

MAE 6291

Internet of Things for Engineers

Prof. Kartik Bulusu, MAE Dept.

Week 12 [04/16/2025]

- Guest lecture: **Innovation @ IOT+Human Behaviour+Finance** by Anurag Bhatnagar, CEO and Co-Founder, ShiftAltCap - Investment banking firm.
- MQTT using ThingSpeak
- Using SenseHat with MQTT
- In-class Raspberry Pi Lab – ThingSpeak MQTT

git clone https://github.com/gwu-mae6291-iot/spring2025_codes.git



School of Engineering
& Applied Science

Spring 2025

THE GEORGE WASHINGTON UNIVERSITY

Photo: Kartik Bulusu

Final projects [Things to remember]



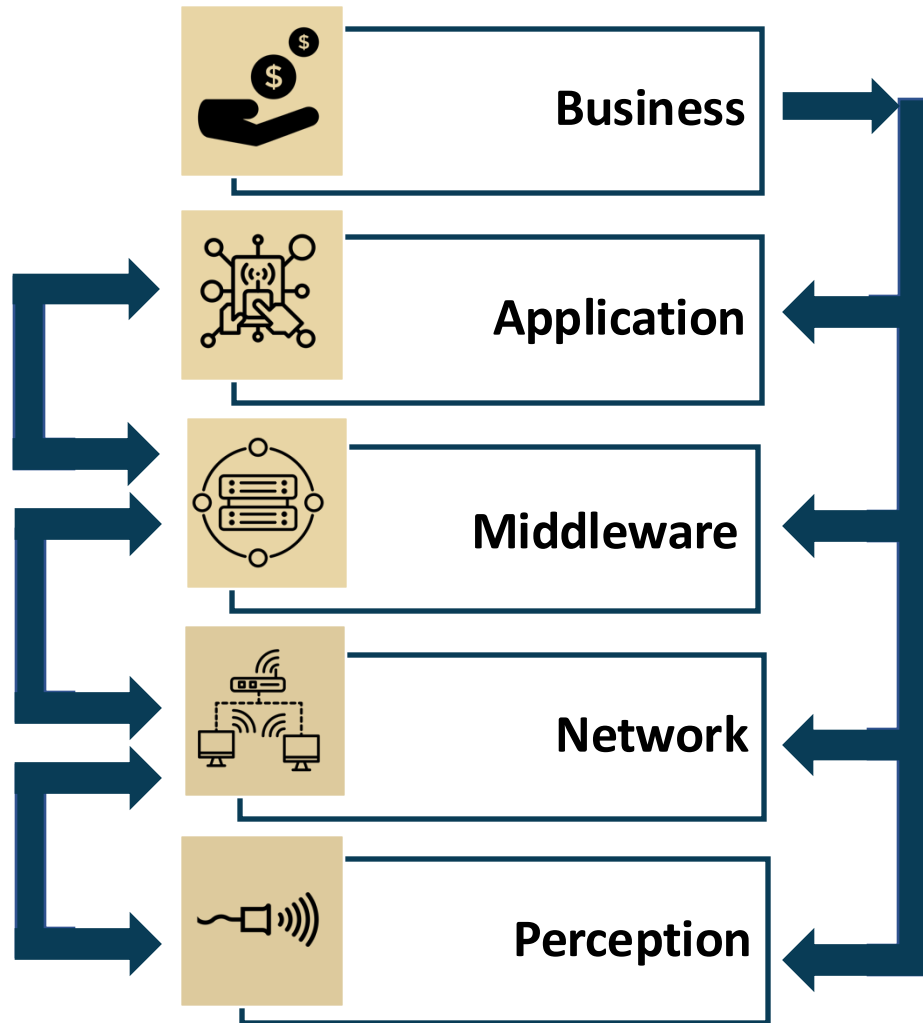


Expectations on student deliverables:

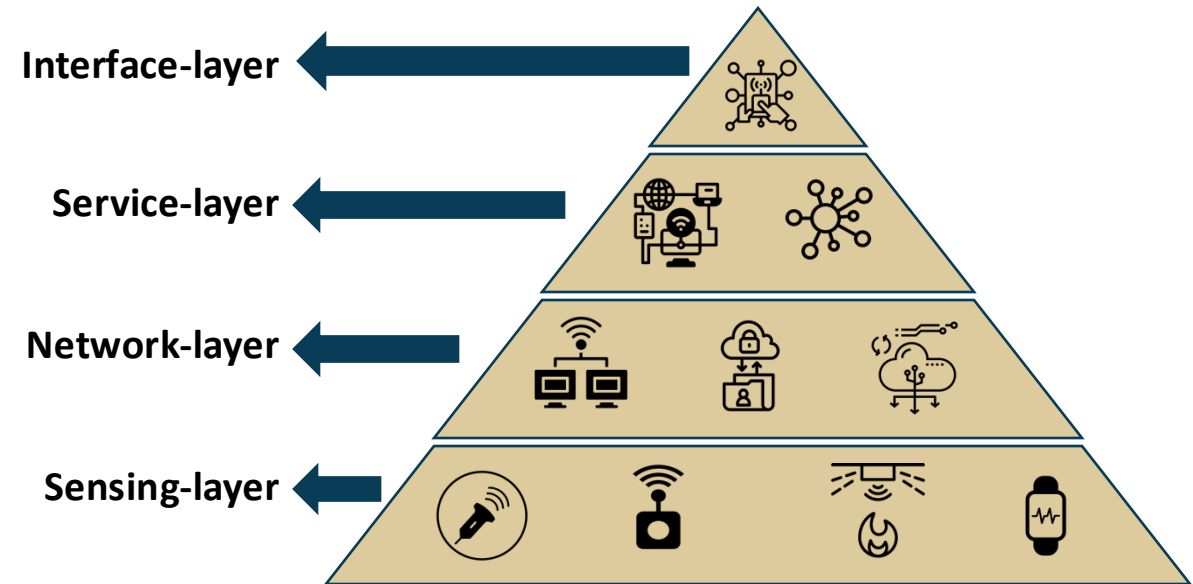
1. [Upload by 11:00 AM on April 23, 2025] Final project presentation [25 points]
2. [Upload by 11:00 AM on April 23, 2025] Final project 2-minute video [25 points]
3. [April 23, 2025] Final project demo [Tied to #1]
4. [Upload by April 24, 2025] Executive summary [10 points]
5. [Upload on April 28, 2025] Final project written report [25 points]
6. [Upload on April 30, 2025] Journal paper reviews by Grad students [10 points]
7. [On Google form] Share the Github repo of midterm and final projects [Tied to #1]
8. **Attendance and no extension**



The 5-Layer IoT Architecture



Service-oriented IoT Architecture



Sources:

sensor by Carolina Cani; sensor by Pham Duy Phuong Hung, sensor by Tippawan Sookruay, sensor by Lorenzo:

<https://thenounproject.com/browse/icons/term/sensor>

wifi network by Matthias Hartmann: <https://thenounproject.com/browse/icons/term/wifi-network/>

application by Chaowalit Koetchuea: <https://thenounproject.com/browse/icons/term/application/>

IoT Architecture layers: <https://www.startertutorials.com/blog/iot-architecture-layers.html>

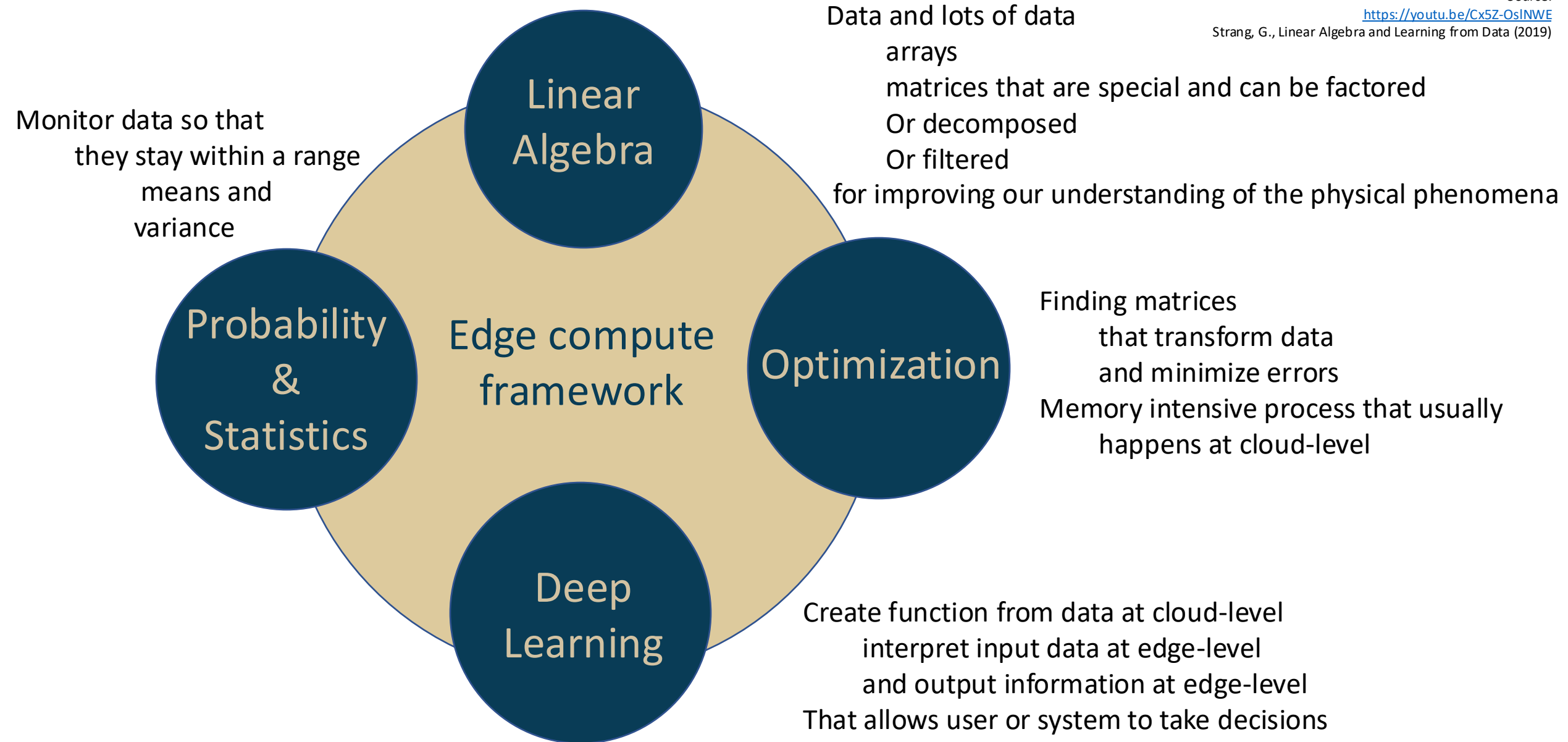


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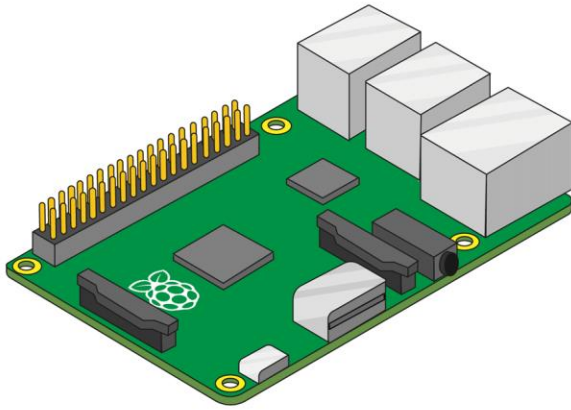
Spring 2025

Internet of Things for Engineers



Topics to be covered today

Hardware:
SenseHat



IoT Strategy #1:
Paho-MQTT with senseHat

paho-mqtt 2.0.0

```
pip install paho-mqtt
```



IoT Strategy #2:
Thingspeak with senseHat

ThingSpeak for IoT
Projects

Data collection in the cloud with advanced data
analysis using MATLAB

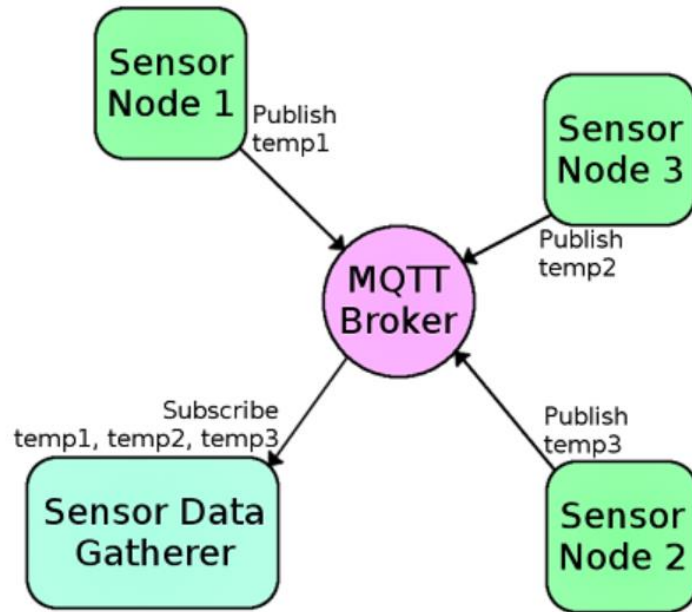


Recap MQTT with senseHat Message Queuing Telemetry Transport

Goal: To understand how publishing and subscribing works practically



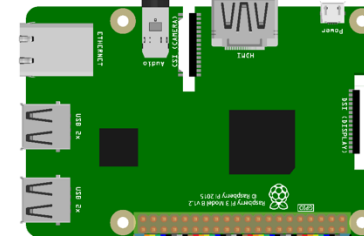
MQTT paradigm



Hardware

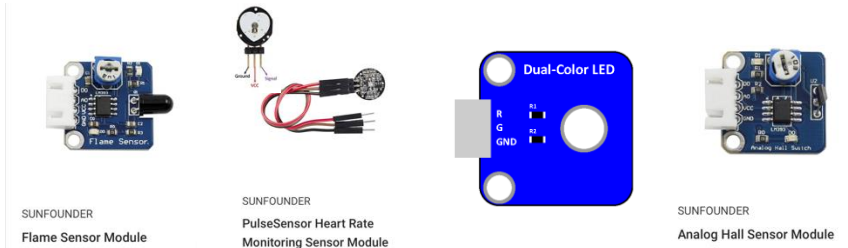
Broker

- The broker is the server
- It distributes the information to the interested devices connected to the server.



Client

- The device that connects to broker to send or receive information.



Messaging

Topic

- The name that the message is about.
- Clients publish, subscribe, or do both to a topic.

Subscribe

- Clients tell the broker which topic(s) they're interested in.

Publish

- Clients that send information to the broker to distribute to interested clients based on the topic name.

QoS

- Quality of Service to the broker
- Integer value ranging from 0-2.



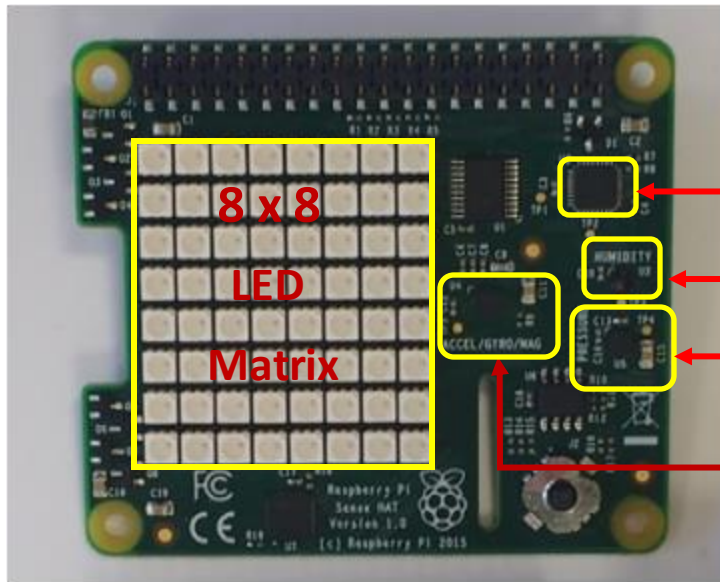
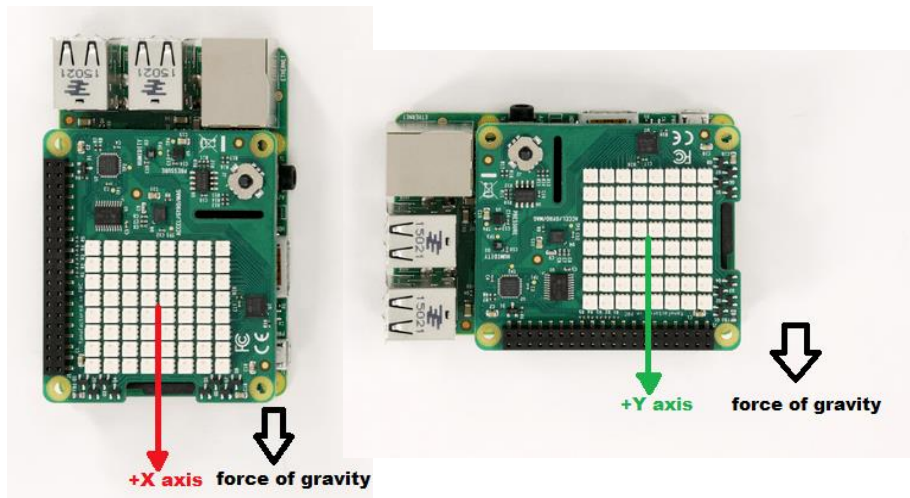


Image source: <https://projects.raspberrypi.org/en/projects/getting-started-with-the-sense-hat/2>

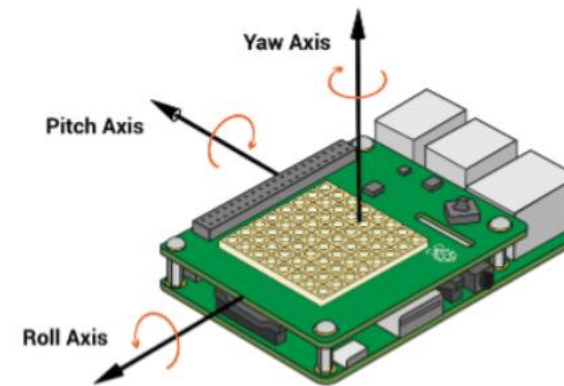


Source: <https://www.mathworks.com/help/supportpkg/raspberrypi/examples/auto-rotate-an-image-displayed-on-sense-hat-led-matrix.html>

▪ The Sense HAT has a variety of sensors that can be read from:

| | |
|------------------|---|
| "Temperature" | reads temperature in degrees Celsius |
| "Humidity" | reads humidity in % RH |
| "Pressure" | reads atmospheric pressure in millibars |
| "Rotation" | reads gyroscopic motion in revolutions per second |
| "Acceleration" | reads acceleration in terms of standard accelerations due to gravity on Earth's surface |
| "Orientation" | reads orientation relative to magnetic north in degrees |
| "Magnetic Field" | reads strength and direction of a magnetic field around the sensor in microteslas |

▪ The gyroscope, accelerometer, and magnetometer sensors return a list of three values that corresponds to $\{roll, pitch, yaw\}$, as oriented according to the following image:



Starting point for further exploration:

[Link for “Getting started with the Sense HAT”](#)

Source: <https://reference.wolfram.com/language/ref/device/SenseHAT.html>

Eclipse paho - Another open source MQTT broker



paho-mqtt 1.6.1

```
pip install paho-mqtt
```



Paho is an

eclipse
iot
project

Eclipse-paho provides a client class which enable applications to connect to an [MQTT](#) broker to publish messages, and to subscribe to topics and receive published messages.

It also provides some helper functions to make publishing one off messages to an MQTT server very straightforward.



Step-2: Install paho-mqtt & psutil libraries

sudo apt-get update && sudo apt-get upgrade

```
pi@raspberrypi: ~  
File Edit Tabs Help  
pi@raspberrypi:~$ sudo apt-get update && sudo apt-get upgrade  
Get:1 http://raspbian.raspberrypi.org/raspbian stretch InRelease [15.0 kB]  
Hit:2 http://archive.raspberrypi.org/debian stretch InRelease  
Fetched 15.0 kB in 5s (2,647 B/s)  
Reading package lists... Done  
Reading package lists... Done  
Building dependency tree  
Reading state information... Done  
Calculating upgrade... Done  
0 upgraded, 0 newly installed, 0 to remove and 0 not upgraded.  
pi@raspberrypi:~$
```

sudo pip --upgrade install psutil

sudo pip install paho-mqtt

```
pi@raspberrypi: ~  
File Edit Tabs Help  
pi@raspberrypi:~$ sudo pip3 install paho-mqtt  
/usr/lib/python3/dist-packages/secretstorage/dhcrypto.py:15: CryptographyDeprecationWarning: Python 3.5 support will be dropped in the next release of cryptography. Please upgrade your Python.  
  from cryptography.utils import int_from_bytes  
DEPRECATION: Python 3.5 reached the end of its life on September 13th, 2020. Please upgrade your Python as Python 3.5 is no longer maintained. pip 21.0 will drop support for Python 3.5 in January 2021. pip 21.0 will remove support for this functionality.  
Looking in indexes: https://pypi.org/simple, https://www.piwheels.org/simple  
Requirement already satisfied: paho-mqtt in /usr/local/lib/python3.5/dist-packages (1.6.1)  
pi@raspberrypi:~$
```

sudo pip install psutil

```
pi@raspberrypi: ~  
File Edit Tabs Help  
pi@raspberrypi:~$ sudo pip3 install psutil  
/usr/lib/python3/dist-packages/secretstorage/dhcrypto.py:15: CryptographyDeprecationWarning: Python 3.5 support will be dropped in the next release of cryptography. Please upgrade your Python.  
  from cryptography.utils import int_from_bytes  
DEPRECATION: Python 3.5 reached the end of its life on September 13th, 2020. Please upgrade your Python as Python 3.5 is no longer maintained. pip 21.0 will drop support for Python 3.5 in January 2021. pip 21.0 will remove support for this functionality.  
Looking in indexes: https://pypi.org/simple, https://www.piwheels.org/simple  
Requirement already satisfied: psutil in /usr/local/lib/python3.5/dist-packages (5.9.4)  
pi@raspberrypi:~$
```

Source:

<https://towardsdatascience.com/iot-made-easy-esp-micropython-mqtt-thingspeak-ce05eea27814>

<https://nothans.com/thingspeak-tutorials/update-a-thingspeak-channel-using-mqtt-on-a-raspberry-pi>

<https://pypi.org/project/paho-mqtt/>

<https://pypi.org/project/psutil/>

paho-mqtt 2.0.0

pip install paho-mqtt

psutil 5.9.8

pip install psutil

psutil (process and system utilities) is a cross-platform library for retrieving information on **running processes** and **system utilization** (CPU, memory, disks, network, sensors) in Python



Explore MQTT with ThingSpeak IoT Analytics [10 points]



Thingspeak – An IoT analytics platform

ThingSpeak for IoT Projects

Data collection in the cloud with advanced data analysis using MATLAB

ThingSpeak is an IoT analytics platform service that allows you to aggregate, visualize, and analyze live data streams in the cloud.

You can send data to ThingSpeak from your devices, create instant visualization of live data, and send alerts.



Collect

Send sensor data privately to the cloud.



Analyze

Analyze and visualize your data with MATLAB.



Act

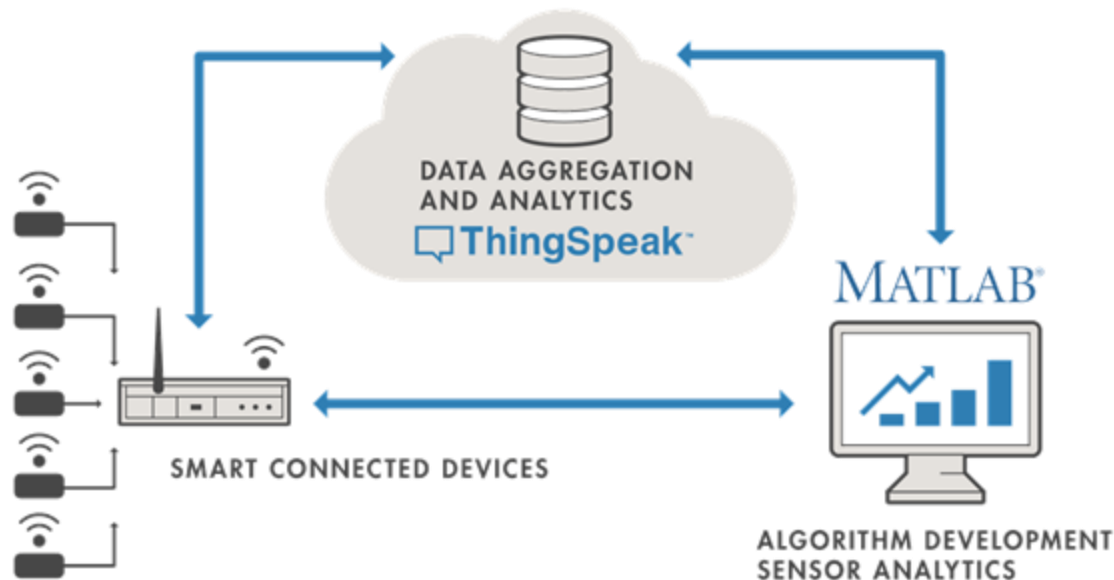
Trigger a reaction.

Create a Thingspeak account:

<https://thingspeak.com/login?skipSSOCheck=true>

To use ThingSpeak, you must sign in with your existing MathWorks account or create a new one.

Non-commercial users may use ThingSpeak for free.



Email

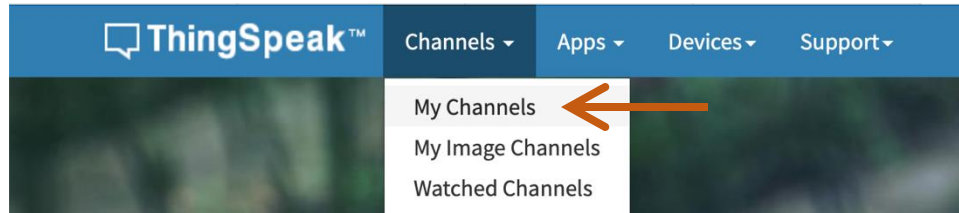


No account? [Create one!](#)

By signing in, you agree to our [privacy policy](#).

Next

Step-3: Build the ThingSpeak channels



New Channel

Name ←

Description ←

| | | | |
|----------------|--------------------------------------|-------------------------------------|---|
| Field 1 | <input type="text" value="CPU (%)"/> | <input checked="" type="checkbox"/> | ← |
| Field 2 | <input type="text" value="RAM (%)"/> | <input checked="" type="checkbox"/> | ← |
| Field 3 | <input type="text"/> | <input type="checkbox"/> | |
| Field 4 | <input type="text"/> | <input type="checkbox"/> | |
| Field 5 | <input type="text"/> | <input type="checkbox"/> | |
| Field 6 | <input type="text"/> | <input type="checkbox"/> | |
| Field 7 | <input type="text"/> | <input type="checkbox"/> | |
| Field 8 | <input type="text"/> | <input type="checkbox"/> | |

Tompkins Hall of Engineering

Type: University building
Address: 725 23rd Street Northwest, DC 20052
Categories: [building](#) and [education](#)
Location: [Washington, D.C., Mid-Atlantic, United States, North America](#)
[View on OpenStreetMap](#)

| | |
|--|--|
| Latitude 38.899° or 38° 53' 56" north | Longitude -77.04967° or 77° 2' 59" west |
| Elevation 62 feet (19 metres) | Levels 4 |
| Operator The George Washington University | Open Location Code 87C4VXX2+H4 |
| OpenStreetMap ID way 331159440 | OpenStreetMap Feature building=university |
| GeoNames ID 6342433 | |

Thanks for contributing to our open data sources. [open data](#)

This page is based on [OpenStreetMap](#), [GeoNames](#), [Wikidata](#) and [Wikimedia Commons](#).

Source:
<https://towardsdatascience.com/iot-made-easy-esp-micropython-mqtt-thingspeak-ce05eea27814>
<https://nothans.com/thingspeak-tutorials/update-a-thingspeak-channel-using-mqtt-on-a-raspberry-pi>
<https://www.mathworks.com/help/thingspeak/collect-data-in-a-new-channel.html>
<https://mapcarta.com/25030544>



My Channels

[New Channel](#)



Tags

(Tags are comma separated)

Link to External Site

Link to GitHub

Elevation

Show Channel Location ☒ ←

Latitude ←

Longitude ←

Show Video ☐

☒ YouTube
☐ Vimeo

Video URL

Show Status ☐

[Save Channel](#) ←

ThingSpeak™ Channels Apps Devices Support Commercial Use How to Buy

IoT_CPU_RAM_demo

Channel ID: 2097727 | Demo channel for CS3907-Spring 2023
 Author: kartikbulusu
 Access: Private

Private View Public View Channel Settings Sharing API Keys Data Import / Export

Add Visualizations Add Widgets

Export recent data

MATLAB Analysis MATLAB Visualization

Channel 3 of 3 < >

Channel Stats

Created: about a minute ago
 Entries: 0

Field 1 Chart

Field 2 Chart

Channel Location

- Familiarize yourself with the panel
- Note down the Channel ID

ThingSpeak™ Channels Apps Devices Support

IoT_CPU_RAM_demo

Channel ID: 2097727 | Demo channel for CS3907-Spring 2023
 Author: kartikbulusu
 Access: Private

Private View Public View Channel Settings Sharing API Keys Data Import / Export

Channel Settings

Percentage complete 50%

Channel ID 2097727

Name IoT_CPU_RAM_demo

Description Demo channel for CS3907-Spring 2023

Field 1 CPU (%) ☒

Field 2 RAM (%) ☒

Step-4: Add MQTT device –Raspberry Pi

Source:
<https://towardsdatascience.com/iot-made-easy-esp-micropython-mqtt-thingspeak-ce05eea27814>
<https://nothans.com/thingspeak-tutorials/update-a-thingspeak-channel-using-mqtt-on-a-raspberry-pi>
<https://www.mathworks.com/help/thingspeak/collect-data-in-a-new-channel.html>
<https://mapcarta.com/25030544>

ThingSpeak™ Channels Apps Devices Support

IoT_CPU_RAM_demo

Channel ID: **2097727**
Author: **kartikbulusu**
Access: Private

Demo channel for CS3907-Spring 2023

MQTT

Private View Public View Channel Settings Sharing API Keys Data Import / Export

ThingSpeak™ Channels Apps Devices Support

MQTT Devices

Add a new device

Add a new device

Device Information

Name* Pi3 [Raspberry Pi 3B+]

Description Pi3 to demo of ThingSpeak MQTT

Authorize channels to access ⓘ

✓ -- Select a Channel --

Your Channels & Public Channels

-- Enter a channel ID below --

Your Recent Channels

IoT_CPU_RAM_demo (2097727)

IoT1_CPU_RAM_demo (2033598)

testing_IoT2 (2097384)

Add Channel

Allow Subscribe

Cancel Add Device

New Device Added

Device Information

ThingSpeak has added a new MQTT device and authorized it to access the channels you selected.

Device Name: Pi3 [Raspberry Pi 3B+]

MQTT Credentials

Use these MQTT credentials to publish and subscribe to ThingSpeak channels. [Learn More](#)

Client ID NC0zDxwrJgEUAYxPA08Bhc

Username NC0zDxwrJgEUAYxPA08Bhc

Password

⚠ ThingSpeak does not store a copy of your device's MQTT password. Download or copy it to keep it safe.

Download Credentials

MATLAB-file (*.m)

Arduino (mqtt_secrets.h)

Plain Text (*.txt)

Done

Graded in-class lab
Download codes from shared-drive and demonstrate
[10 points]

Someone should summarize what we learned today

