Hardware II Seminar

Sensors and Data Analysis

FAB LAB BCN

Iaac

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Quick recap

Making an actual sensor setup

Interfacing with hardware for sensing

Sensors and computers

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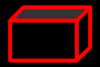
Making an actual sensor setup

SENSOR

- *How do we read the sensor? Analog, or digital sensor?*
- *Can the computer read it?*
- *Are there libraries for it?*



COMPUTER I

- *Do we need an additional computer for storing the data?*
- *Or for post-processing it?*
- *How do both computers communicate? Cable or wireless? Serial, WiFi… ?*

COMPUTER II

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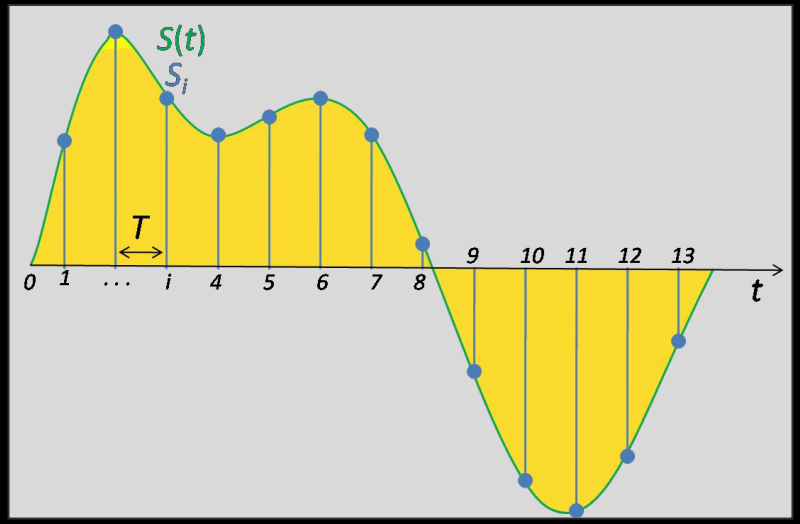
Making an actual sensor setup - Streaming data

Three important frequencies to take into account:

1. *The frequency at which the sensor gives us data*
2. *The frequency at which we (can) sample the sensor*
3. *The natural frequencies that we want to capture*



Key takeaways:

1. *We don't need to sample faster than the sensor gives us data*
2. *We need to sample at least twice as fast as the Nyquist frequency (Nyquist-Shannon theorem)*

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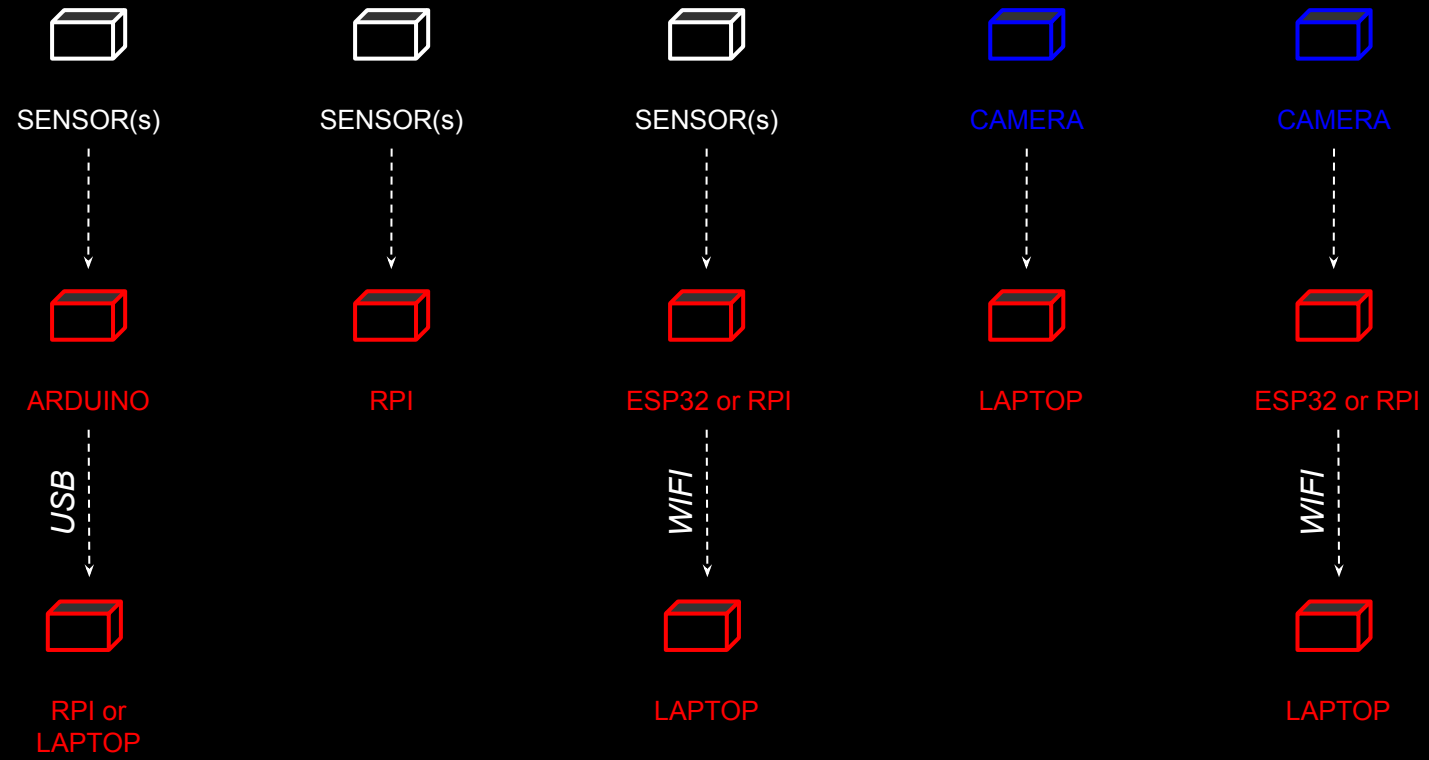
Making an actual sensor setup - Some use cases



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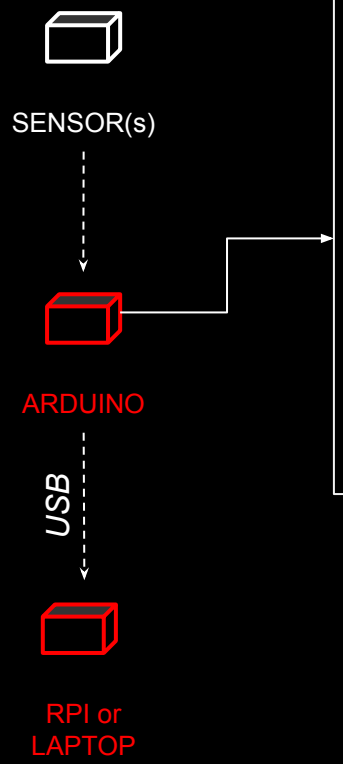
Making an actual sensor setup - Some use cases



C++

```
#include <Arduino.h>
#include <math.h>

[...]
void setup()
{
  Serial.begin(9600);
}

void loop()
{
  int val = analogRead(0);
  float temp = thermistor(val);
  Serial.println(temp);
  delay(1000);
}
```

Start the communication via Serial at 9600 bauds

Read the sensor and process slightly the data to get a temperature value

Send the data every 1000ms (1s)
We can change this parameter depending on:

- *Our assessment of the sensor changes with time (is it worth going faster?)*
- *Our storing capacity on the other side (speed and size)*

Full examples at: https://github.com/oscgonfer/sensors_dsp_lectures/tree/master/01_introduction/examples

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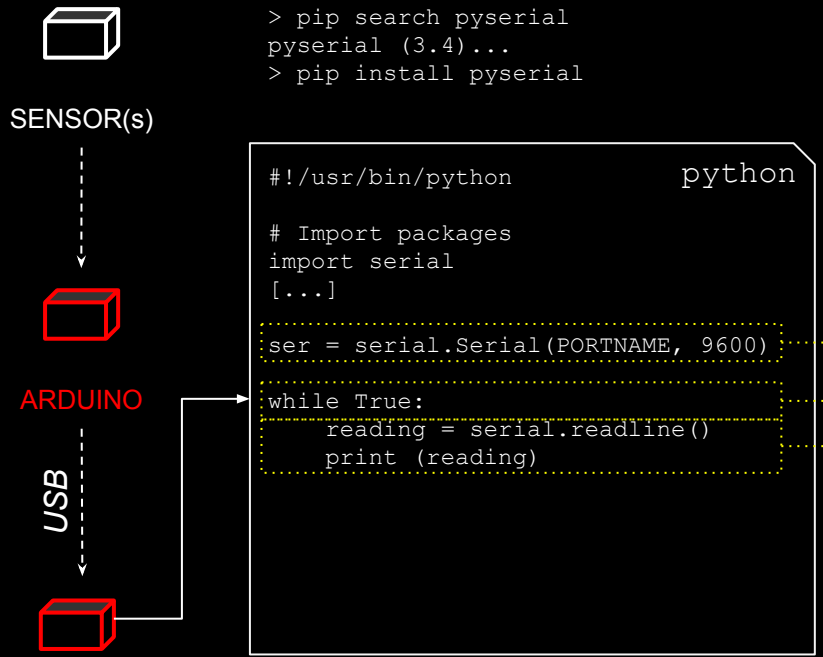
Making an actual sensor setup - Some use cases

First, in the terminal

```
> pip search pyserial
pyserial (3.4)...
> pip install pyserial
```



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Complete explanation at: https://fablabbcn-projects.gitlab.io/learning/fabacademy-local-docs/clubs/codeclub/pythonhardware/

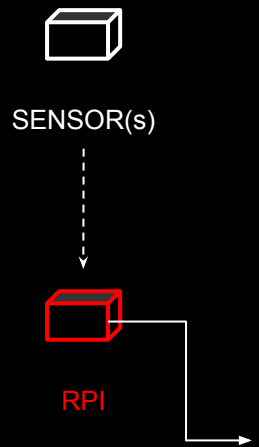
Quick note

Environments in python

In any computer, you can use `python` *in different ways. You can install libraries* ***system-wide*** *or in a* ***virtual environment****. The best one depends on your use case, but normally, it's a good idea to use* ***virtual environments****. Some environment managers are:*

- `Anaconda` *(easy, with GUI, but quite heavy):* https://www.anaconda.com/products/individual
- `Virtualenv` *(official):* https://pipenv.kennethreitz.org/en/latest/install/#make-sure-you-ve-got-python-pip
- `Virtualenvwrapper` *(the best, IMHO):* https://virtualenvwrapper.readthedocs.io/en/latest/

Making an actual sensor setup - Some use cases



First, install necessary packages

```
sudo apt update
sudo apt upgrade
sudo apt install -y i2c-tools python3-smbus
```

Second, enable your I2C interface in `raspi-config` and go to `Interfacing options`

```
> sudo raspi-config
…
> sudo reboot
```

Then, connect the sensor following the pinout (see next slide). Make sure voltage levels are ok for your sensor - the raspberry pi *talks* `I2C` at 3V3

Then, detect your sensor with (SHT31 address is `44`):

```
> i2cdetect -y 1
     0  1  2  3  4  5  6  7  8  9  a  b  c  d  e  f
00:          -- -- -- -- -- -- -- -- -- -- -- -- --
10: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
20: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
30: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
40: -- -- -- -- 44 -- -- -- -- -- -- -- -- -- -- --
50: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
60: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
70: -- -- -- -- -- -- -- --
```

More on setting up a pi: https://github.com/oscgonfer/sensors_dsp_lectures/blob/master/02_datalogging/rpi-ssh.md

Making an actual sensor setup - Some use cases

SENSOR(s)

RPI

Also findable in the Raspberry Pi 4 with:

```
> pinout
```

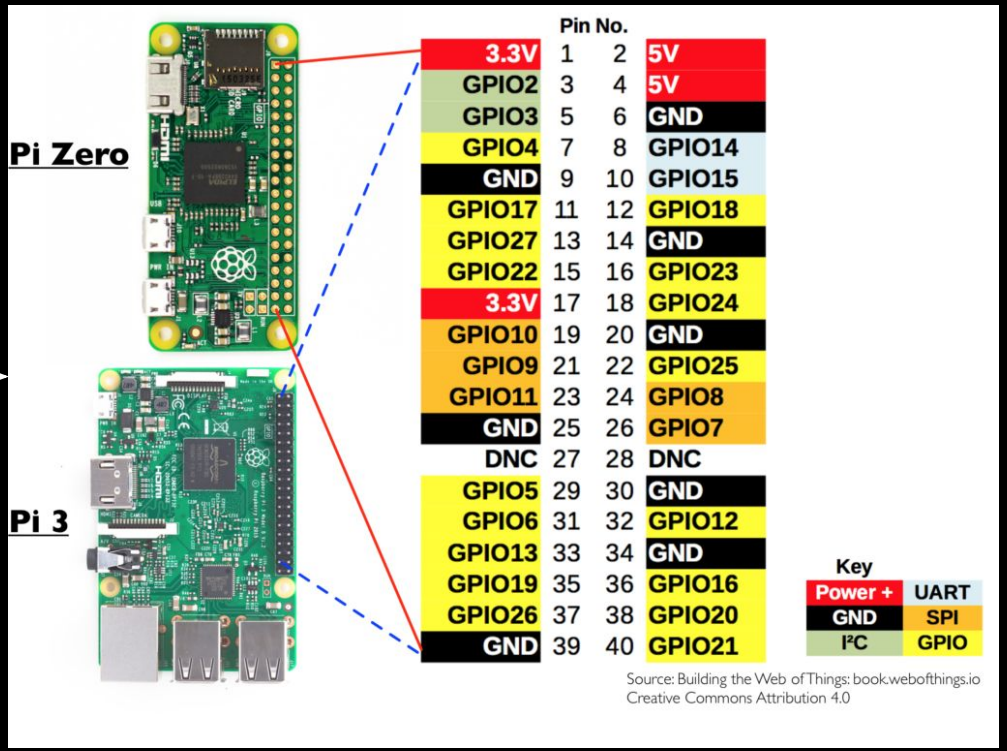


Image from: https://webofthings.org. Interactive pinout at: https://pinout.xyz/#

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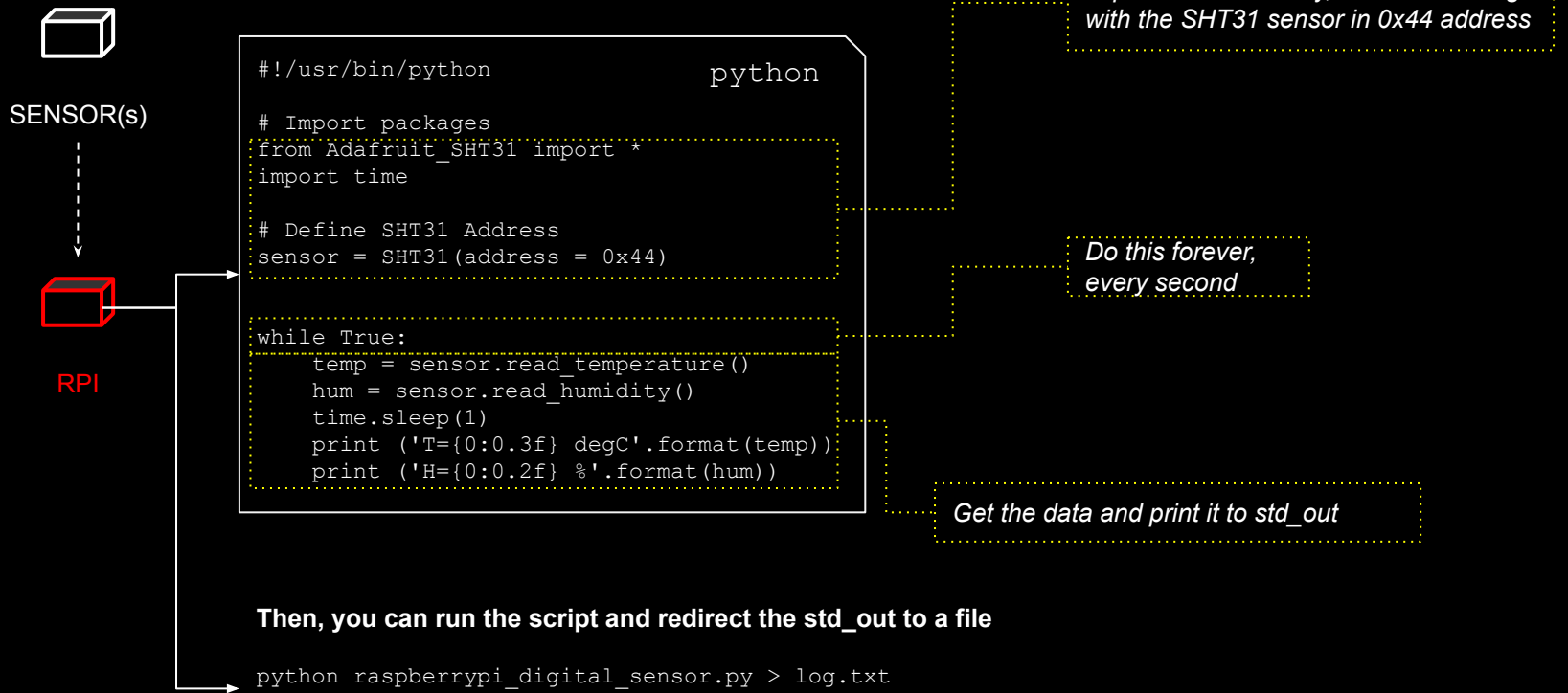
Making an actual sensor setup - Some use cases



Then, you can run the script and redirect the std_out to a file

```
python raspberrypi_digital_sensor.py > log.txt
```

And magically, the data will be saved in the file. You can go on and modify the above pseudocode to add a timestamp in your file

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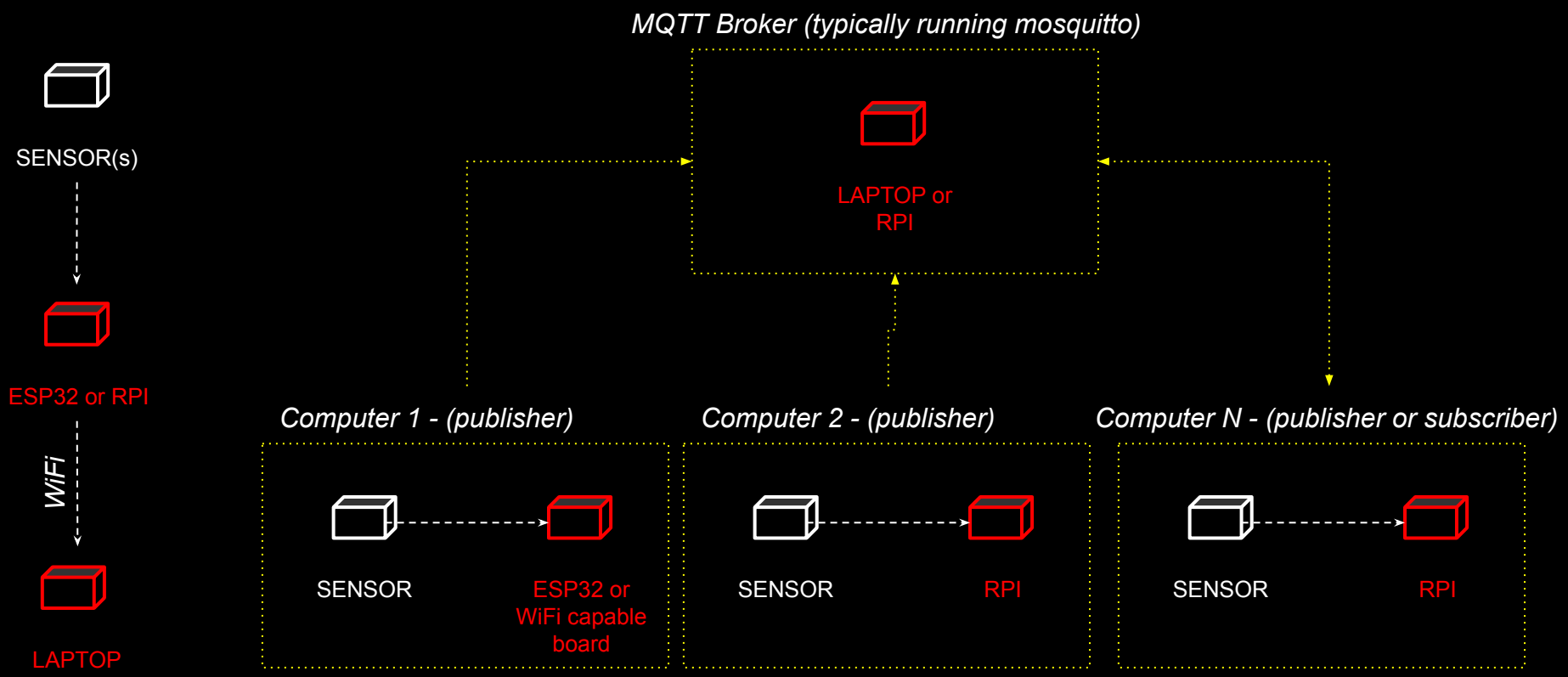

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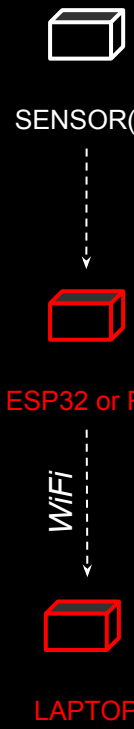
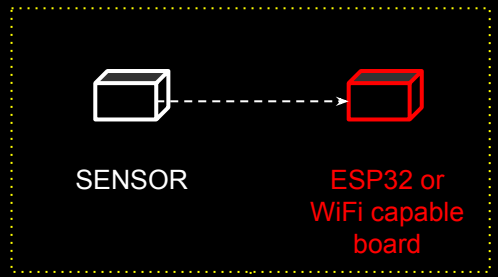
Full example using MQTT in the repo
More on mqtt here

Used in: Smart Citizen Firmware
Other year example: here

Making an actual sensor setup - Some use cases

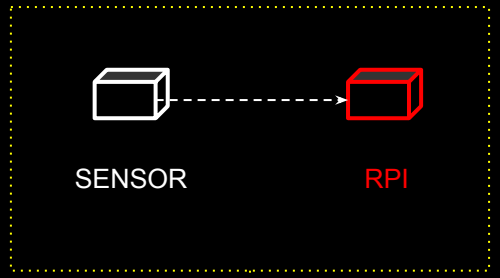


Computer 1 - (publisher)



Example in:
https://github.com/oscgonfer/sensors_dsp_lectures/blob/current/02_dataloggging/examples/mqtt_esp8266_example.ino

Computer N - (publisher or subscriber)



Example in:
https://github.com/oscgonfer/sensors_dsp_lectures/blob/current/02_datalogging/examples/mqtt_rpi_example.py

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Making an actual sensor setup - Some use cases

SENSOR(s)

ESP32 or RPI

WiFi

LAPTOP

MQTT Broker (typically running mosquitto)

LAPTOP or RPI

Doing this on a pi? Check this:
https://gist.github.com/xoseperez/e23334910fb45b0424b35c422760cb87#file-rpi3_iot_server-md

shell

```
# Linux debian based
$ sudo apt-get install
mosquitto mosquitto-clients

# OSX
$ brew install mosquitto

# Windows
# Visit:
https://mosquitto.org/download/
```

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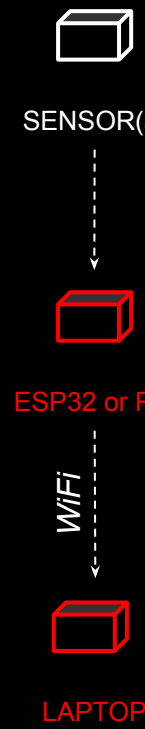
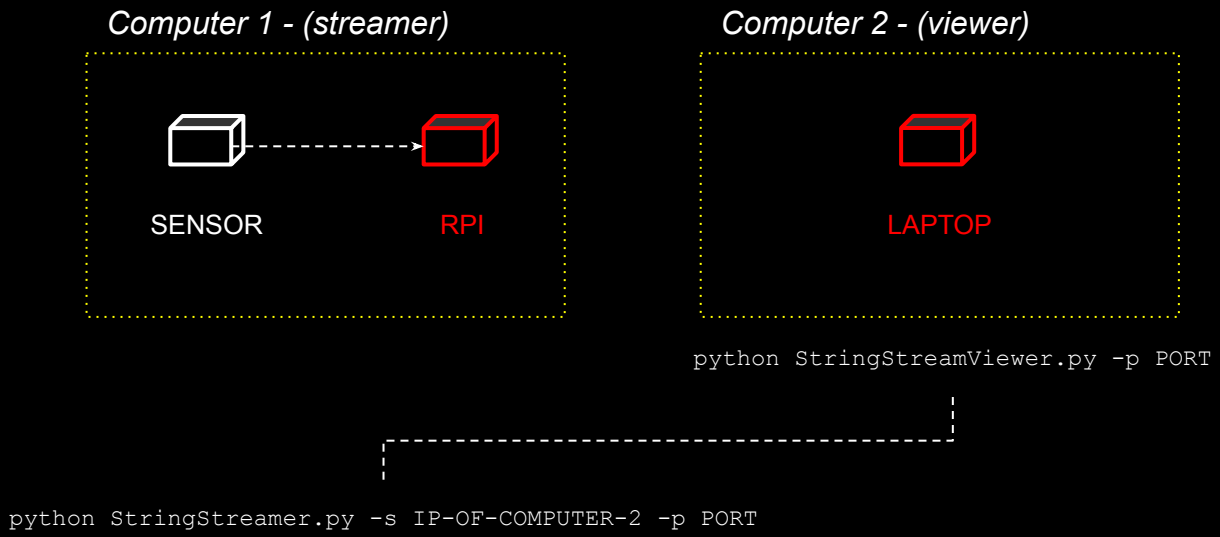
Making an actual sensor setup - Some use cases



Full example using zeromq in the repo
https://github.com/oscgonfer/sensors_dsp_lectures/tree/master/02_datalogging/examples



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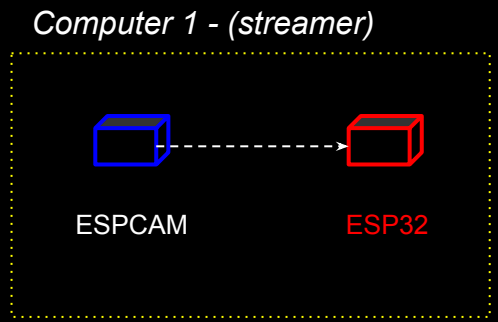
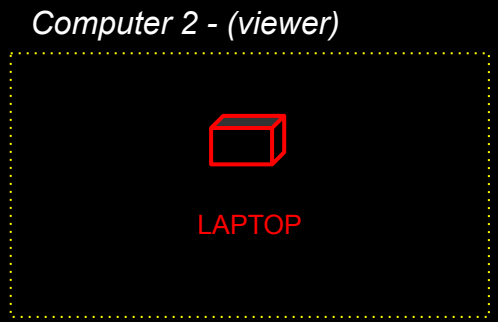
Making an actual sensor setup - Some use cases

Check example in this repository:
https://github.com/oscgonfer/sensors_dsp_lectures/tree/current/02_datalogging/examples/ESP32Cam/00_CameraStream





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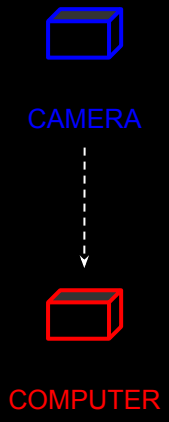
Making an actual sensor setup - Some use cases

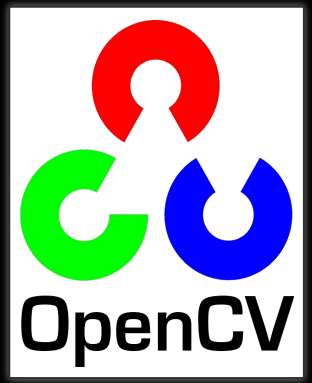


When using a camera, always look for documentation on the hardware:

- ***Kinect:*** *https://openkinect.org/wiki/Main_Page*
- ***Intel REALSENSE:*** *https://dev.intelrealsense.com/docs/opencv-wrapper (openNI too)*
- ***Raspberry PI camera:*** *https://projects.raspberrypi.org/en/projects/getting-started-with-picamera*

Mainly, we will use `OpenCV` to interact with most of them:

OpenCV (Open Source Computer Vision Library: http://opencv.org) is an open-source BSD-licensed library that includes several hundreds of computer vision algorithms.



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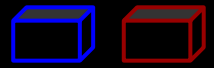
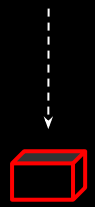
Making an actual sensor setup - Some use cases



CAMERA



COMPUTER

There are many ways to interact with cameras using `OpenCV`.
For using depth cameras, we'll use *freenect*

OpenCV with python

Two options (full-fledged) or pre-built in python (enough for non-super-mega cutting edge).

Easy to use, well documented.

processing

Easy to use for new coders. Well documented and running easily for RGBD camera.

openframeworks

Seemly more complex at the beginning. Need of some notions to compile C++ and build the code. Robust and well documented.
See Lewis Lepton videos to get started

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Making an actual sensor setup - Some use cases

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Follow instructions on https://docs.opencv.org/4.3.0/df/d65/tutorial_table_of_content_introduction.html for a cutting edge OpenCV installation or use the `opencv-python` ***package***

Recommended, create a virtualenv for opencv and:

```
pip install opencv-python
```

Basic example (RGB camera capture):

```python
#!/usr/bin/python

import cv2 as cv

cap = cv.VideoCapture(0)

while(True):
    ret, frame = cap.read()
    cv.imshow('Output', frame)

    if cv.waitKey(1) & 0xFF == ord('q'):
        break

cap.release()
cv.destroyAllWindows()
```

OpenCV with python

Open video capture on device 0 (webcam in my case)

Capture a frame and display it

Close everything if `q` *is pressed*

More info at: https://fablabbcn-projects.gitlab.io/learning/fabacademy-local-docs/clubs/codeclub/computervision/#installation

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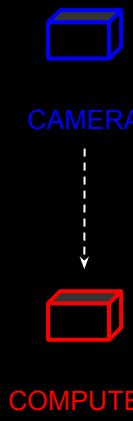
Making an actual sensor setup - Some use cases



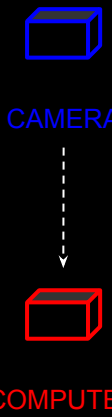
Follow instructions on *https://docs.opencv.org/4.3.0/df/d65/tutorial_table_of_content_introduction.html* ***for a cutting edge OpenCV installation***

Installing OpenCV on the Pi:
https://pimylifeup.com/raspberry-pi-opencv/
(perfect guide to help you set it up)

OpenCV with python

More info at: https://fablabbcn-projects.gitlab.io/learning/fabacademy-local-docs/clubs/codeclub/computervision/#installation

Making an actual sensor setup - Some use cases



Video capture and storage of RGB camera example:

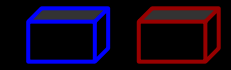
```python
import cv2

cap = cv2.VideoCapture(0)
if (cap.isOpened() == False):
    print("Unable to read camera feed")

frame_width = int(cap.get(3))
frame_height = int(cap.get(4))

out = cv2.VideoWriter('out.avi',cv2.VideoWriter_fourcc('M','J','P','G'), 10, (frame_width,frame_height))

while(cap.isOpened()):
    ret, frame = cap.read()
    if ret==True:
        frame = cv2.flip(frame,0)
        out.write(frame)
        cv2.imshow('frame',frame)
        if cv2.waitKey(1) & 0xFF == ord('q'):
            break
    else:
        break
cap.release()
out.release()
cv2.destroyAllWindows()
```



OpenCV with python

Open video capture on device 0 (webcam in my case)

VideoWriter (see https://www.fourcc.org/fourcc.php)

Capture, store and show frame

Close everything if `q` is pressed

Full example at: https://gitlab.fabcloud.org/barcelonaworkshops/code-club/-/tree/2020/04_computer_vision

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A word about video files and video codecs

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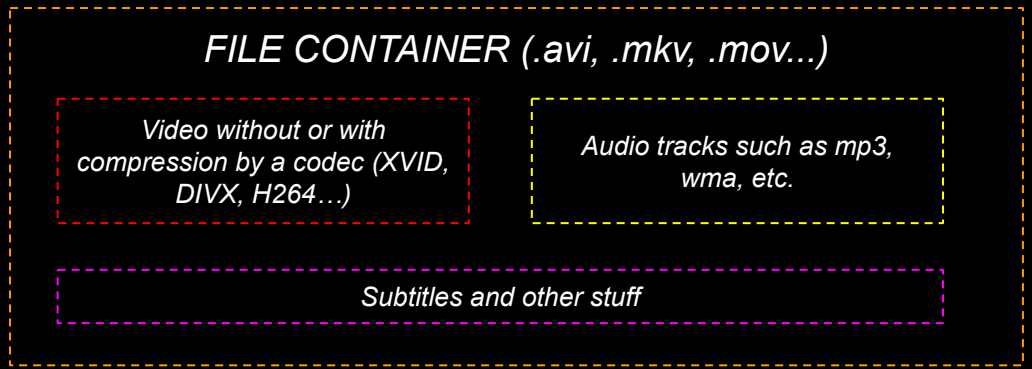
Every video file in itself is a container. The type of the container is expressed in the files extension (for example avi, mov or mkv). This contains multiple elements like: video feeds, audio feeds or other tracks (like for example subtitles). How these feeds are stored is determined by the codec used for each one of them. In case of the audio tracks commonly used codecs are mp3 or aac. For the video files the list is somehow longer and includes names such as XVID, DIVX, H264 or LAGS (Lagarith Lossless Codec). The full list of codecs you may use on a system depends on just what one you have installed.



From: https://docs.opencv.org/3.4/d7/d9e/tutorial_video_write.html

Making an actual sensor setup - Some use cases

OpenCV with python

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Kinect openCV python

python

MAYBE NOT WELL IMPLEMENTED - SEE https://github.com/OpenKinect/libfreenect/tree/master/wrappers/python/
Better use OPENFRAMEWORKS OR PROCESSING

Full example at: https://gitlab.fabcloud.org/barcelonaworkshops/code-club/-/tree/2020/04_computer_vision

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Making an actual sensor setup - Some use cases

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Basic example of video capture with RGB camera:

java

```
import processing.video.*;

Capture cam;

void setup() {
  size(640, 480);

  String[] cameras = Capture.list();
  cam = new Capture(this, cameras[0]);
  cam.start();
}

void draw() {
  if (cam.available() == true) {
    cam.read();
  }
  image(cam, 0, 0);
}
```

processing

Init camera

Capture RGB image and then show it

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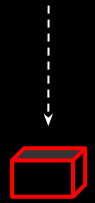
Full example at: https://www.processing.org/reference/libraries/video/Capture.html

Making an actual sensor setup - Some use cases

CAMERA



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Follow instructions on https://shiffman.net/p5/kinect/ for setting up processing for Kinect. For REALSENSE, refer to https://github.com/cansik/realsense-processing

Basic example of Depth camera (Kinect):

java

```
import org.openkinect.freenect.*;
import org.openkinect.processing.*;

Kinect kinect;

void setup() {
  kinect = new Kinect(this);
  kinect.initDevice();
  kinect.initDepth();
  kinect.initVideo();
}

void draw() {
  background(0);
  image(kinect.getVideoImage(), 0, 0);
  image(kinect.getDepthImage(), 640, 0);
}
```

Init Kinect device

Capture RGB image and depth image, and place it in the output window

processing

More info at: https://github.com/shiffman/OpenKinect-for-Processing

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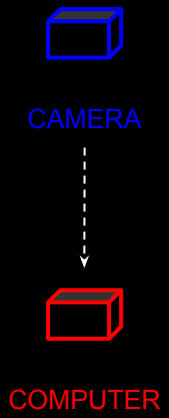
Making an actual sensor setup - Some use cases



Check examples in openframeworks repository:
https://github.com/openframeworks/openFrameworks/tree/master/examples/computer_vision/kinectExample

Basic example of Depth camera (Kinect):

```C++
TOO LONG TO SHOW HERE, BUT
MUCH BETTER CONTROL OF
EVERYTHING...
```

openframeworks

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Making an actual sensor setup - Some use cases

Check example in this repository:
https://github.com/CT83/SmoothStream