CSCi 4907
Introduction to IoT and Edge Computing Applications

Prof. Kartik Bulusu, CS Dept.

Week 1 [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]

GW School of Engineering & Applied Science
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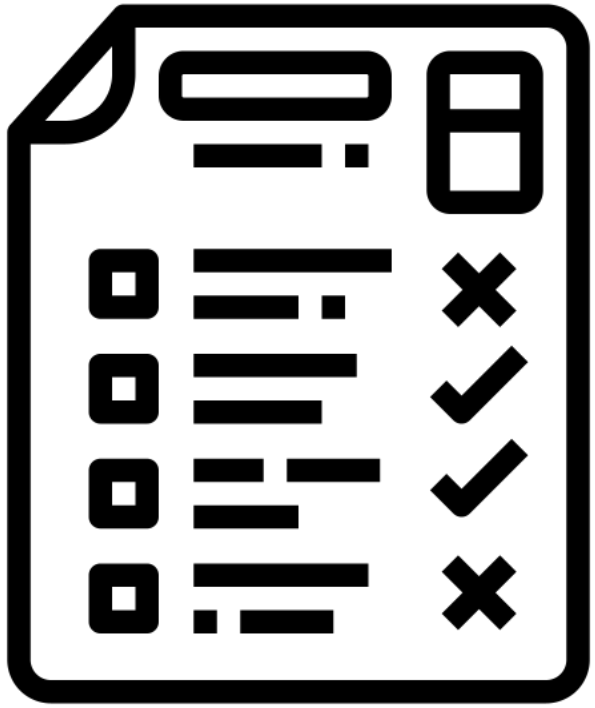
Spring 2024

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

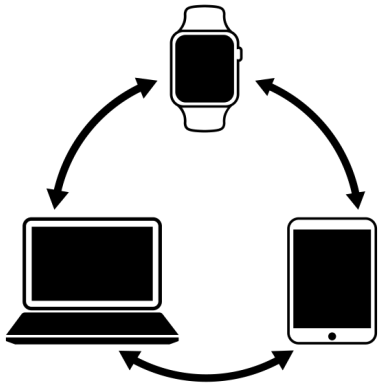
What's the "thing"?

Sources:
Calculator by Markus from https://thenounproject.com/browse/icons/term/calculator/
internet of things by Davo Sime from https://thenounproject.com/browse/icons/term/internet-of-things/
L. Bernardi, S. Sarma and K. R. Traub, The Inversion Factor: How to Thrive in the IoT Economy

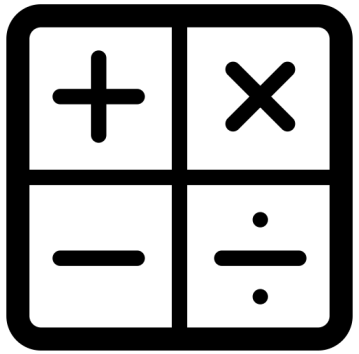
Paradigm #1

- 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

Sources:
Edge computing acts on data at the source: https://www.ibm.com/cloud/what-is-edge-computing
What is Edge computing? https://www.youtube.com/watch?v=3hScMLH7B4o&t=6s

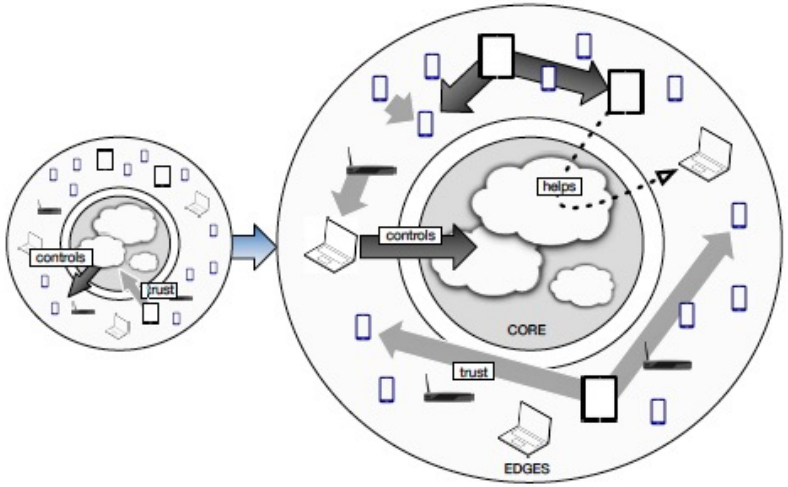
“things” with compute == edge compute

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.

Sources:
Garcia Lopez, Pedro; *et al*., (30 September 2015). "Edge-centric Computing". *ACM SIGCOMM Computer Communication Review*. **45** (5): 37–42. doi:10.1145/2831347.2831354.
M. Rabinovich, Z. Xiao, and A. Aggarwal. Computing on the edge: A platform for replicating internet applications. In Web content caching and distribution, pages 57{77. Springer, 2004.
Difference Between Edge Computing and Fog Computing, https://www.geeksforgeeks.org/difference-between-edge-computing-and-fog-computing/
Kazaa, https://en.wikipedia.org/wiki/Kazaa#/media/File:Kazaa_(logo).png
Napster, https://en.wikipedia.org/wiki/Napster#/media/File:Napster.png

"Edge Computing" was coined around 2002



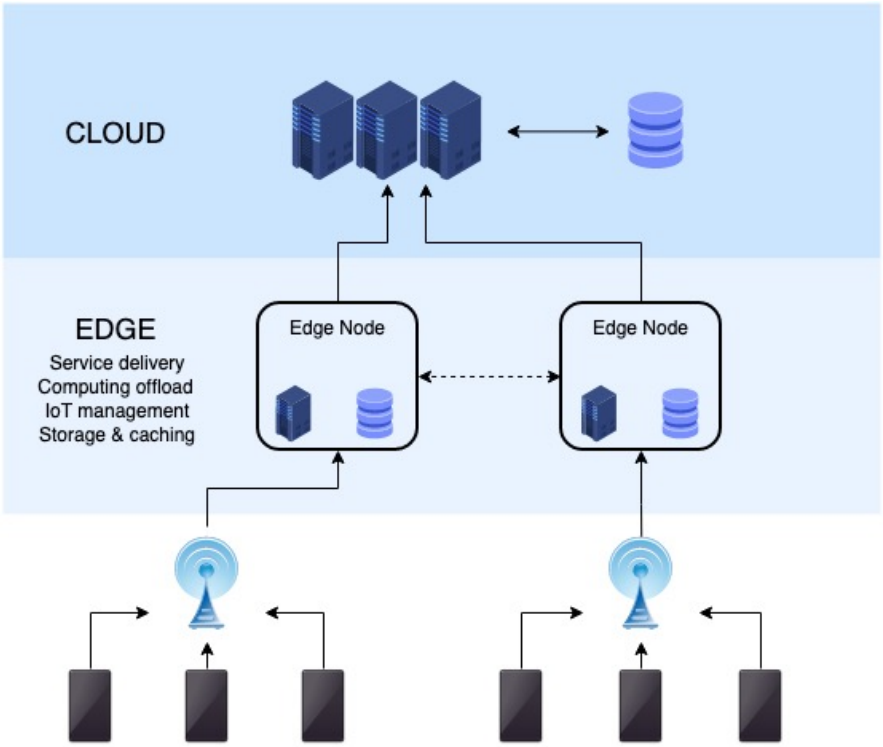
Content Delivery Networks:
It was mainly associated with the deployment of applications over CDNs, when some large companies announced deals to distribute software through CDN edge servers.

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.

Sources:
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/

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

Four (near future) Edge computing examples

Icon sources:
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/

Autononous 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.

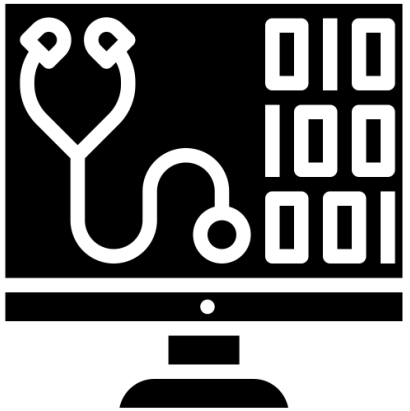
Source: https://www.autoblog.com/2017/02/21/race-for-autonomous-cars-is-over-mcelroy-autoline-opinion/

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/ustainability/?sh=483ebd025fab

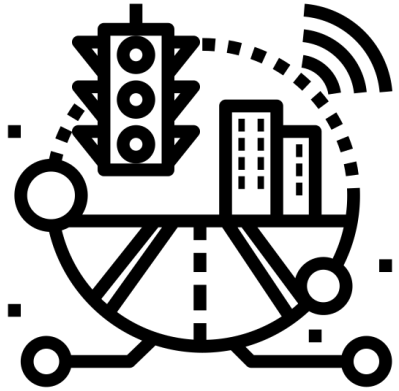


Transforming health care at the edge

- 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 he 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

Sources:
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?

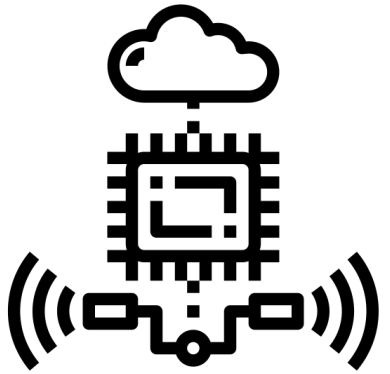
Sources:
Calculator by Markus from https://thenounproject.com/browse/icons/term/calculator/
industrial transformation by dDara from https://thenounproject.com/browse/icons/term/industrial-transformation
Definition: Edge Device, https://www.techtarget.com/searchnetworking/definition/edge-device

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



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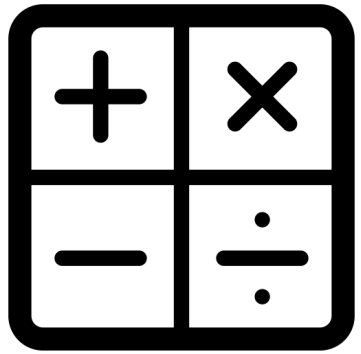
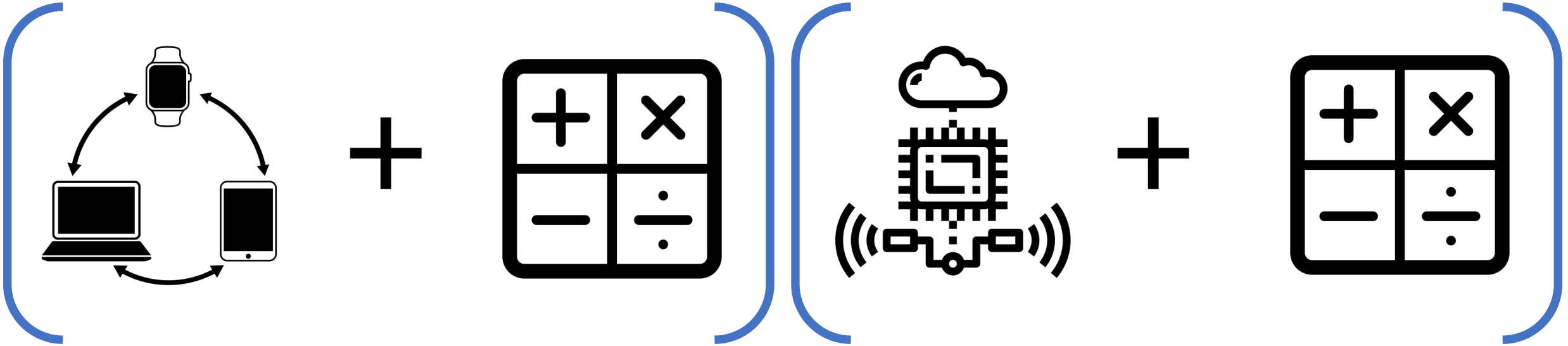


Paradigm #3

Overview of Computing in IoT

Sources:
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

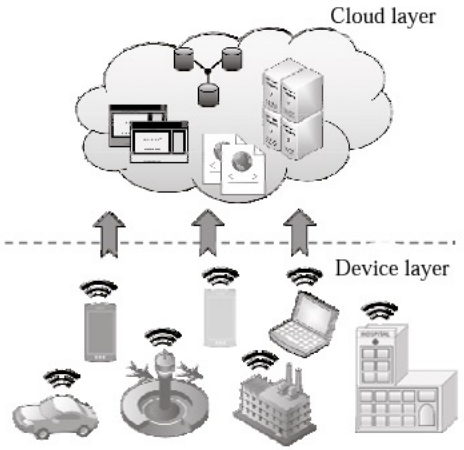


The Internet of Things (IoT) is made up of smart devices connected to a network—sending and receiving large amounts of data to and from other devices—which produces a large amount of data to be processed and analyzed.

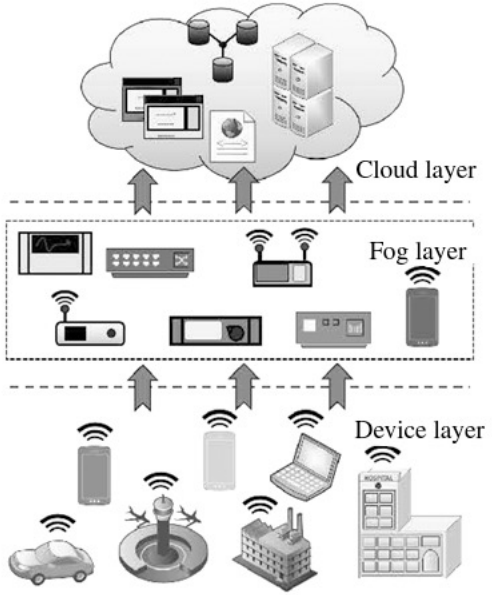
Edge computing, a strategy for computing on location where data is collected or used, allows IoT data to be gathered and processed at the edge, rather than sending the data back to a datacenter or cloud.

Edge, Fog and Cloud Landscape

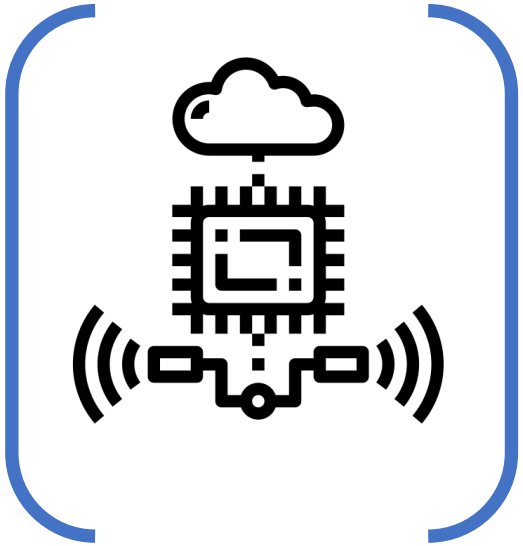
Sources:
internet of things by Davo Sime from https://thenounproject.com/browse/icons/term/internet-of-things/
Calculator by Markus from https://thenounproject.com/browse/icons/term/calculator/
industrial transformation by dDara from https://thenounproject.com/browse/icons/term/industrial-transformation
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



(a) Cloud computing



(b) Fog computing



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

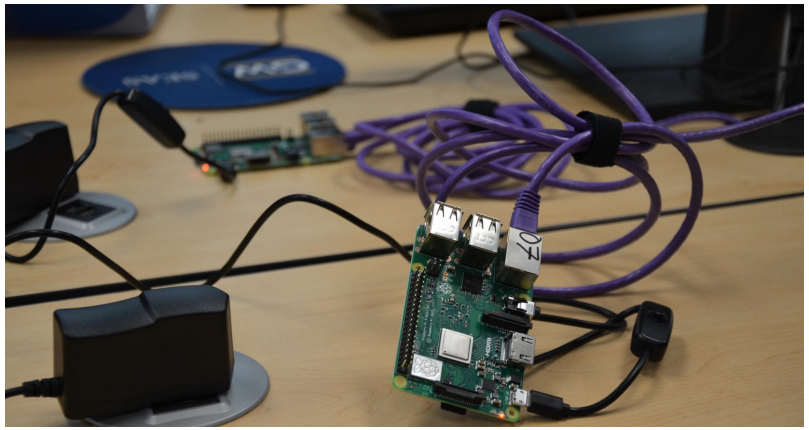
Sources:
Edge Computing and IoT: https://youtu.be/OHNANtfh1QQ
S. Mishra, A. Mukherjee and A. Roy, Introduction to IoT
Bera,S.,S.Misra,andJ.J.Rodrigues.2014."CloudComputingApplicationsforSmart Grid: A Survey." IEEE Transactions on Parallel and Distributed Systems 26(5): 1477–1494.

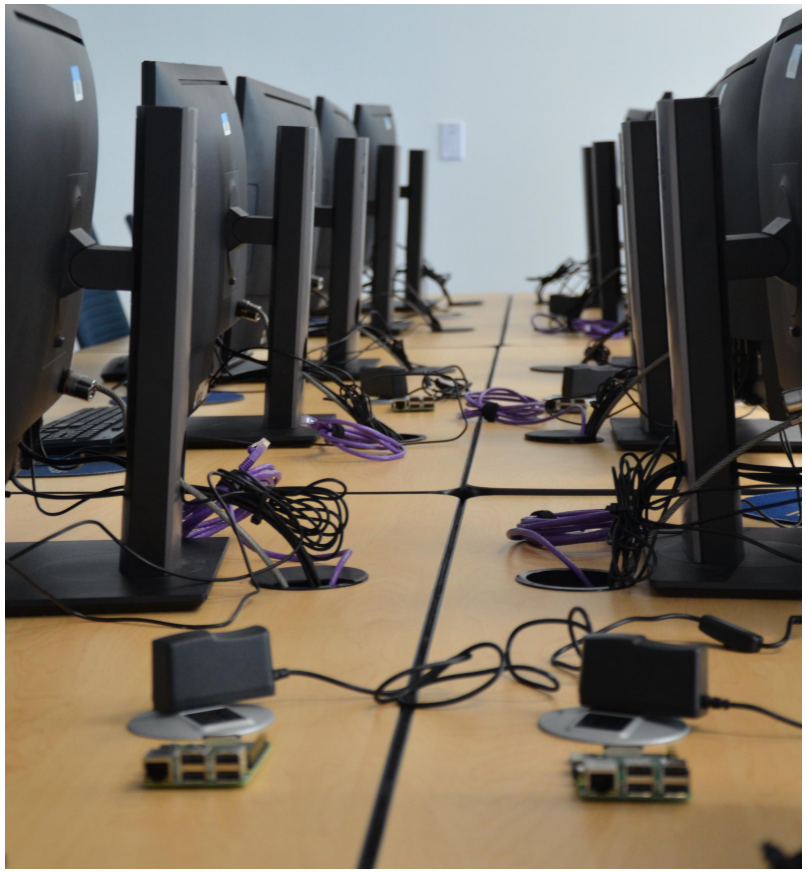
Summarizing the need for Edge Computing

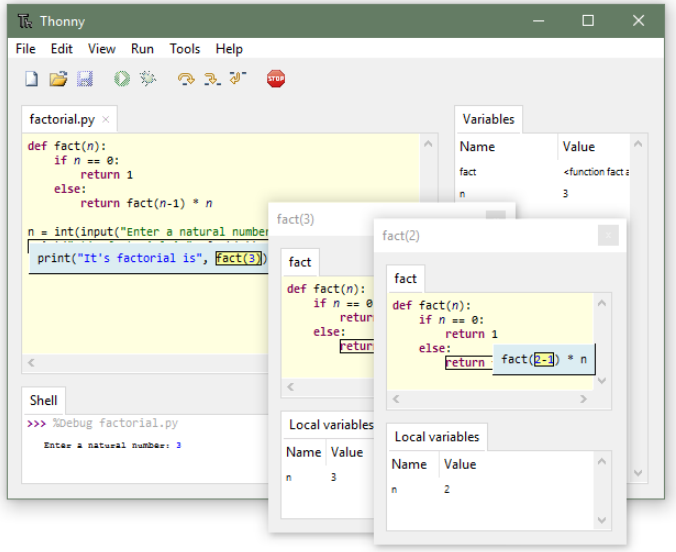
- IoT devices are low-power and getting smaller in size
- Formidable amount of information to be processed and handled.
- IoT devices need to depend on external platforms
  - Cloud
  - Fog
  - **Edge computing (more recent paradigm)**

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

School of Engineering & Applied Science
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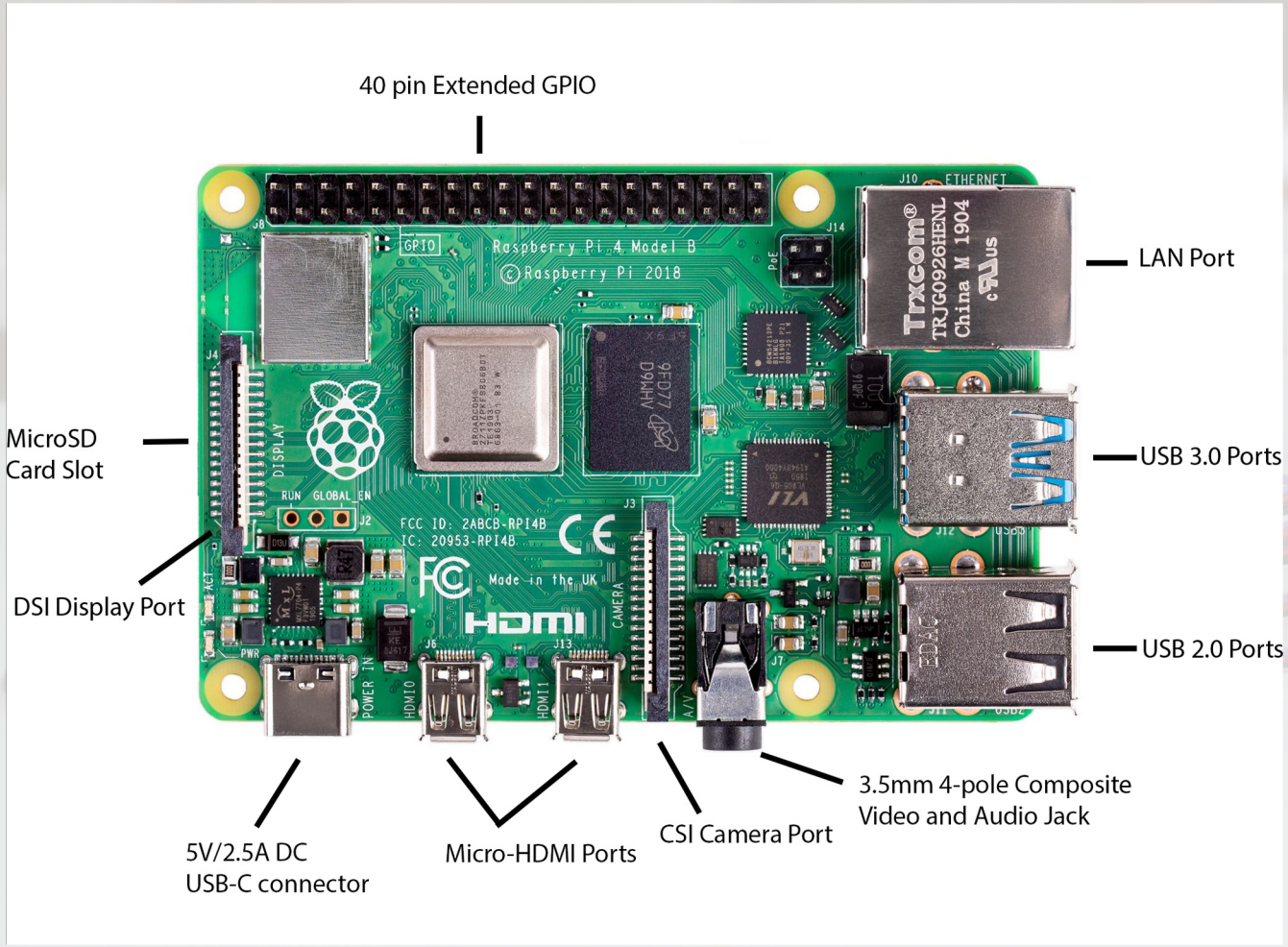
Prof. Kartik Bulusu, CS Dept. Spring 2024
CSCI 4907 Introduction to IoT and Edge Computing

Image Source:
https://seascf.seas.gwu.edu/th-201

STEP [-1]:
Familiarize yourself with TH201 classroom layout

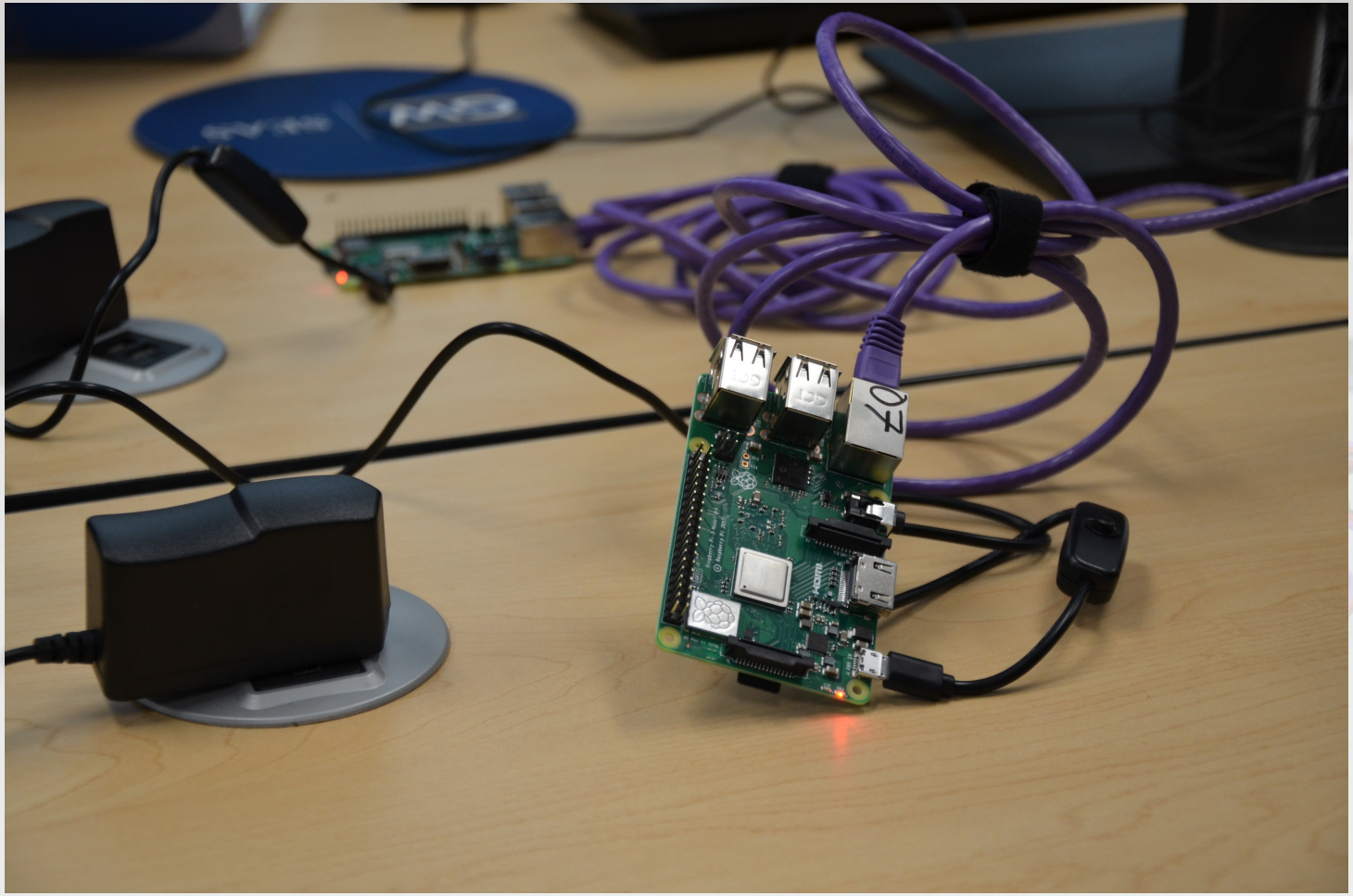
- 6 clusters of desks
- Each cluster 2-3 laptop power cables (Dell Inspiron)
- Each cluster has 2-3 blue colored ethernet cables specifically connectivity
- Each cluster should have surge protector (on the desk)

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 alpha-numeric 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)

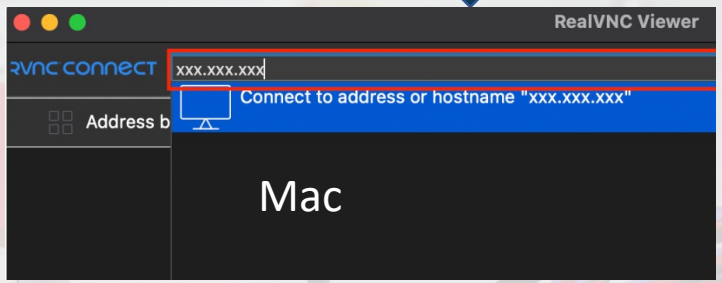
Each RPi has unique alpha-numeric name (e.g., Pi07, Pi152 etc)

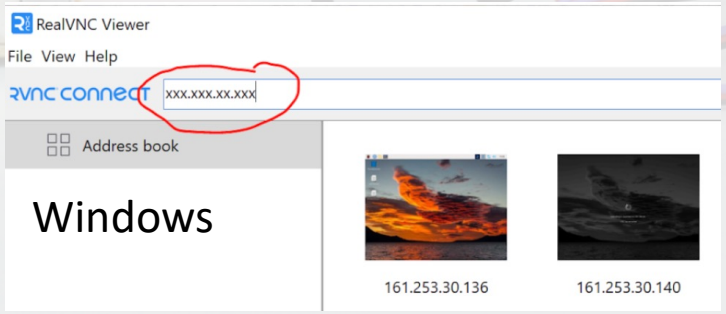
- Locate the Pi-name and the IP address on the <128.164.139.xx>

OR

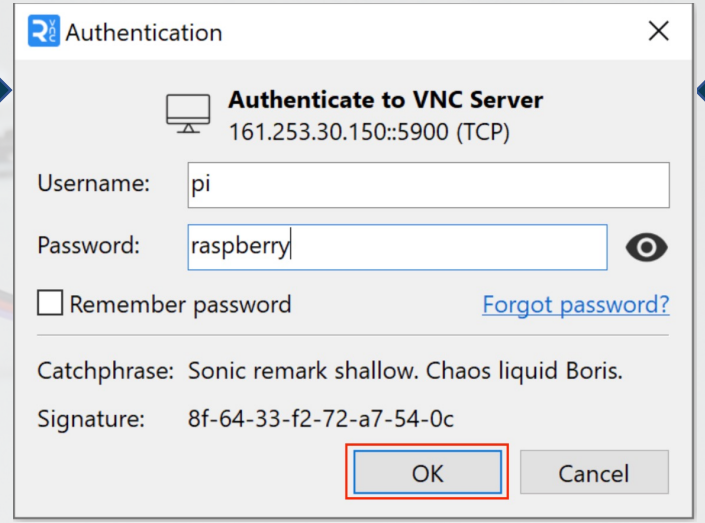
Each RPi connected using an ethernet cable directly to your laptops

- raspberrypi.local





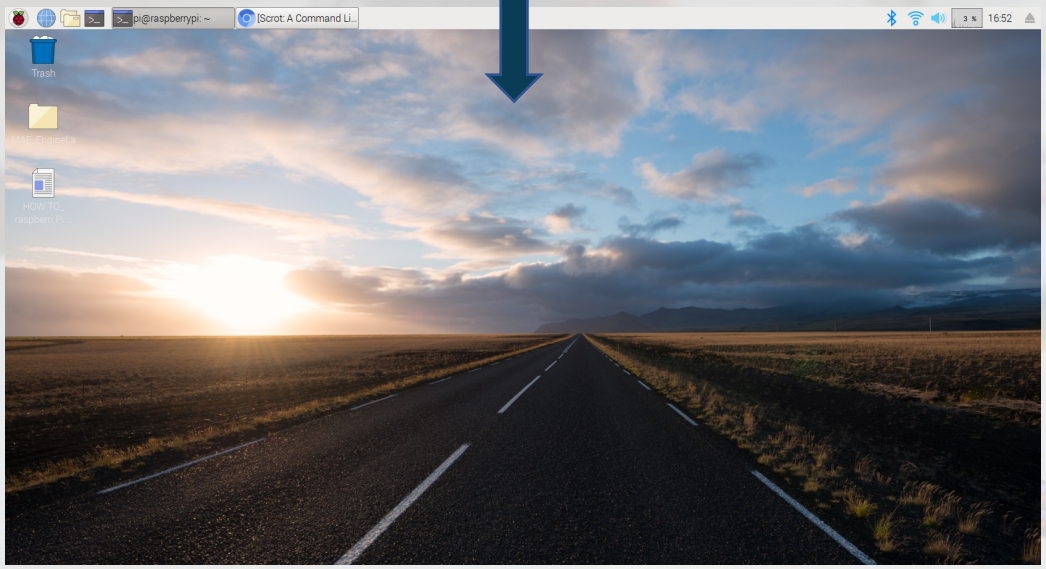
2.2 Once you are connected you will
- See Authentication box below
- Type in the Username and Password



STEP [3]:

Now that you accessed the RPi…

You will see a screen like the one shown below

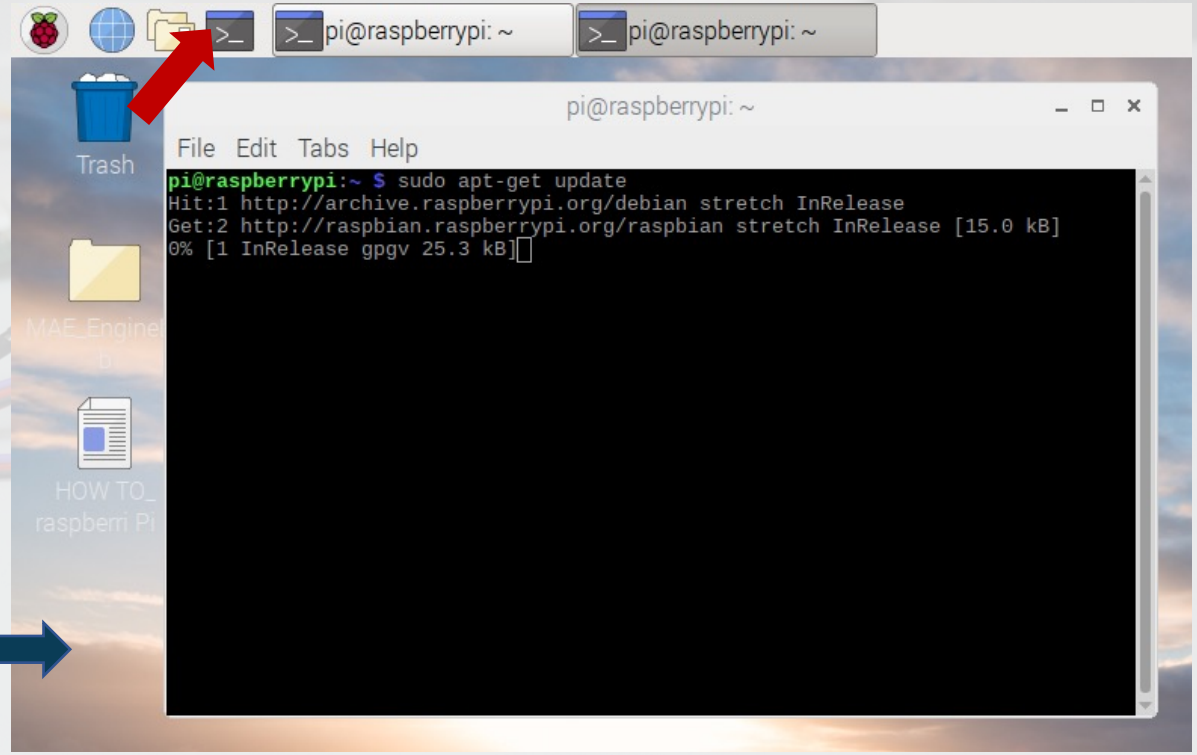


3.2 Testing is complete when you get to this step.

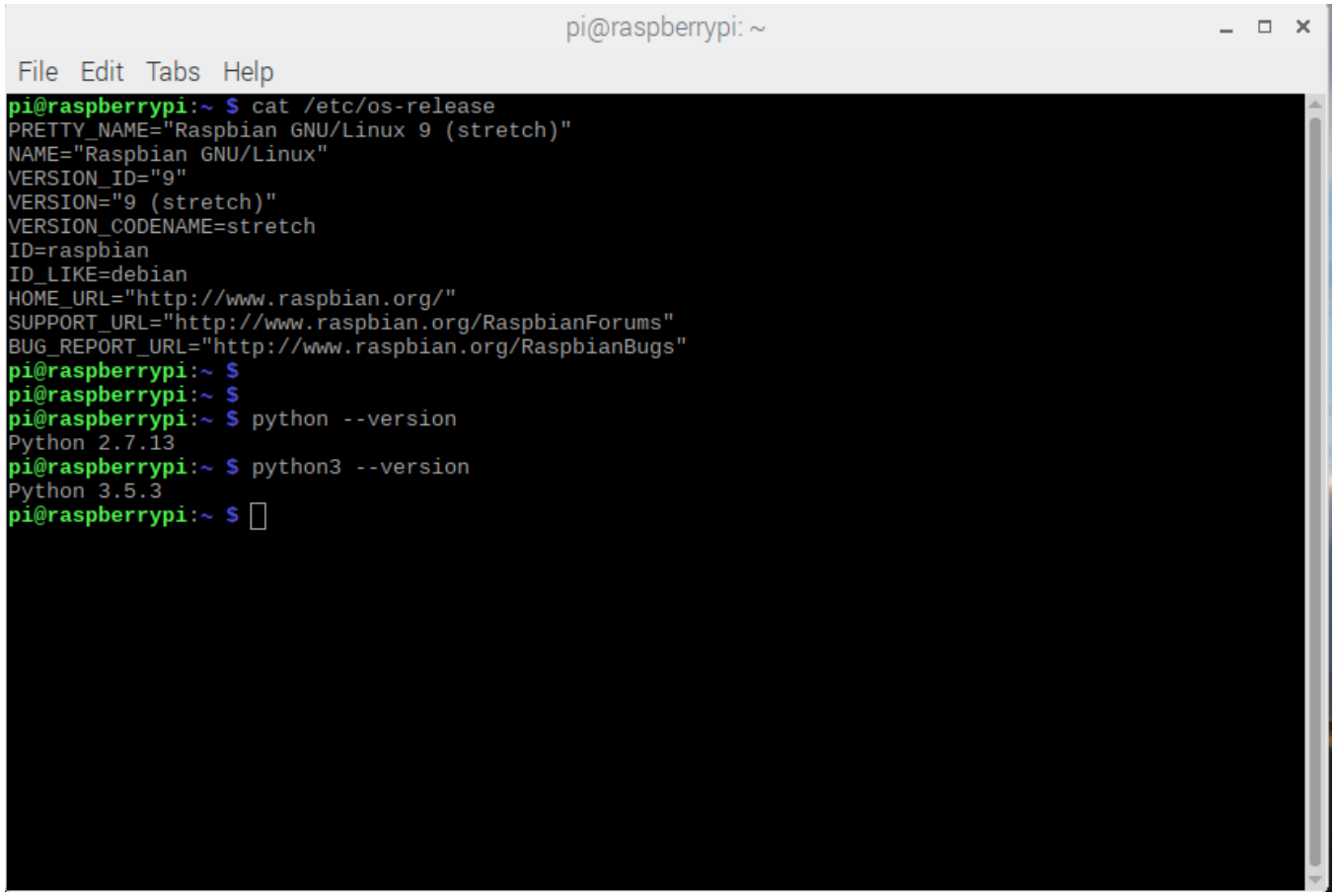
- Students should get the RPis to this step before the laboratory modules begin.

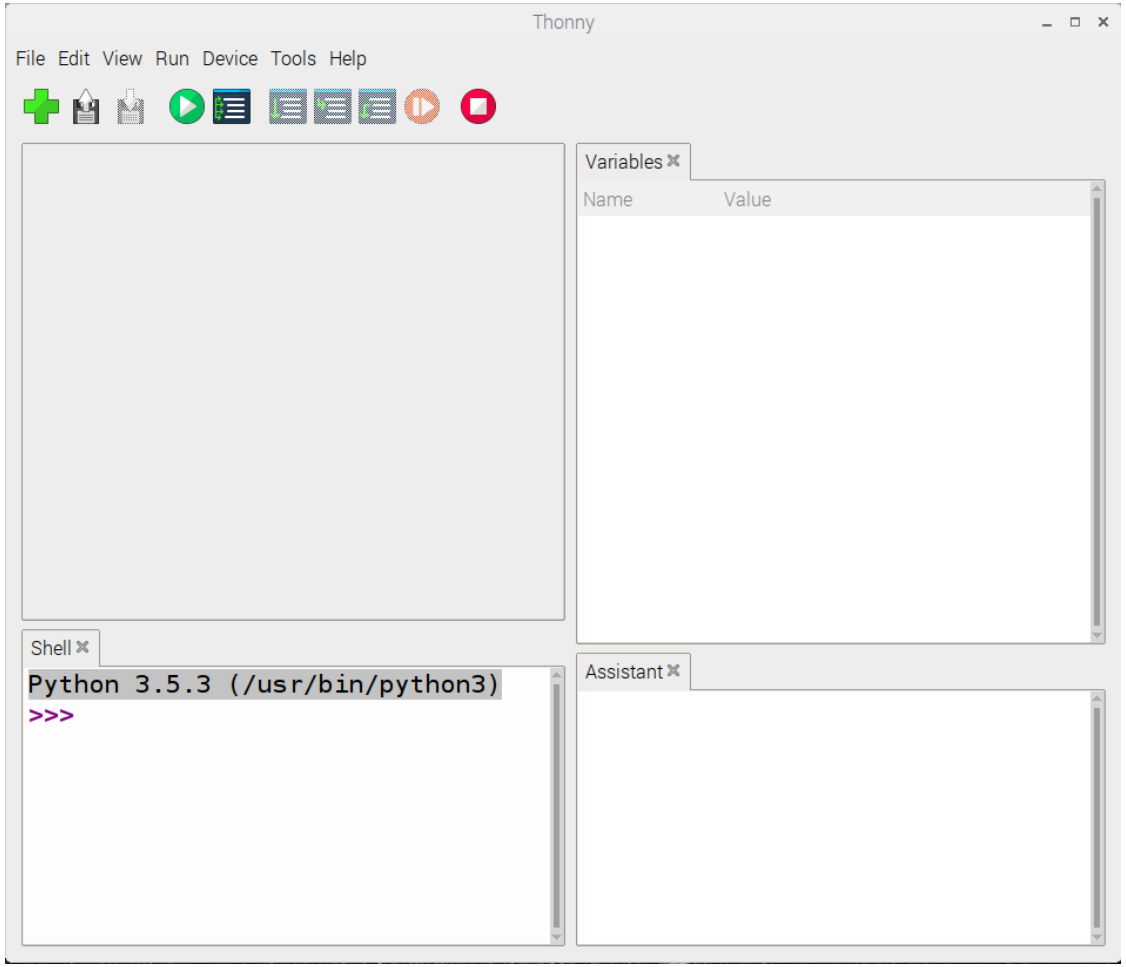
3.1 Click on terminal(shown with a red arrow below)

- 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

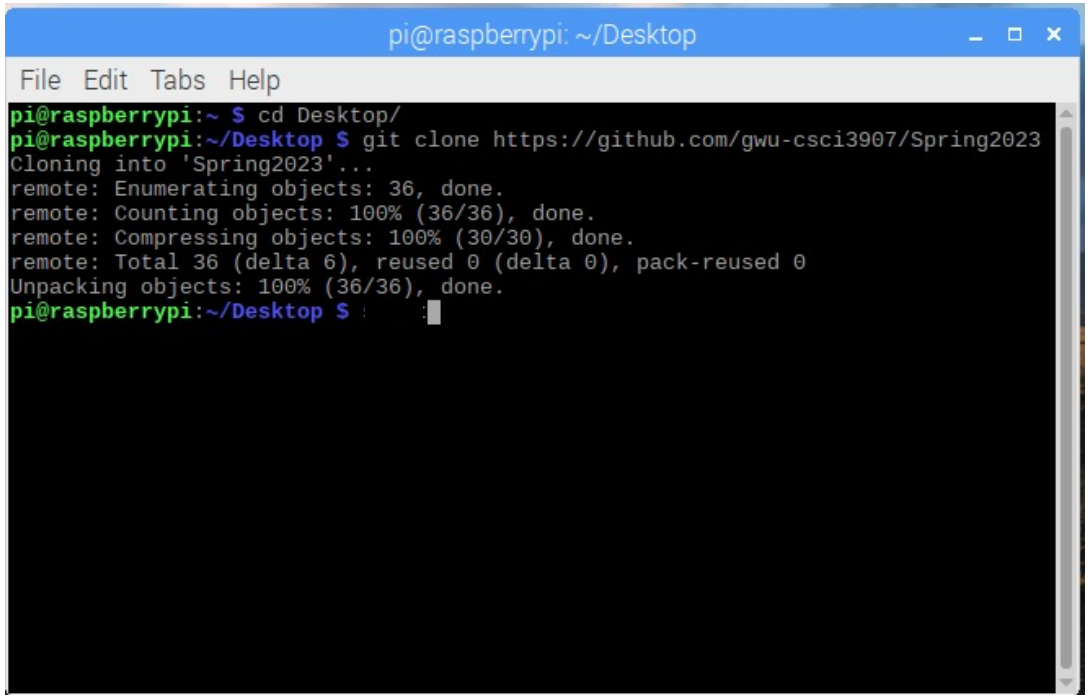

pi@raspberrypi: ~
File Edit Tabs Help
pi@raspberrypi:~ $ cat /etc/os-release
PRETTY_NAME="Raspbian GNU/Linux 9 (stretch)"
NAME="Raspbian GNU/Linux"
VERSION_ID="9"
VERSION="9 (stretch)"
VERSION_CODENAME=stretch
ID=raspbian
ID_LIKE=debian
HOME_URL="http://www.raspbian.org/"
SUPPORT_URL="http://www.raspbian.org/RaspbianForums"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


Thonny
File Edit View Run Device Tools Help
Variables
Name Value
Shell
Python 3.5.3 (/usr/bin/python3)
>>>
Assistant

Downloading folders from course git-repository

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

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



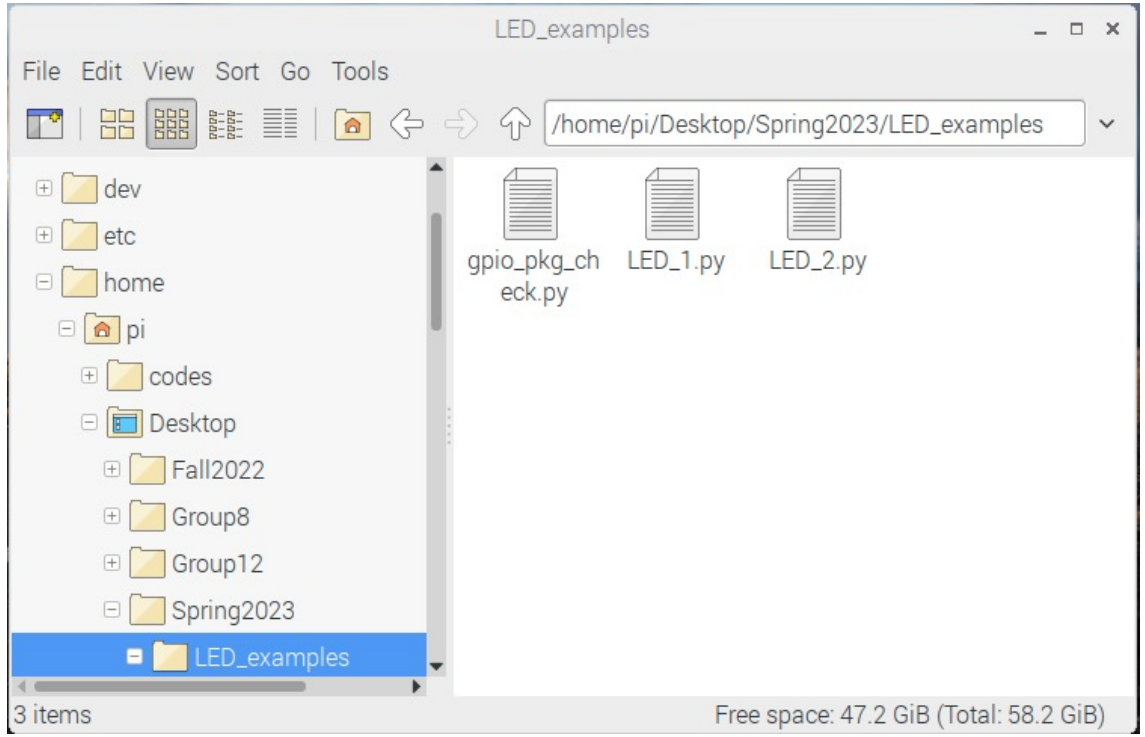


Photo: Kartik Bulusu

Practical side of blinking LEDs – the first RPi demo

Someone should summarize what we learned today