PHYSICAL SENSORS FOR ENVIRONMENTAL SIGNALS

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Master Degree in Artificial Intelligence for Science and Technology (AI4ST)

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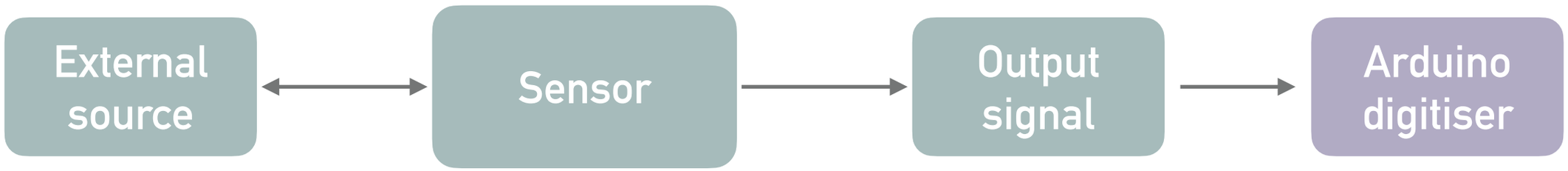
OUTLINE OF THE COURSE

- Lecture 1: Introduction to environmental signals and physical sensors
- Lab 1: Introduction to instruments for measurements
- Lecture 2: Vibrations: sources and detection
- Lab 2: Characterisation of an acoustic system
- Lecture 3: Distance, position and speed measurement
- Lab 3: Measuring distance with ultrasounds and speed with an accelerometer
- Lecture 4: Electromagnetic radiation: sources and detection
- Lab 4: Detecting and generating light

SENSING THE ENVIRONMENT

EXAMPLE: IR/ULTRASOUND DISTANCE DETECTOR READOUT CHAIN



- Source: element in space (static / in motion)
- Sensor: IR/ultrasounds detector → ***Lab.3 (today)***
- Read the signal output: Arduino digitiser

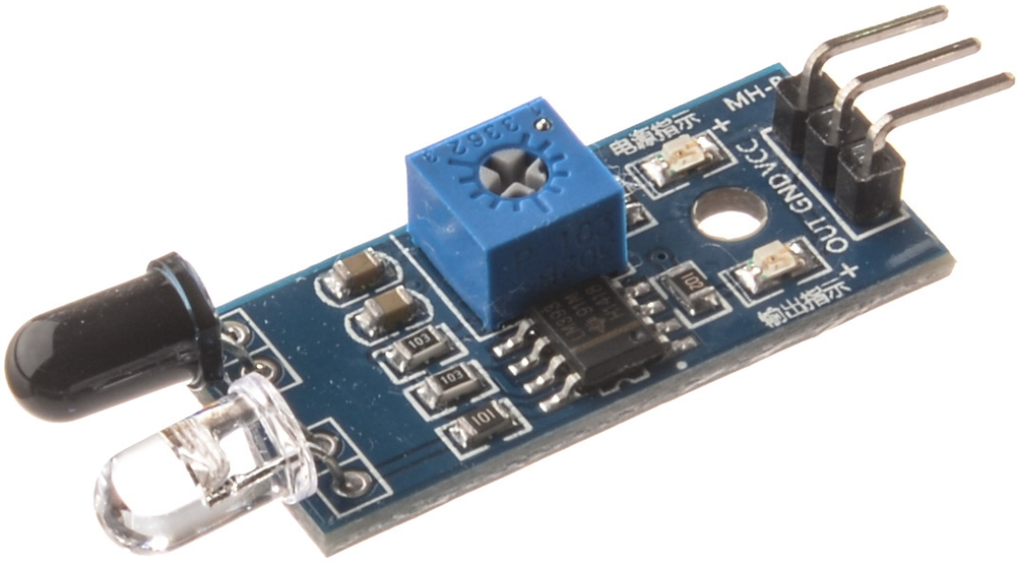
INFRARED DETECTOR

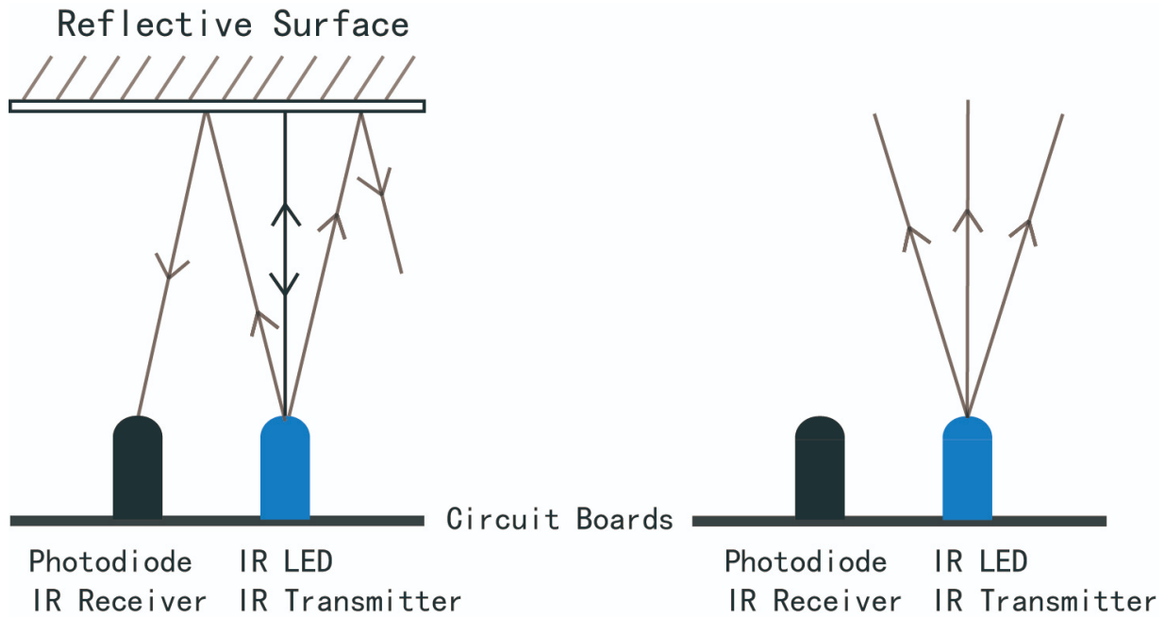
INFRARED DETECTOR

- Source: element in space (static/dynamic)
- Sensor: infrared obstacle detector
- Read the signal output: Arduino digitiser to serial port

Reference example: https://projecthub.arduino.cc/aboda243/obstacle-detector-using-ir-module-tutorial-101320

Other examples: https://arduinogetstarted.com/tutorials/arduino-infrared-obstacle-avoidance-sensor





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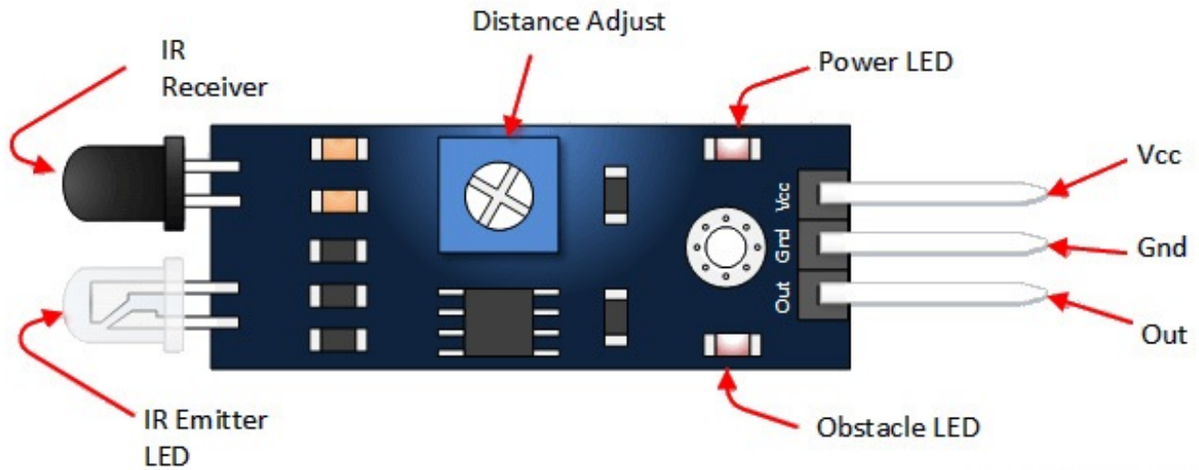

IR sensor elements:

- IR emitter: a led that emits invisible IR light (700nm – 1mm)

- IR receiver: photodiode that detects emitted light in the invisible IR range

- Distance adjust: potentiometer used to adjust the range of detection

IR sensor to Arduino:

- Vcc to pin 5V
- Gnd to pin Gnd
- Out (Digital out) to pin (digital) 2

INFRARED DETECTOR

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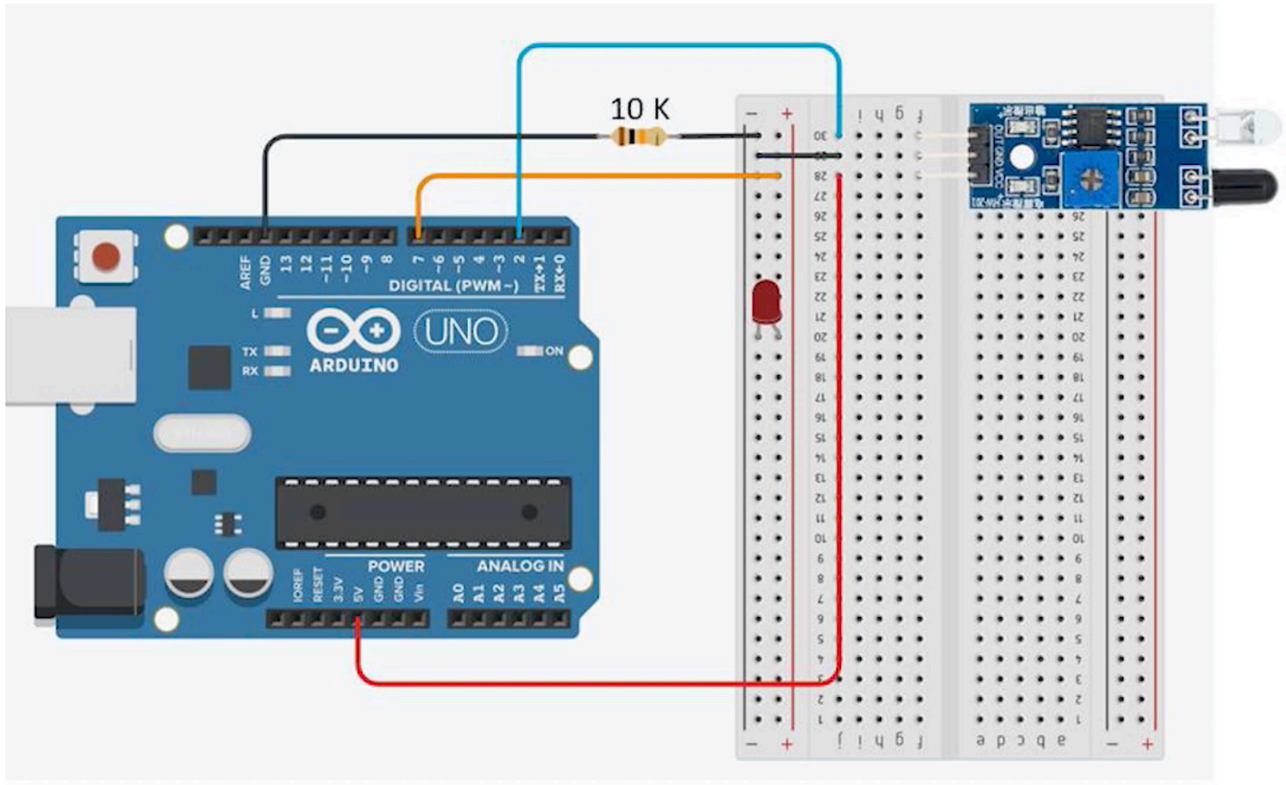
Project: Making the module detect an obstacle placed in front of the sensor; if so a LED on the breadboard is turned on to indicate the presence of the obstacle.



INFRARED DETECTOR

- Reading the Signal output with Arduino and turn on LED if obstacle detected

distanza_led

```
void setup() {
  // put your setup code here, to run once:
 pinMode(2,INPUT);
 pinMode(7,OUTPUT);
  // put your setup code here, to run once:
}

void loop() {
  int k=0;
  // put your main code here, to run repeatedly:
  k=digitalRead(2);
  if(k==LOW) {
  digitalWrite(7,HIGH);
  } else {
  digitalWrite(7,LOW);
  }
}
```

Example

INFRARED DETECTOR

- The module detects an object at a distance between 2 and 30 cm, with a detection angle of 35°. The distance can be adjusted using the *trimmer*: turning it clockwise increases the detection range, while turning it counterclockwise decreases it.

Verify the sensitivity for different distances and/or angles

- The module uses a pair of infrared diodes (one emitting and one receiving) that operate via *reflection*. Therefore, the shape and reflectivity of the target are important factors. The color of the object also affects performance: the detection distance will be minimal if the object is black and maximal if it is white

Verify the sensitivity for different objects: different dimensions, materials and colours (key, papersheet, black power supply, …)

ULTRASOUND DETECTOR

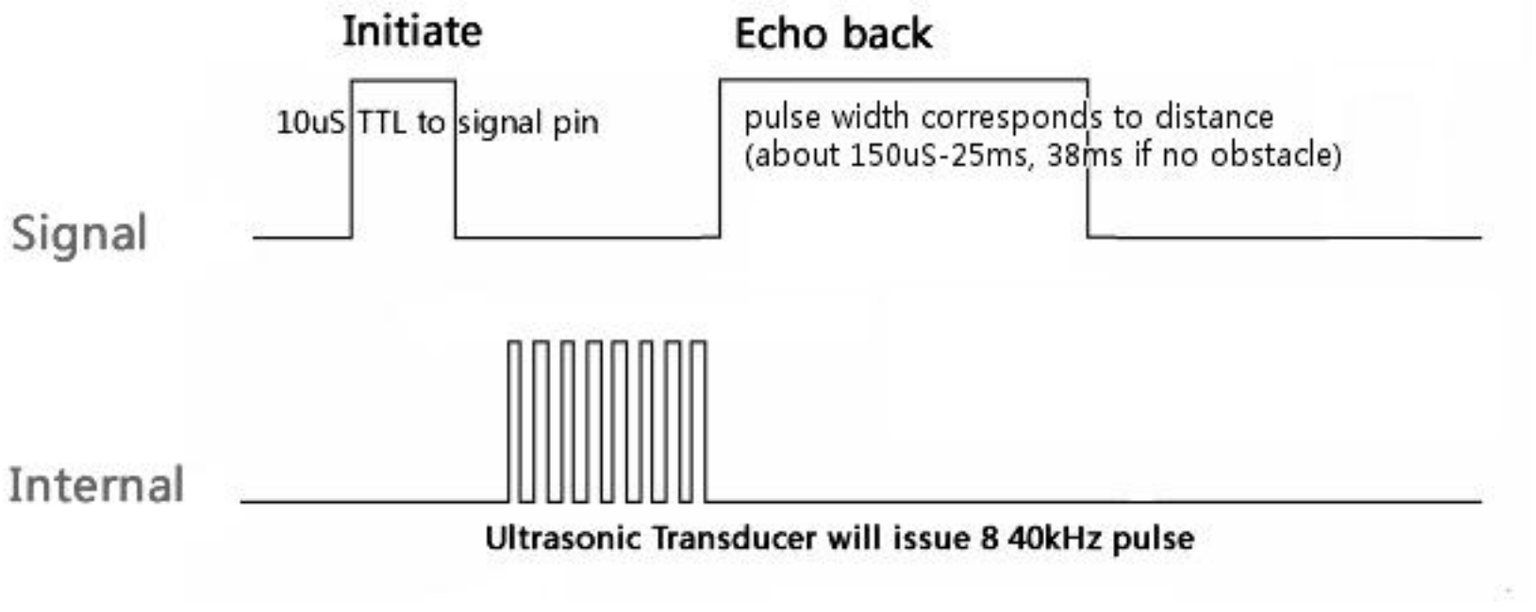
ULTRASOUND DETECTOR

- Source: element in space (static/dynamic)
- Sensor: ultrasounds detector
- Read the signal output: Arduino digitiser to serial port

Reference example: https://win.adrirobot.it/sonar/HC-SR04/Sensore_sonar_HC-SR04.htm

Other examples: https://docs.arduino.cc/built-in-examples/sensors/Ping

- Transmitter
- Receiver



ULTRASOUND DETECTOR

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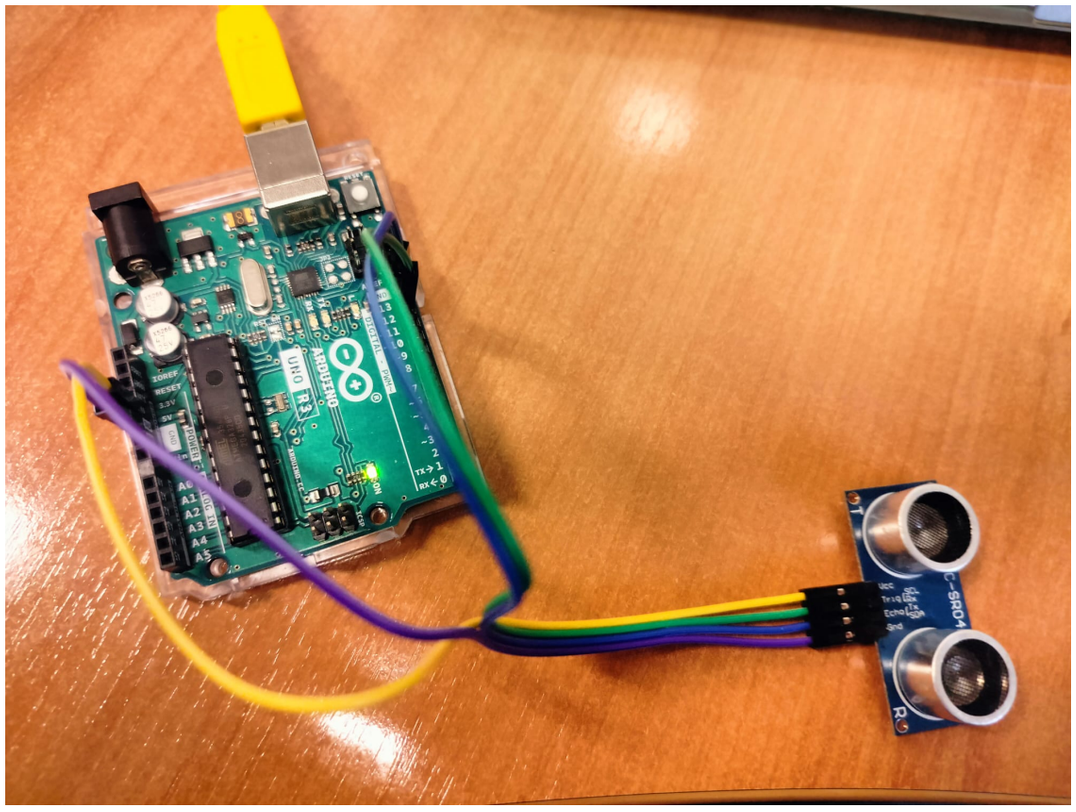


Ultrasound sensor (HC-SR04) to Arduino
- Vcc to pin 5V
- Trig to pin12
- Echo to pin 23
- Gnd to pin Gnd

ULTRASOUND DETECTOR

- Reading the Signal output with Arduino

Onde_sonore.ino

```
#define TRIG 12
#define ECHO 13

#include <Ultrasonic.h>

Ultrasonic ultrasonic(12, 13); //(trig, echo)

void setup() {

Serial.begin(9600);

}

void loop() {

Serial.print("New Measurement. \n");

int i =0;
Serial.print("Time[ms] and Distance[cm]: \n");
while(i< 20){
  Serial.println(String(micros()*1e-3) + String('\t') + ultrasonic.read());
  //Serial.println(micros()*1e-3);
  delay(1000);
  i++;
}

exit(0);

}
```

Output Serial Monitor ×

Message (Enter to send message to 'Arduino Uno' on '/dev/cu.usbmodem14101') | No Line Ending | 9600 baud

```
New Measurement.
Time[ms] and Distance[cm]:
18.67   293
1037.70 293
2056.76 293
3075.84 293
4094.94 293
5114.03 293
6133.08 293
```

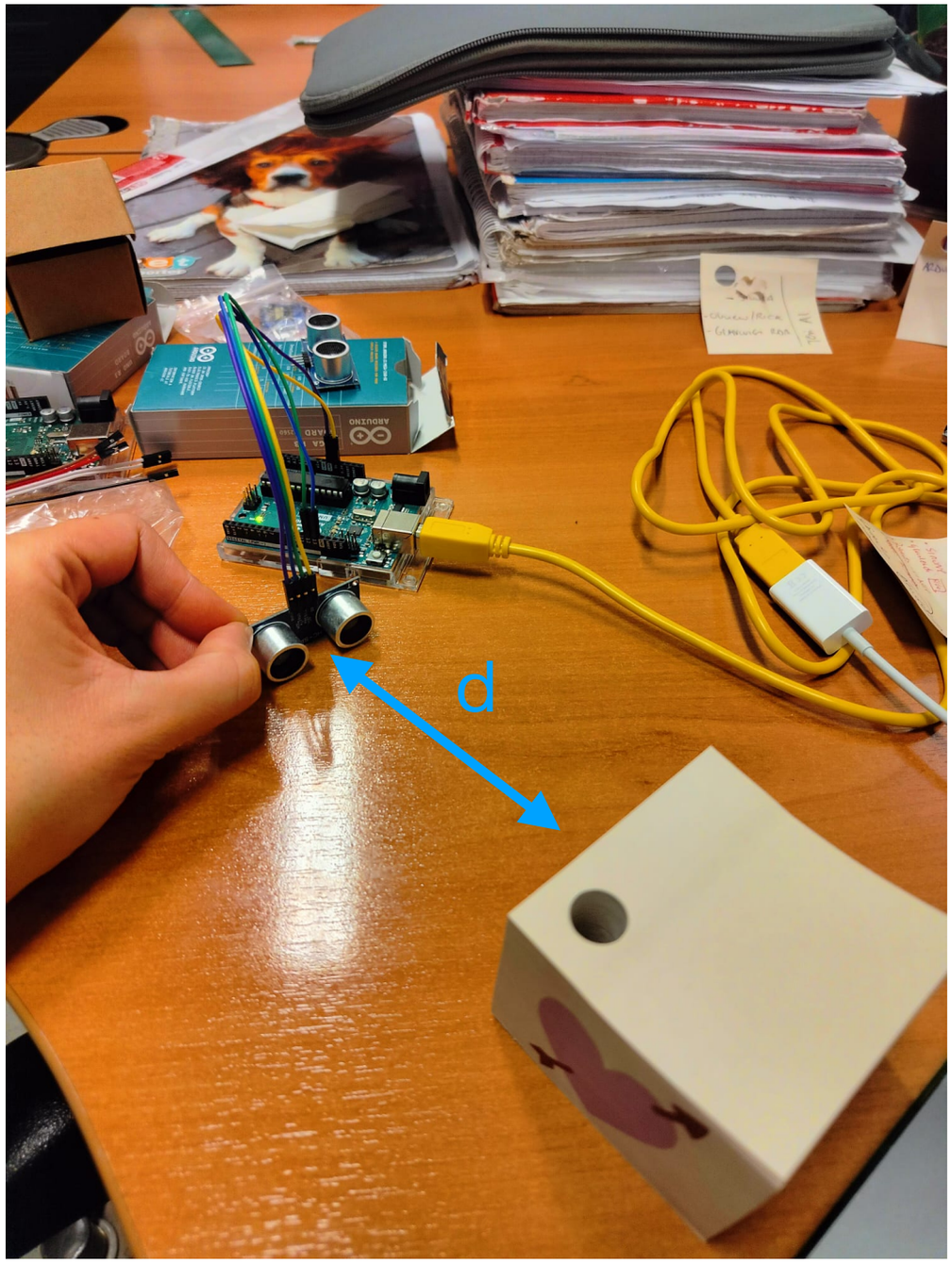
Ln 2, Col 16 Arduino Uno on /dev/cu.usbmodem14101 3

- *https://github.com/ErickSimoes/Ultrasonic/tree/master/src*

ULTRASOUND DETECTOR: MEAS (1)

Position a static object in front of the sensor (theta=0)

- Goal: Check the range capabilities of the us-sensor, varying the object distance d. Compare reconstructed d (us-sensor) vs measured d (tape)
- Goal: for a fixed d, check the capabilities of the sensor to reconstruct the distance for different size/shape of the object

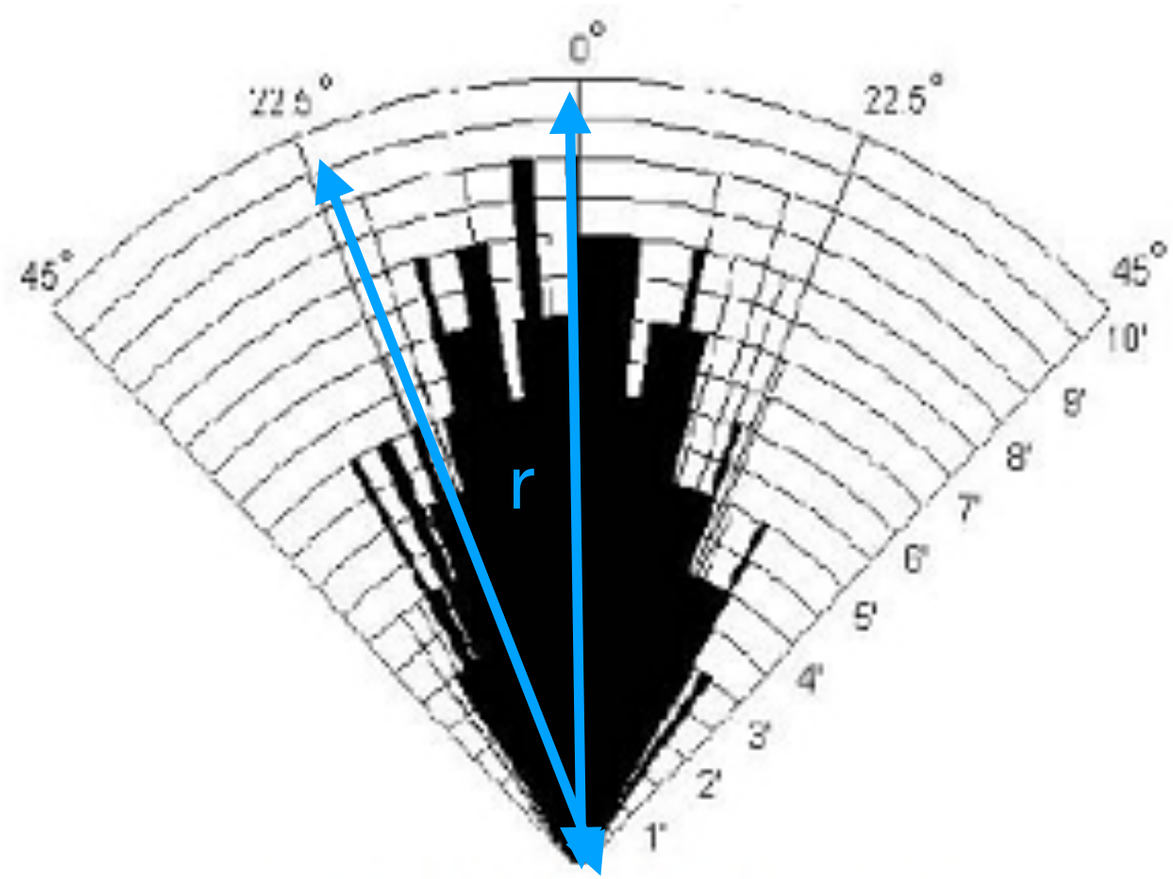


Additional: Use 2 us-sensors to sample the position variation in a plane of an object

ULTRASOUND DETECTOR: MEAS (2)

Position a static object at a given distance and angle from the sensor (r, theta)

- Goal: Check the capabilities to measure r vs theta. Compare reconstructed r (us-sensor) vs measured r (tape) at different angles
- Goal: Check the effect of possible interfering objects in the quality of the measurement



Practical test of performance,

Best in 30 degree angle

ULTRASOUND DETECTOR: MEAS (3)

Position an object at a given distance d in front of the sensor and, while starting the digitization, move it along the vertical direction on the plane

- Goal: Plot distance vs time from the us-sensor. Check the capabilities to reconstruct the average speed
- Goal(+): free fall (from height h (tight the object with a wire) to ground (where the us-sensor is positioned)