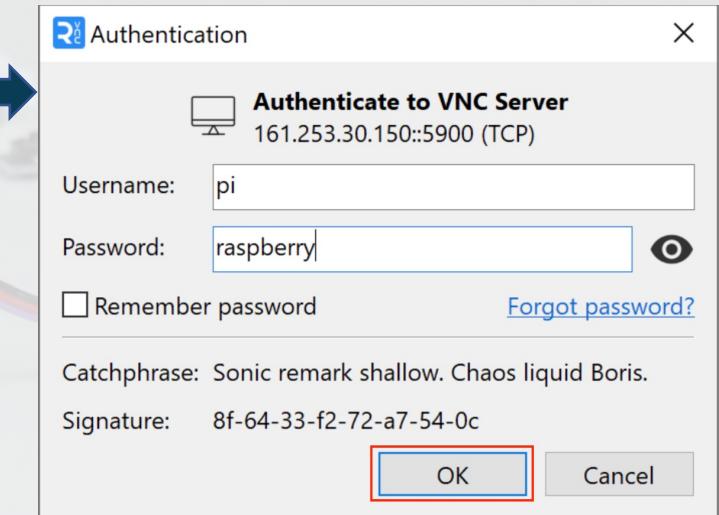
Each RPi connected using an ethernet cable directly to your laptops

- raspberrypi.local



2.2 Once you are connected you will

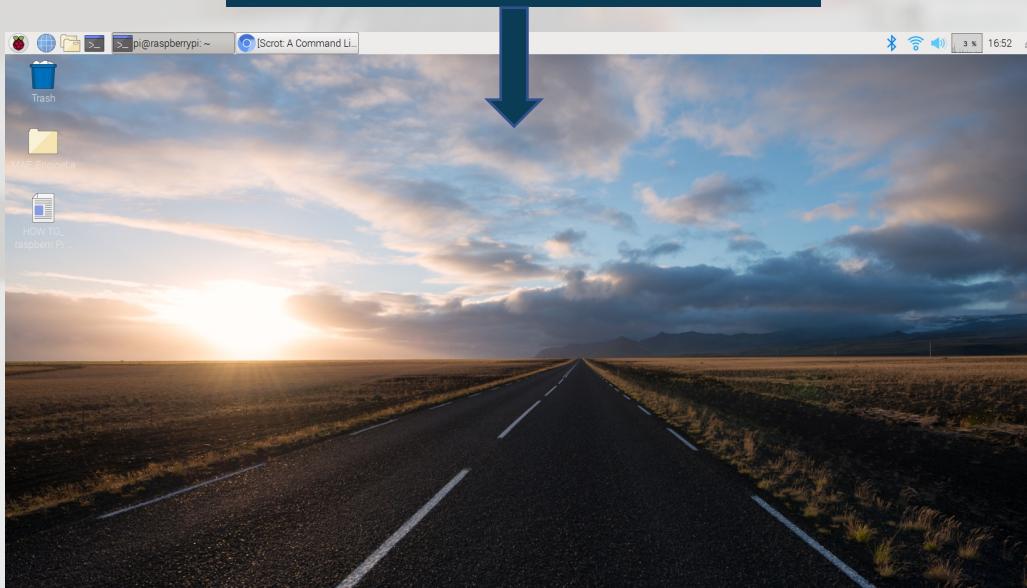
- See Authentication box below
- Type in the Username and Password



STEP [3]:

Now that you accessed the RPi...

You will see a screen like the one shown below

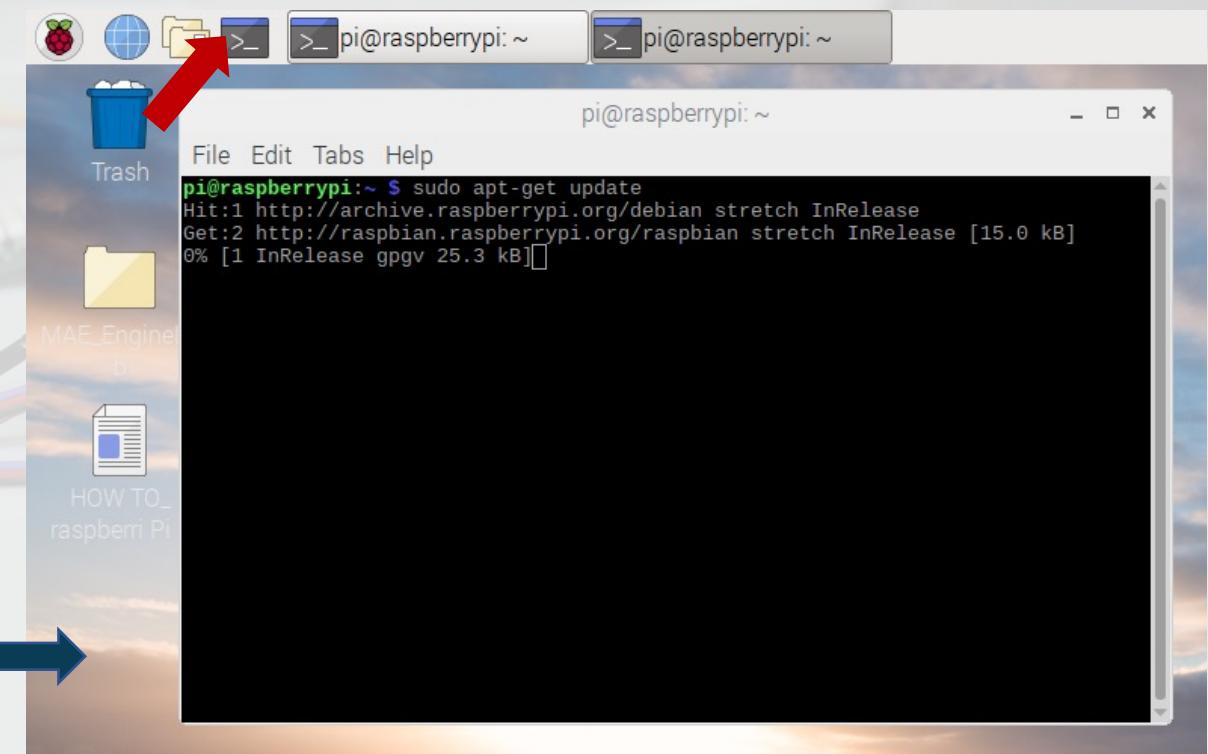


3.2 Testing is complete when you get to this step.

- Students should get the RPis to this step before the laboratory modules begin.

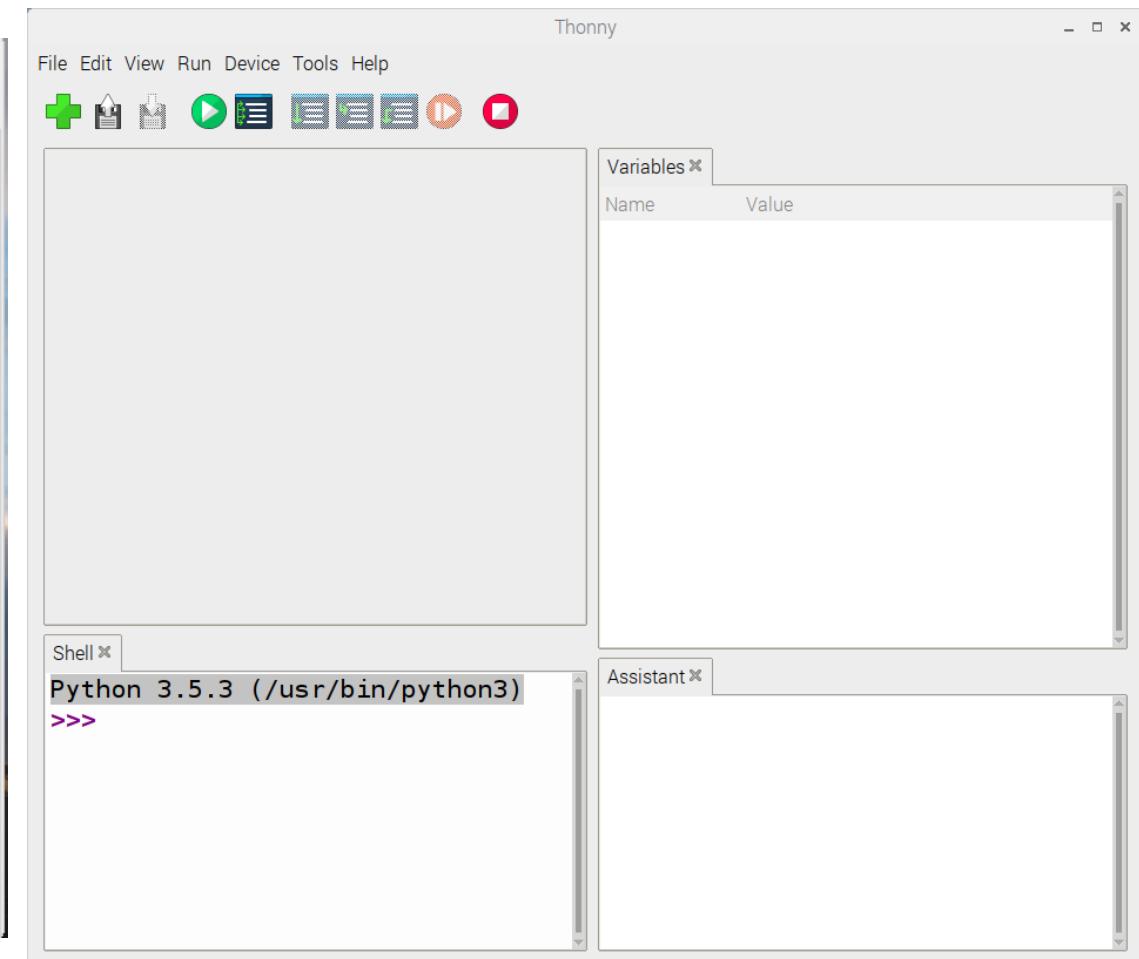
3.1 Click on terminal(shown with a red arrow below)

- At the prompt type: **sudo apt-get update**
- Wait for the updates to complete
- Then type: **sudo apt-get upgrade**
- If you get the following prompt
 - **Do you want to continue [Y/n]**
 - Type: **y**
 - And hit "Enter" on your keyboard and let the upgrades complete



Understanding your Python installation on the Raspberry Pi

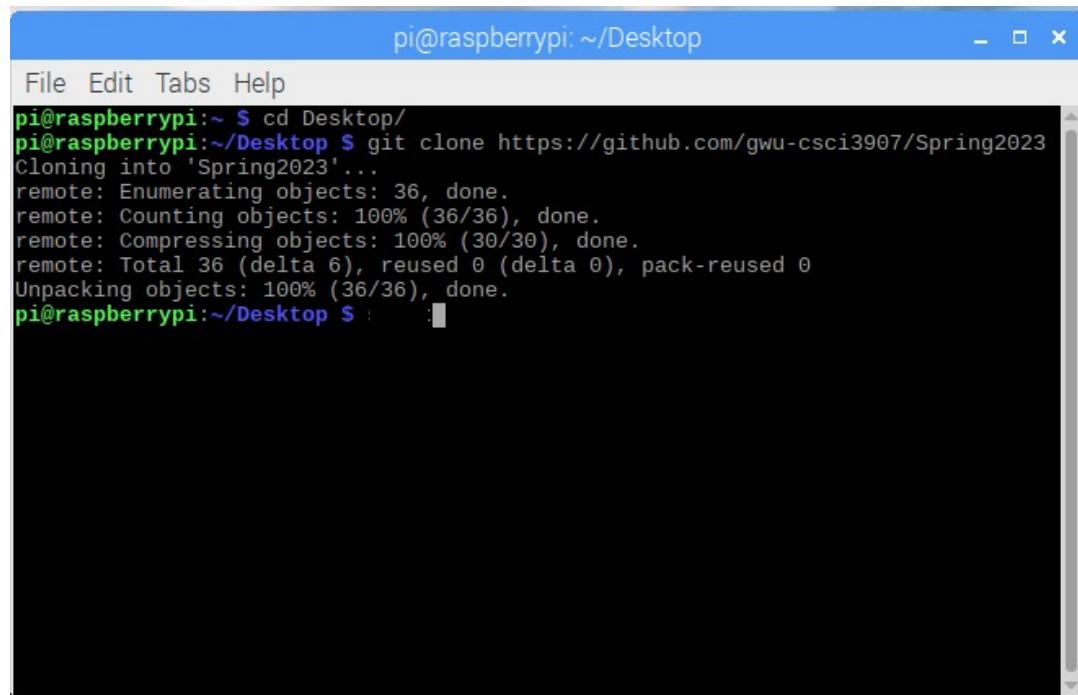
```
pi@raspberrypi: ~
File Edit Tabs Help
pi@raspberrypi:~ $ cat /etc/os-release
PRETTY_NAME="Raspbian GNU/Linux 9 (stretch)"
NAME="Raspbian GNU/Linux"
VERSION_ID="9"
VERSION="9 (stretch)"
VERSION_CODENAME=stretch
ID=raspbian
ID_LIKE=debian
HOME_URL="http://www.raspbian.org/"
SUPPORT_URL="http://www.raspbian.org/RaspbianForums"
BUG_REPORT_URL="http://www.raspbian.org/RaspbianBugs"
pi@raspberrypi:~ $
pi@raspberrypi:~ $
pi@raspberrypi:~ $ python --version
Python 2.7.13
pi@raspberrypi:~ $ python3 --version
Python 3.5.3
pi@raspberrypi:~ $
```



Downloading folders from course git-repository

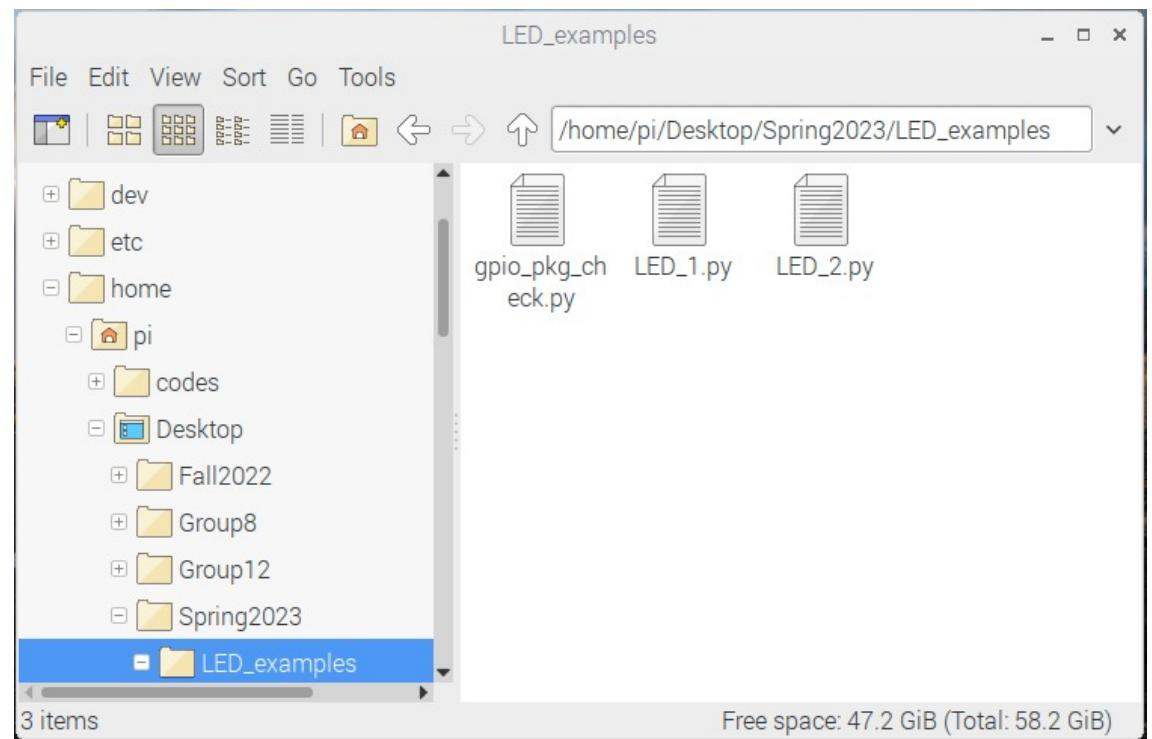
```
git clone git@github.com:gwu-csci3907/Spring2024.git
```

```
git clone https://github.com/gwu-csci3907/Spring2024.git
```



A terminal window titled "pi@raspberrypi: ~/Desktop". The command "git clone https://github.com/gwu-csci3907/Spring2024.git" is run, resulting in the following output:

```
pi@raspberrypi:~ $ cd Desktop/
pi@raspberrypi:~/Desktop $ git clone https://github.com/gwu-csci3907/Spring2024
Cloning into 'Spring2024'...
remote: Enumerating objects: 36, done.
remote: Counting objects: 100% (36/36), done.
remote: Compressing objects: 100% (30/30), done.
remote: Total 36 (delta 6), reused 0 (delta 0), pack-reused 0
Unpacking objects: 100% (36/36), done.
pi@raspberrypi:~/Desktop $ :
```



Practical side of blinking LEDs – the first RPi demo

Someone should summarize what we learned today