

# IOT Online Course

## Fundamentals of IoT

### F-IOT-2b: Understanding IoT Devices, Architecture & Ecosystem

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Université de Pau, France



🔗 <http://diy.waziup.io>

### IOT COURSES

#### WAZIUP IoT Courses

For users who wants to gain knowledge on IoT in a step-by-step lecture mode, we have defined the following curriculum with materials from both existing sources and specific materials produced by WAZIUP/WAZIHUB project.

#### «Fundamental of IoT»

##### F-IOT-1a: What is IoT ?

- Quick introduction to
- IoT and Big Data Platf
- Intel IoT -- What Does The Inte
- Edureka -- Internet of Things (I
- Geospatial IoT -- IoT- What is I
- IBM Think Academy -- How It V

##### F-IOT-1b: Introduction to

- Introduction To Basic
- Introduction To Basic Electroni
- Basic Electronics - Instructable
- Introducing physical s
- Introducing physical s

##### F-IOT-2: IoT ecosystem an



##### F-IOT-1b: Introduction to Basic Electronics

- Introduction To Basic Electronics -
- Introduction To Basic Electronics - MakerSpaces
- Basic Electronics - Instructables
- Introducing physical sensors, part 1
- Introducing physical sensors, part 2

##### F-IOT-2: IoT ecosystem and hardware

- F-IOT-2a: Wireless Communication Essentials
- F-IOT-2b: Understanding IoT Devices, Architecture & Ecosystem
- F-IOT-2c: Introduction to IoT hardware

##### F-IOT-3: Introduction to Arduino IDE

- Introduction to Arduino IDE - YouTube
- Presentation of the Arduino IDE
- Setting up the Arduino IDE

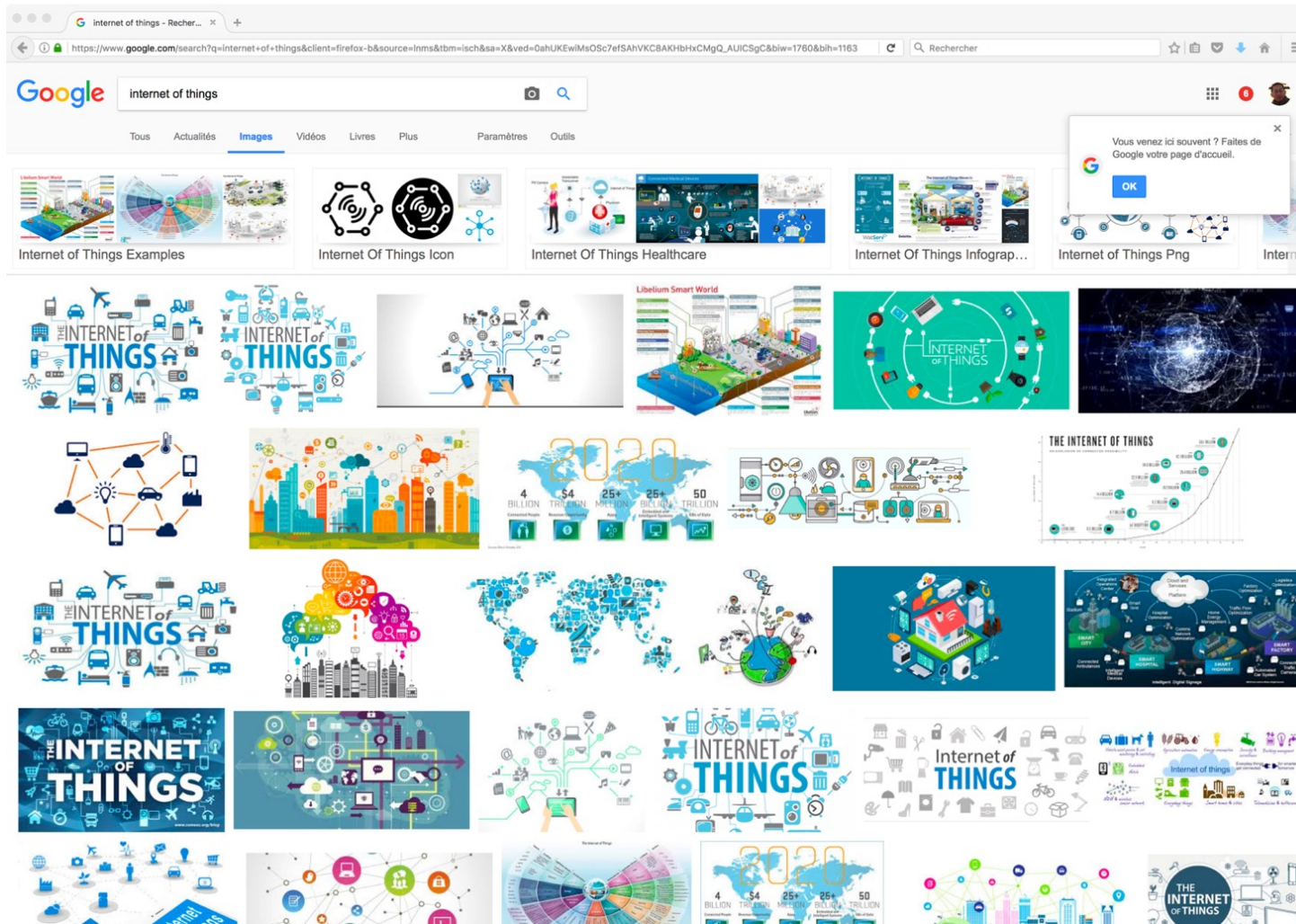
##### F-IOT-4: WAZIUP IoT ecosystem

- F-IOT-4: WAZIUP Open Technologies for Low-cost IoT

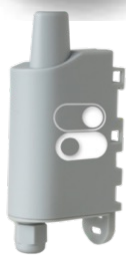
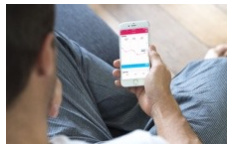
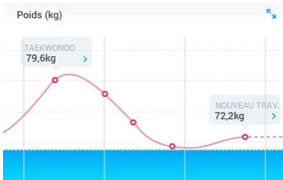
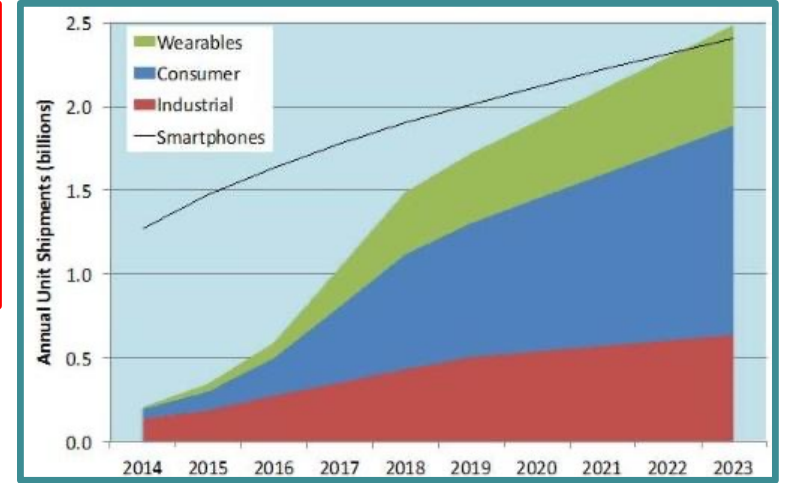




# Googling for « Internet of Things »



# ...shows communicating objects



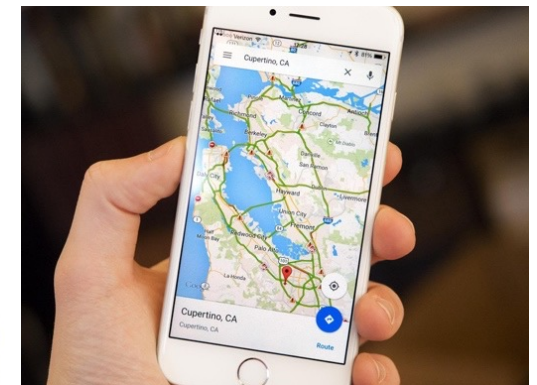
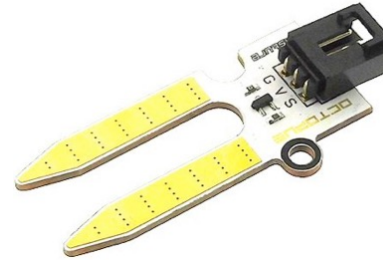


# IoT=interactions with physical world



**Q: Interactions? How?**

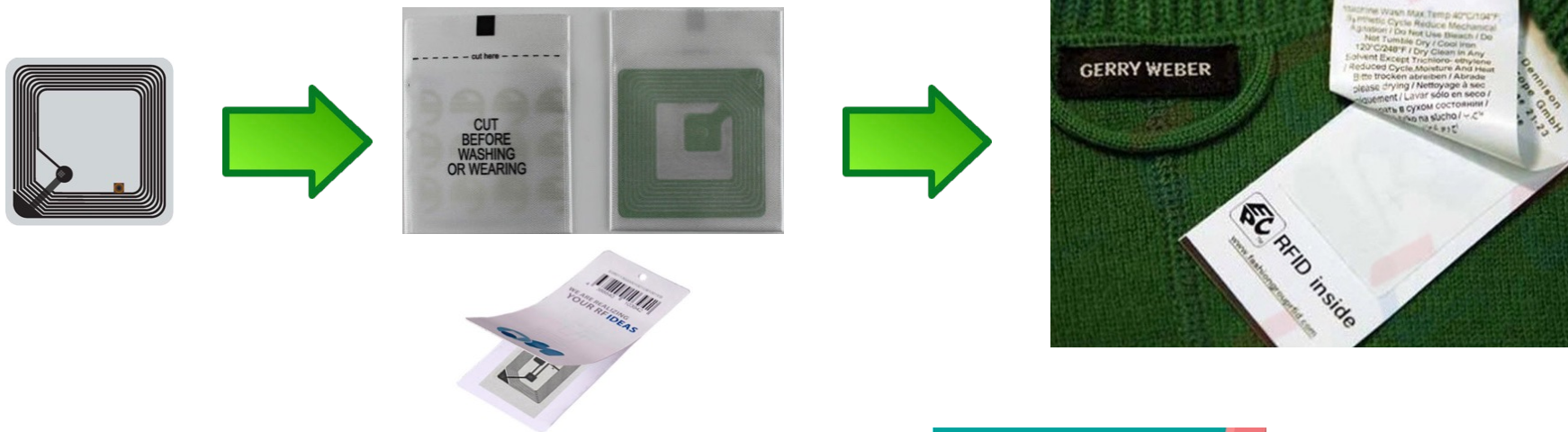
# Interaction: Sensors





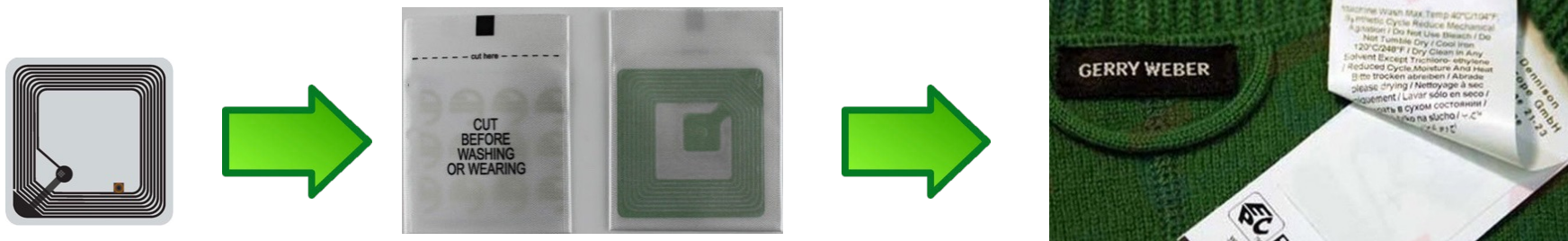
# Interaction: RFID, NFC

- Radio-Frequency Identification (RFID)
- Near Field Contact (NFC)

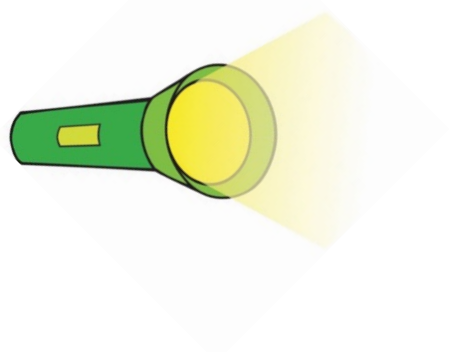


# Interaction: RFID, NFC

- Radio-Frequency Identification (RFID)
- Near Field Contact (NFC)

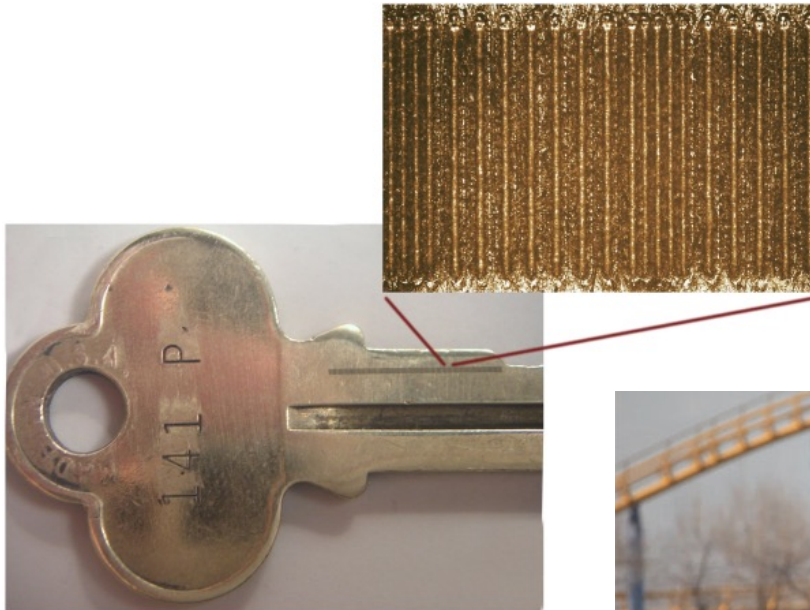


Q: How RFID works?

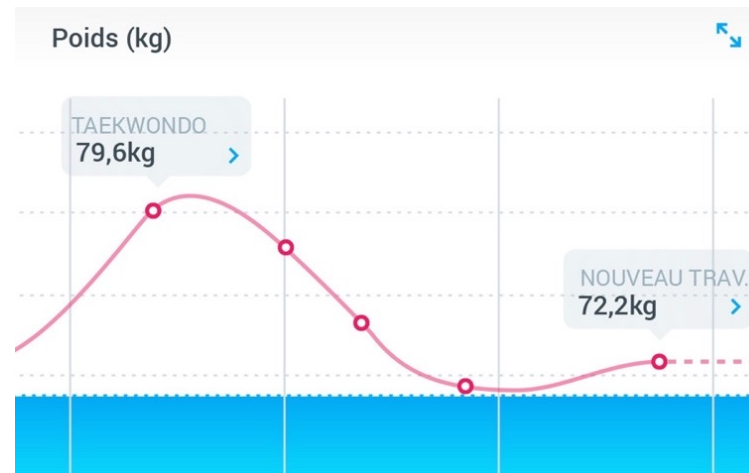
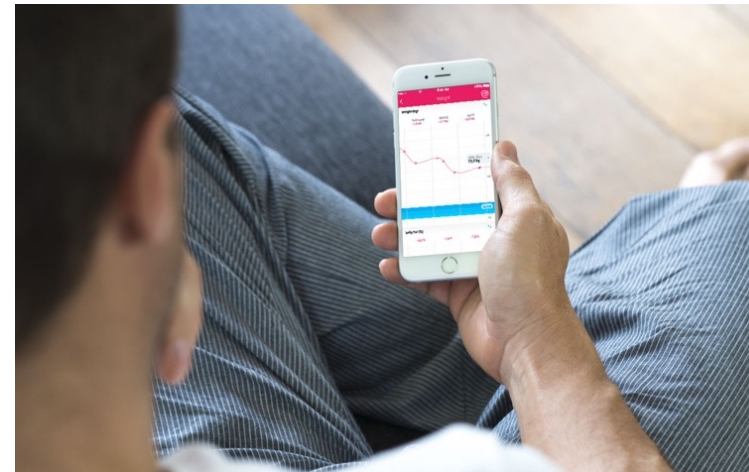




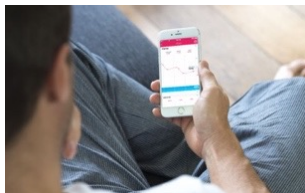
# Interaction: always complex?



# Home/consumer IoT products



# Local interaction is possible...





... but IoT usually means cloud data

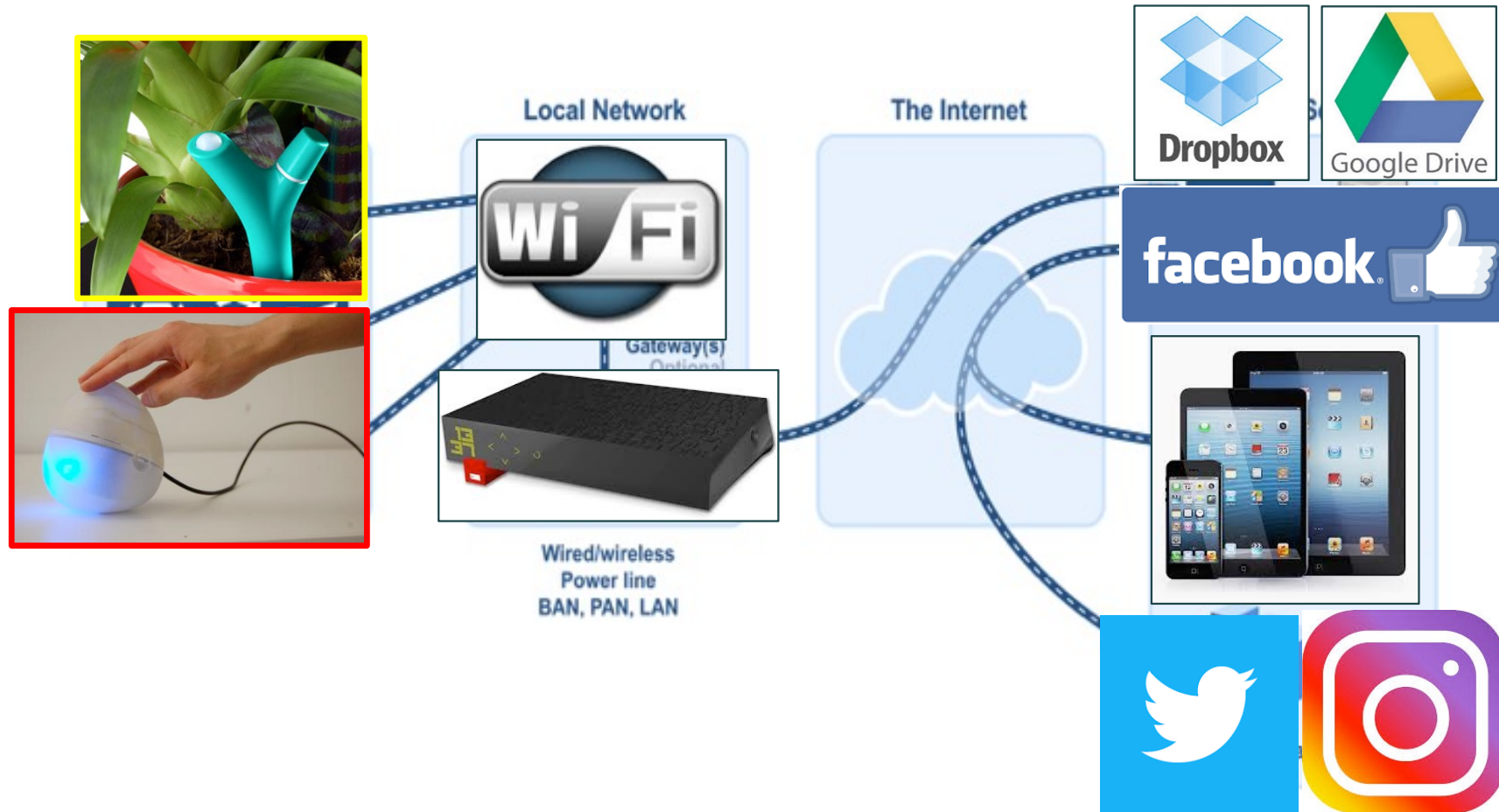
Lot's of data !



# IoT added-values come from interactions and linked data!



# General public IoT architecture

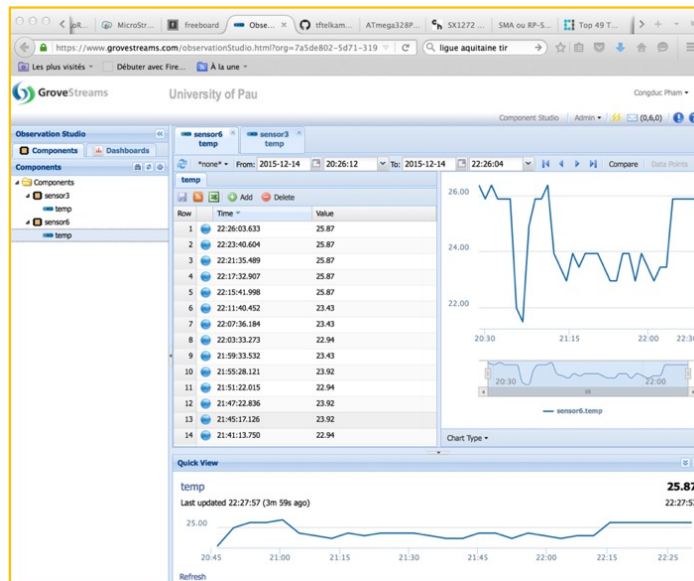


Pictures from ArchitectCorner





# IoT cloud and visualization tools



# Sense, Monitor, Optimize & Control



DATA ANALYSIS, OPTIMIZATION & CONTROL

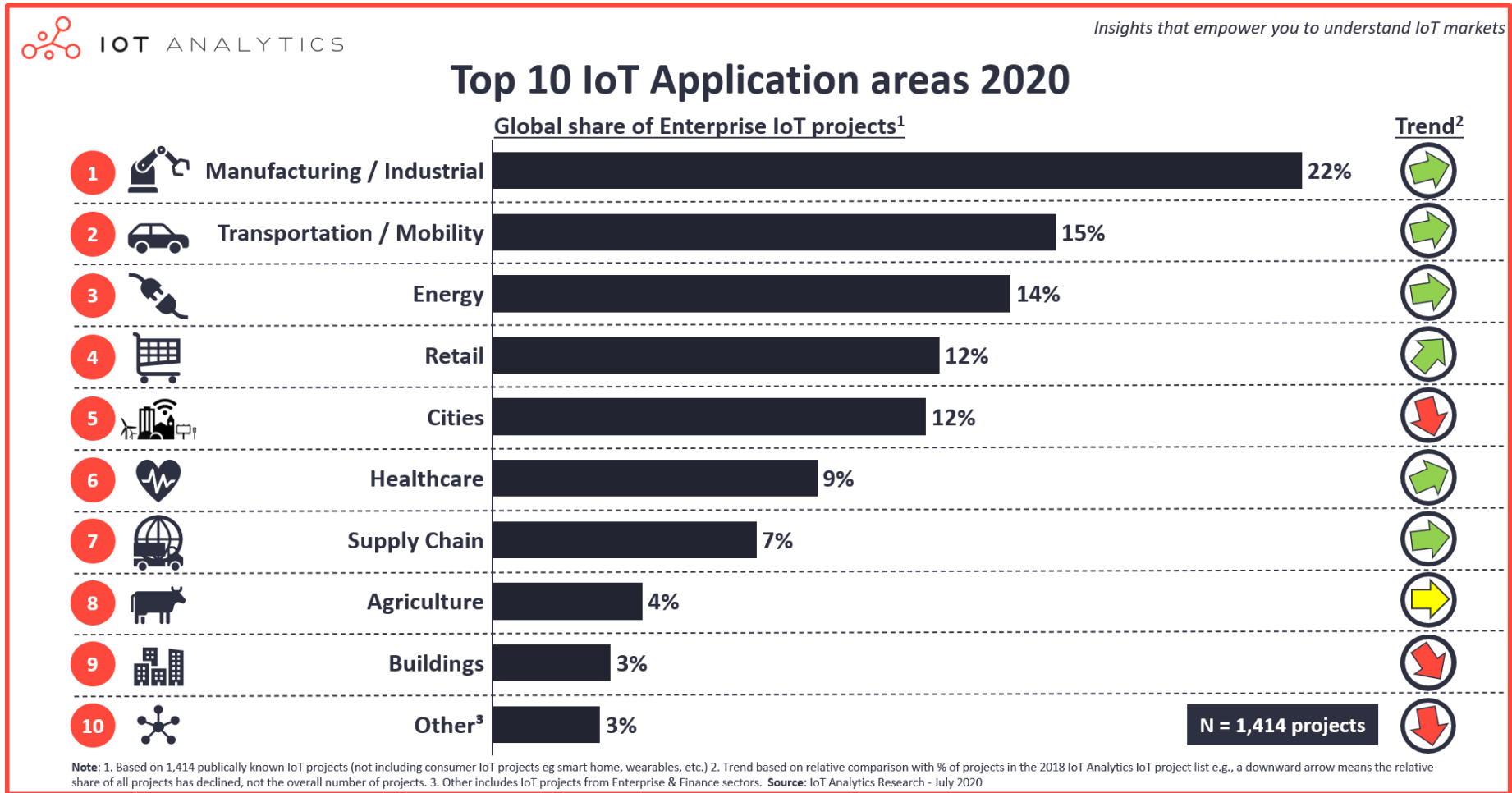
Monitoring

Sensing  
Physical world interaction

APPLICATION DOMAINS



# Top IoT applications, 2020

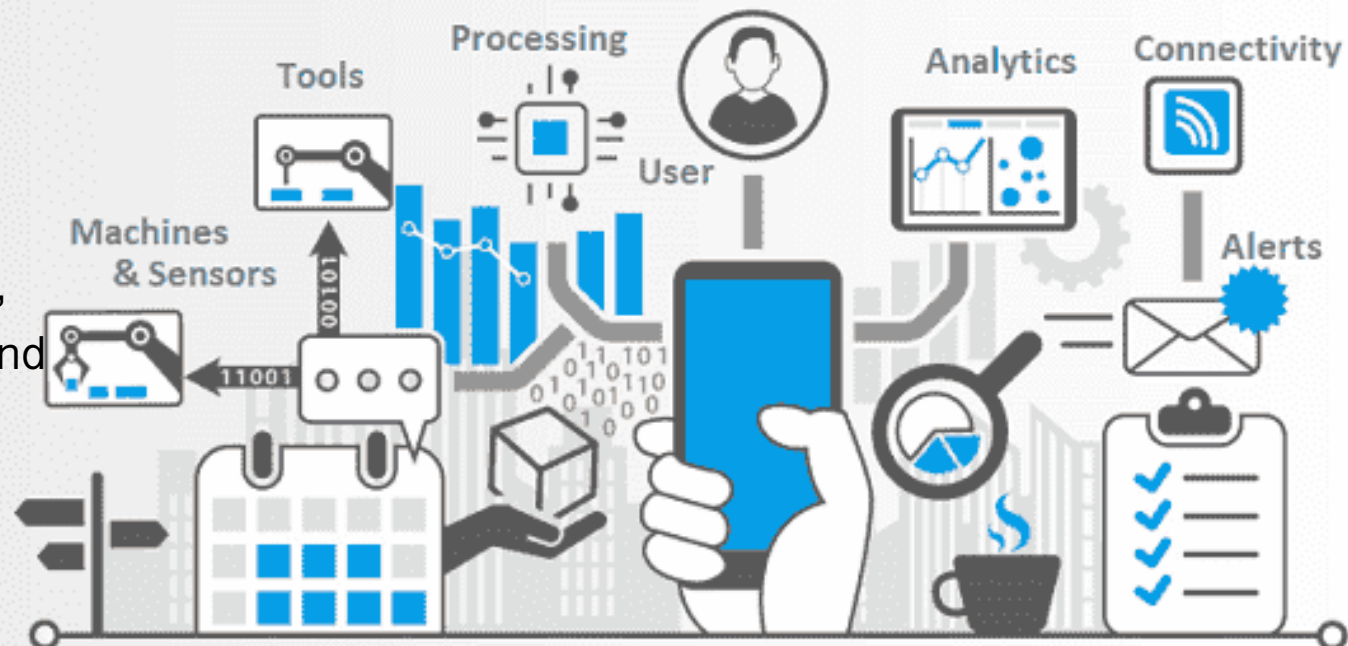


# IoT in industry



- ⦿ Infrastructure monitoring, Security & Safety
- ⦿ Continuous process improvement, Process automation, Process optimization
- ⦿ Smart logistics management, remote management, tracking,
- ⦿ Connectivity to back-end system, integration of smart tools, Interoperability
- ⦿ Data analysis, Supply Chain Optimization, Predictive maintenance

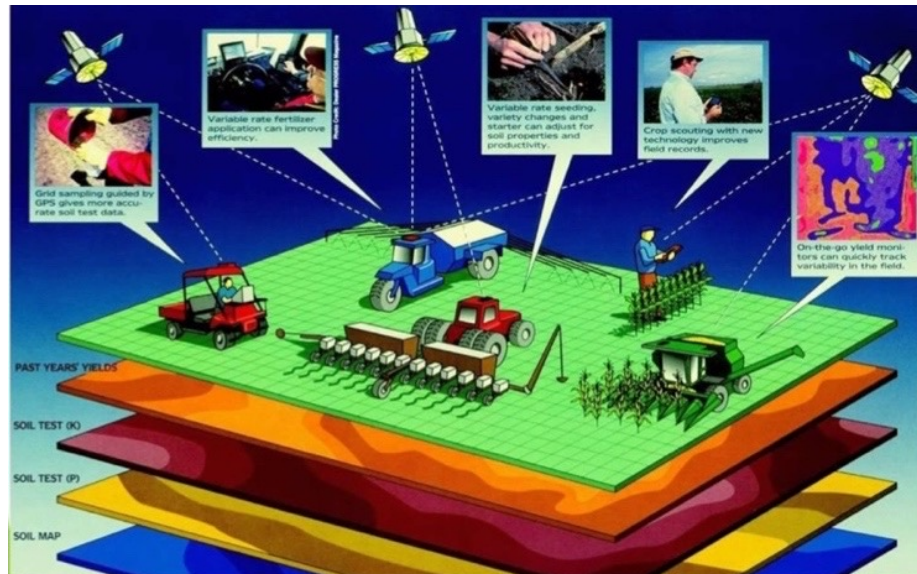
## Industrial Internet of Things







# IoT for Smart Agriculture



# IoT for development!



Irrigation



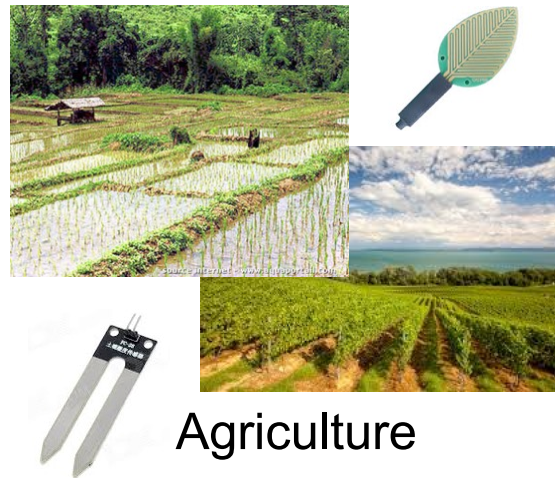
Livestock farming



Fish farming & aquaculture



Logistic, Storage,  
Asset Tracking



Agriculture



Fresh water



# Is IoT the solution for your problem?

**Q: How get real-time position of all city buses?**



**A: Install a GPS + 4G electronic box in each bus to turn the bus into a connected bus!**

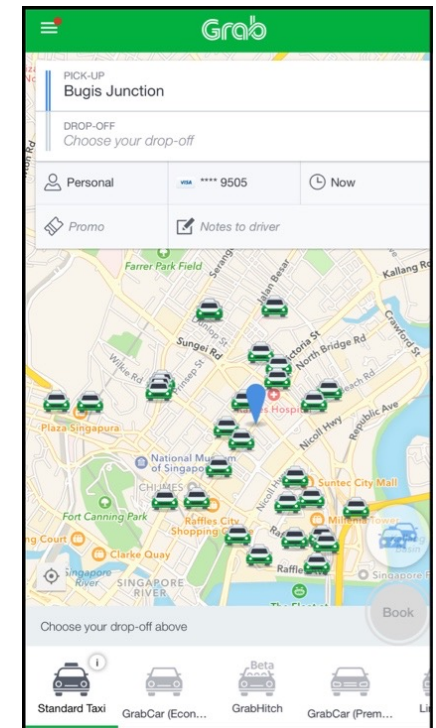
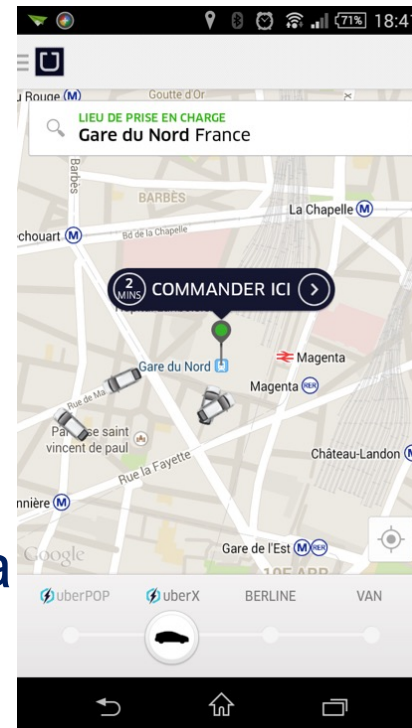
**Q: Is it cost-effective?**

# Is IoT the solution for your problem?

Q: How get real-time position of all city buses?



"GPS + 4G"  
Hum, looks like a  
smartphone...



# Is IoT the solution for your problem?

**Q: How to enable municipal street sweepers to report illegal dumping, leaking pipes and emergencies?**



**I know! I know !**

**A: Give them a smartphone and they can use it for reporting!**

**Q: Is it efficient?**

# Is IoT the solution for your problem?

Q: How to enable municipal street sweepers to report illegal dumping, leaking pipes and emergencies?



"smartphone"  
Hum, they only  
have 2 hands...



ITU Telecom World 2018  
Phathwa Senene at MTN booth

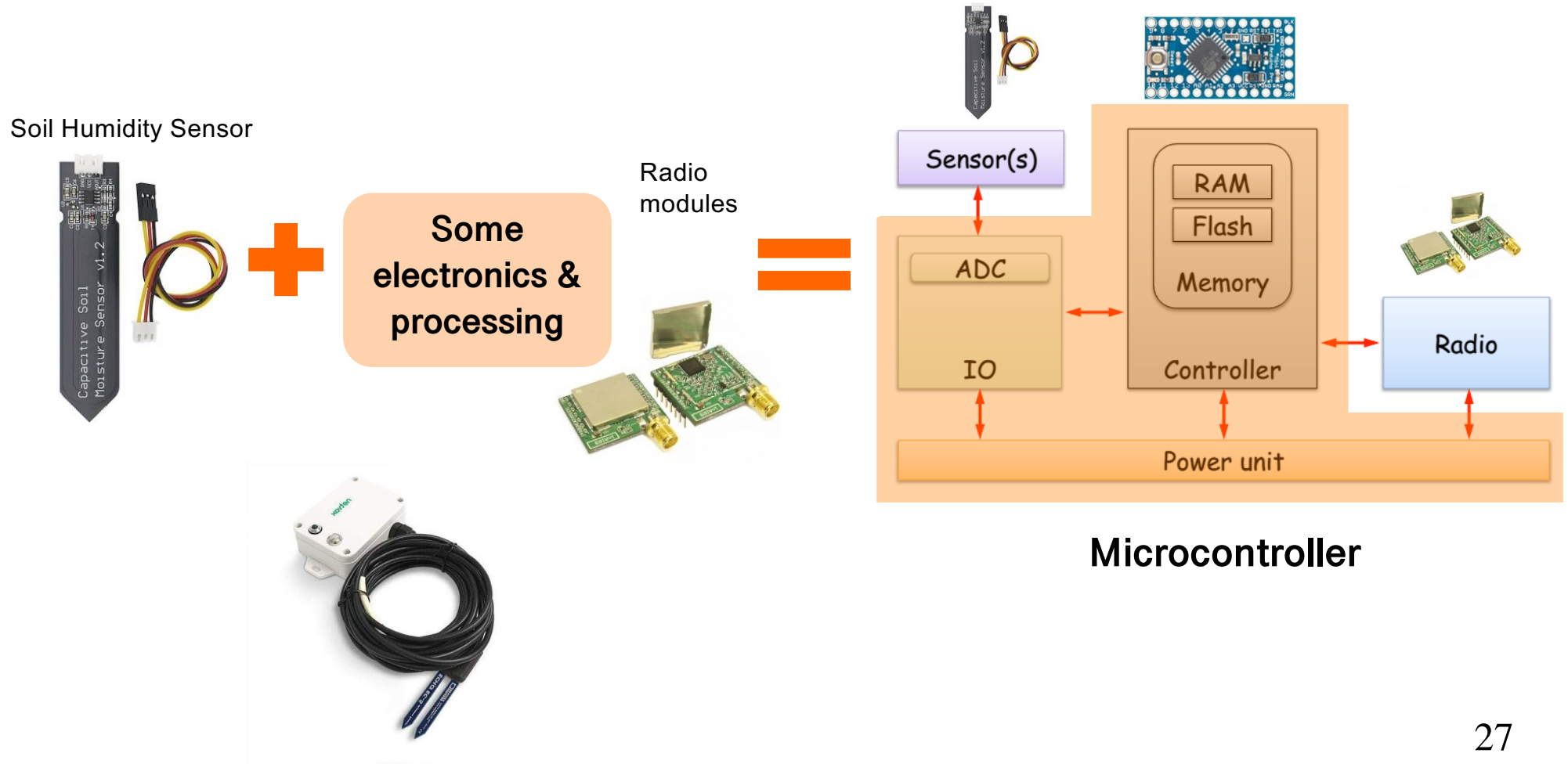






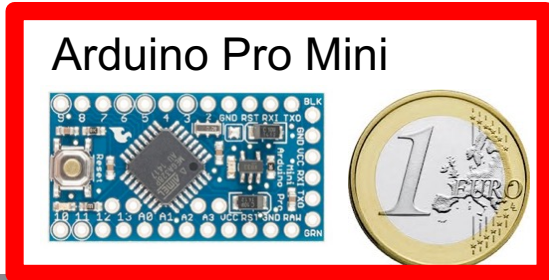
# Typical IoT device

- IoT device can be viewed as a simple Embedded System





# Low-cost microcontroller boards



Arduino Pro Mini



LoPy

<http://blog.atmel.com/2015/12/16/rewind-50-of-the-best-boards-from-2015/>

<http://blog.atmel.com/2015/04/09/25-dev-boards-to-help-you-get-started-on-your-next-iot-project/>



Theairboard



Expressif ESP32



Teensy 3.2



LinkIt Smart7688 duo

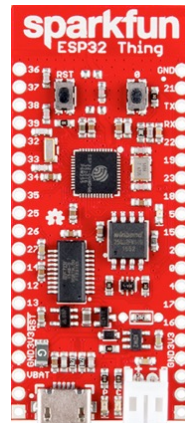
STM32 Nucleo-32



Heltec ESP32 + OLED



Adafruit Feather



Sparkfun ESP32 Thing



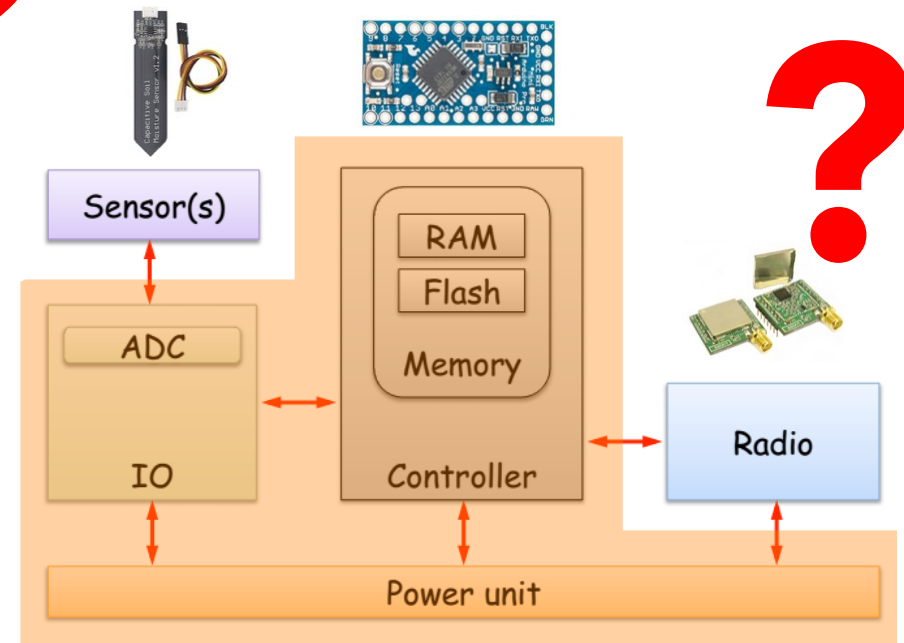
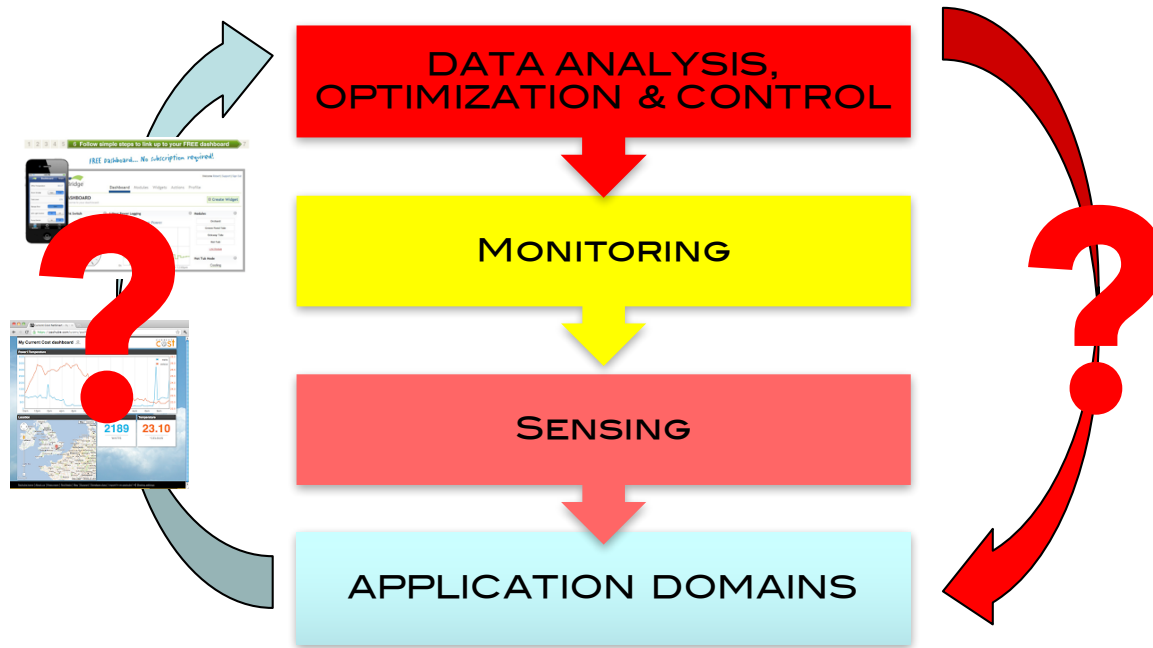
Tessel

SodaqOne2



Tinyduino

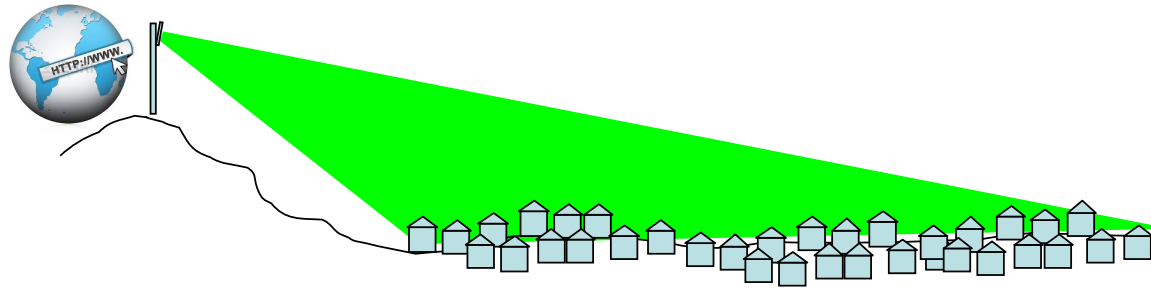
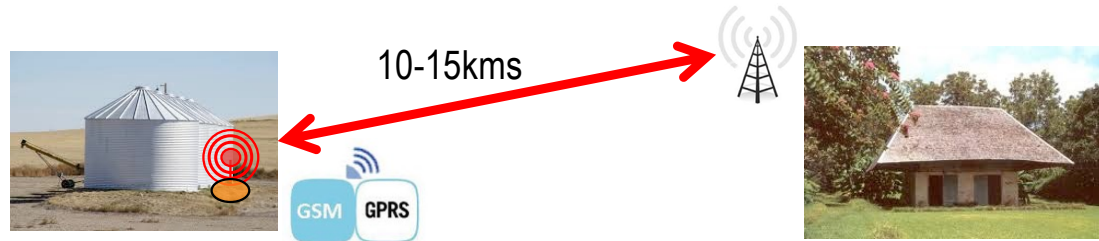
# How to collect data?



Micro-processor  
Micro-controller

# Wireless transmission cost

Moisture/  
Temperature of  
storage areas



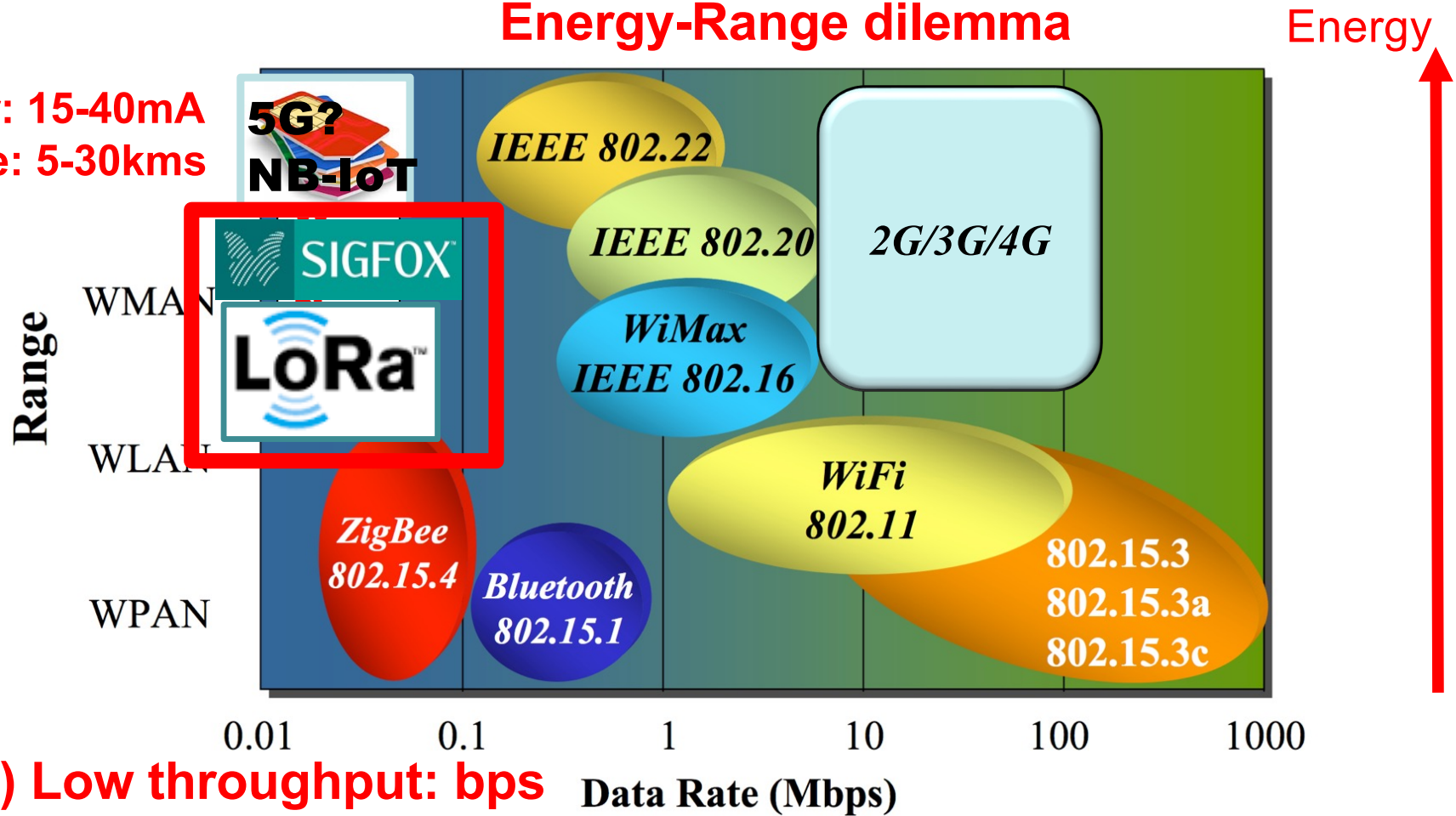
Technology	2G	3G	LAN
Range (I=Indoor, O=Outdoor)	N/A	N/A	O: 300m I: 30m
Tx current consumption	200-500mA	500-1000mA	100-300mA
Standby current	2.3mA	3.5mA	NC



# Low-power & long-range radios for IoT systems: LPWAN networks

**LPWAN**  
Low-power: 15-40mA  
Long-range: 5-30kms

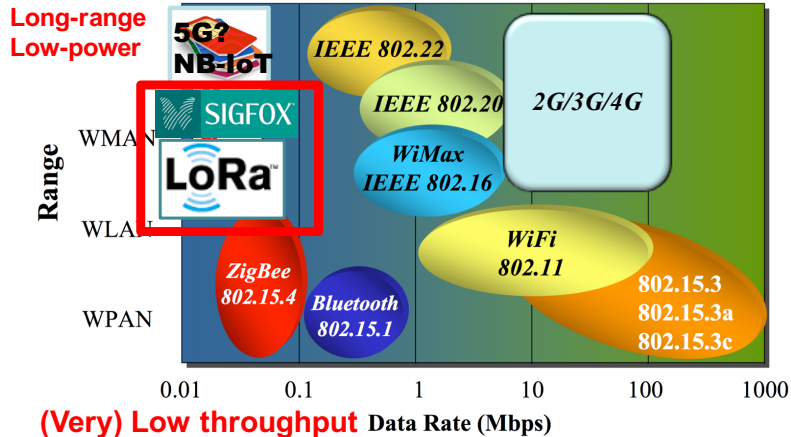
## Energy-Range dilemma



**(Very) Low throughput: bps** Data Rate (Mbps)

# Energy consumption comparaison

## Energy-Range dilemma



Energy ↑

2G	3G	LAN	ZigBee	Lo Power WAN
N/A	N/A	O: 300m I: 30m	O: 90m I: 30m	Same as 2G/3G
200-500mA	500-1000mA	100-300mA	18mA	18mA-40mA
2.3mA	3.5mA	NC	0.003mA	0.001mA



2500mA

TX power: 500mA. Mean consumption:  $(8s \times 500 + 3592s \times 0.005) / 3600 = 1.11mA$

$2500 / 1.11 = 2252h = 93 \text{ days} = 3 \text{ months} \text{ ☹️}$

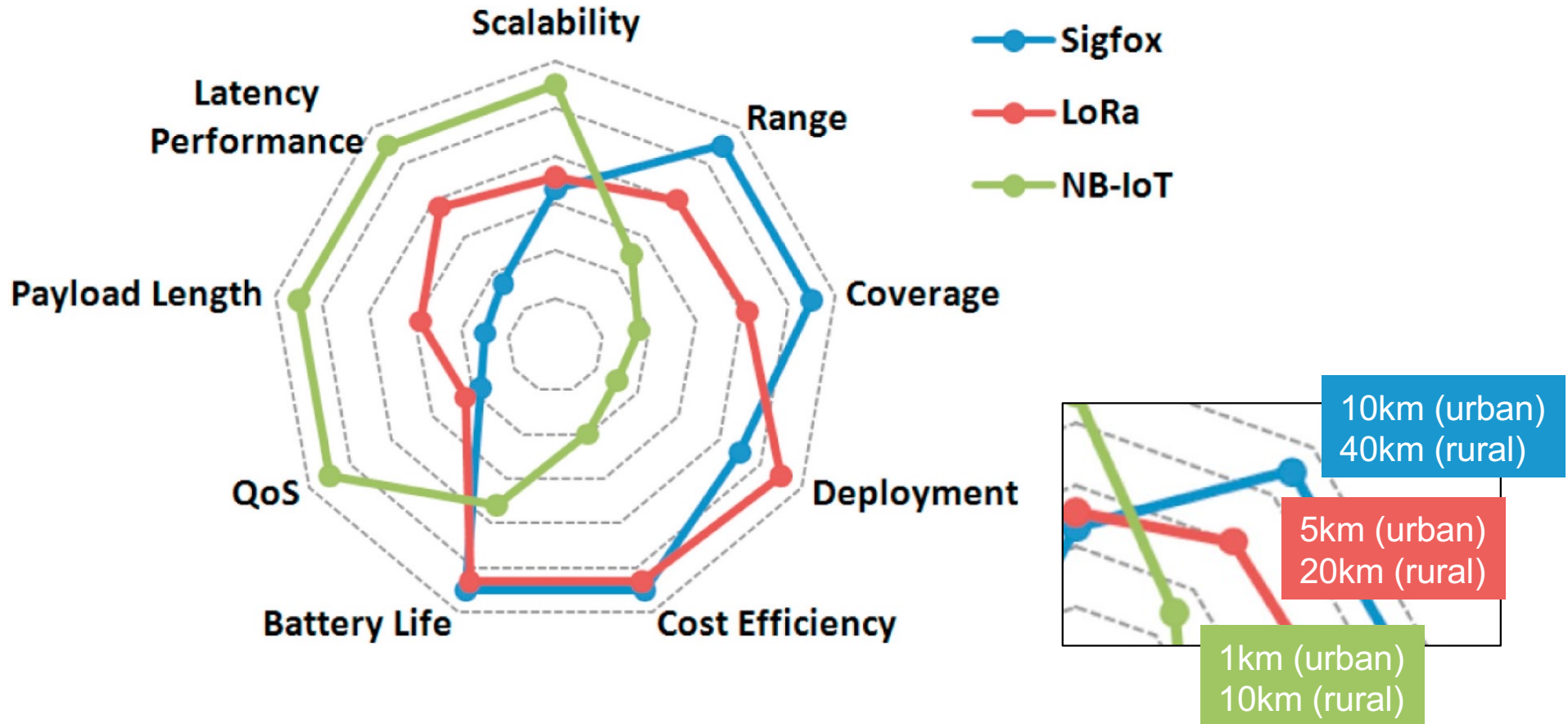
In most cellular networks, the device is still maintaining communication with BS even if it is inactive

TX power: 40mA. Mean consumption:  $(2s \times 40 + 3598s \times 0.005) / 3600 = 0.027mA$

$2500 / 0.027 = 92592h = 3858 \text{ days} = 10 \text{ y.} \text{ 😊}$

LPWAN does not need to maintain connection if not in used

# Expected range of LPWANs?

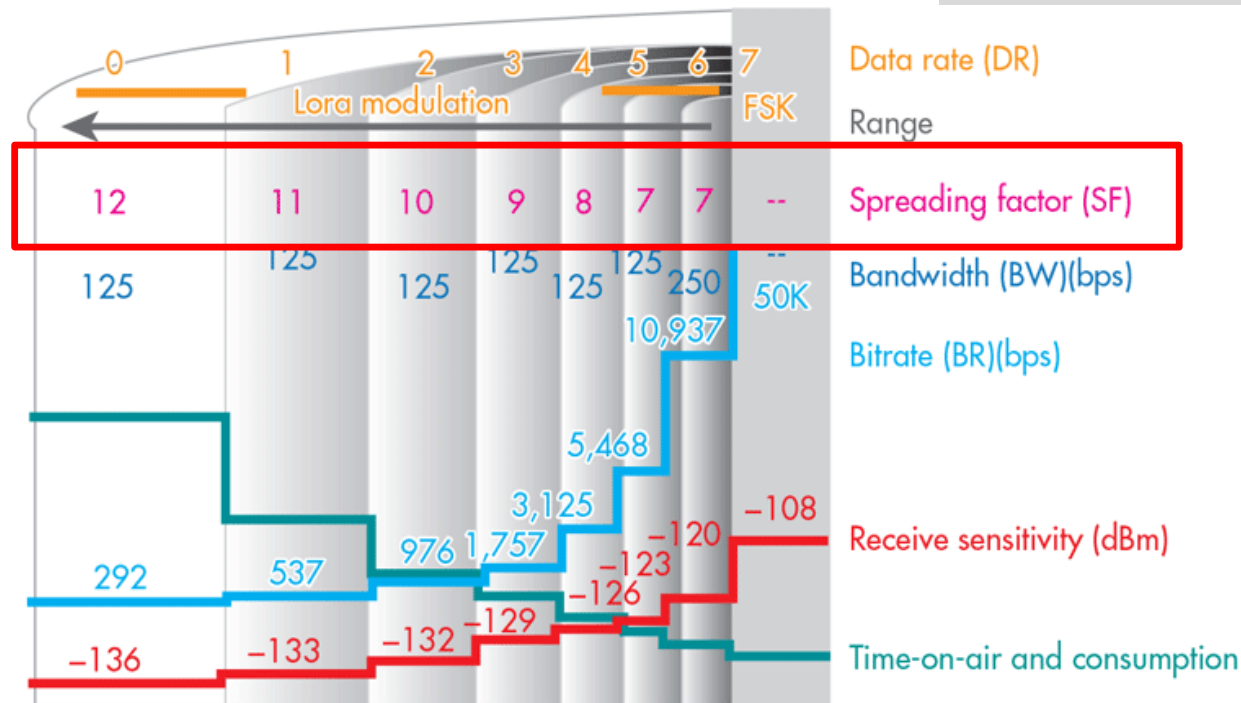




# The price of pay for LPWANs!

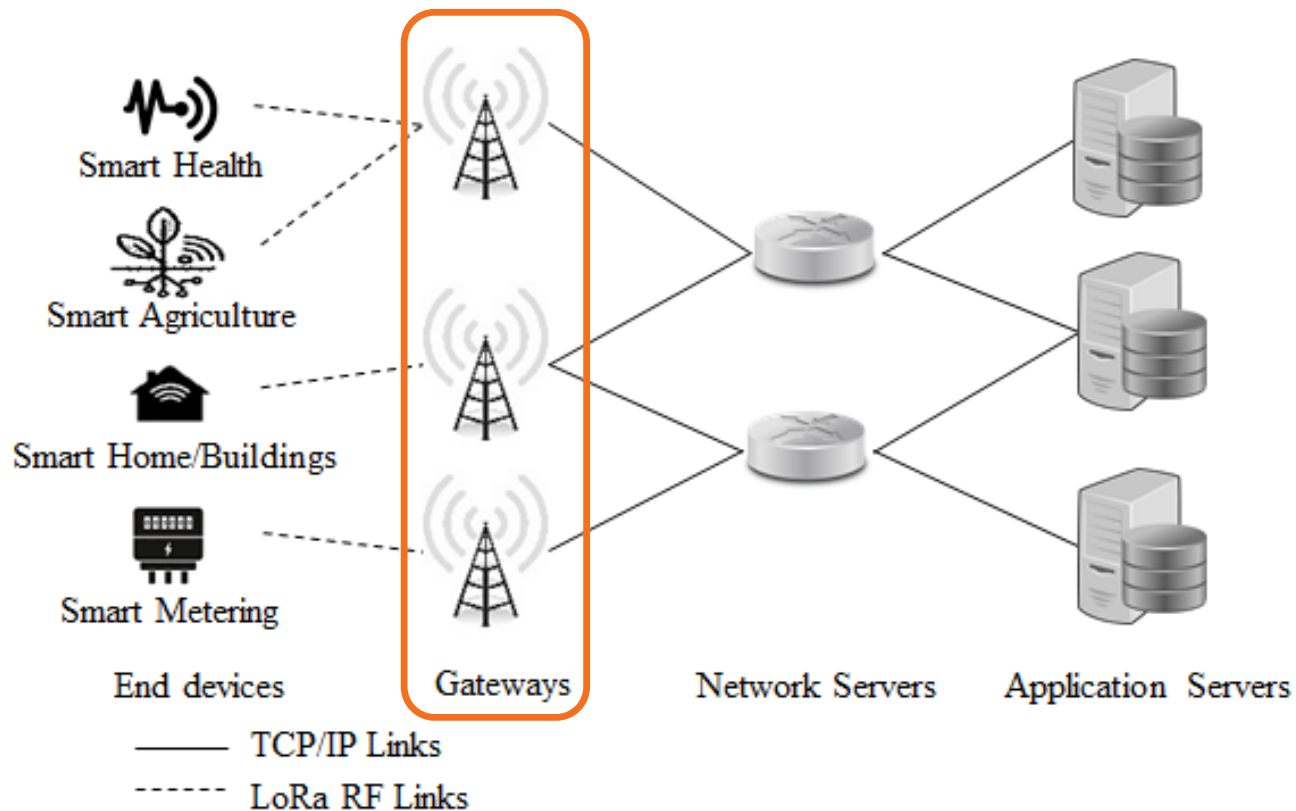
LoRa has **very low** throughput  
**200bps-37500bps**  
**(0.2-37.5kbps)**

- WiFi 802.11n: 450 000 000 bps (450Mbps)
- WiFi 802.11g: 54 000 000 bps (54Mbps)
- Bluetooth3&4: 25 000 000 bps (25Mbps)
- Bluetooth BLE: 2 000 000 bps (2Mbps)
- 3G/4G : 20Mbps-200Mbps
- **LoRa** : 200bps-37500bps (0.0002-0.0375Mbps)
- **3G/LoRa ratio: 20,000,000bps/200bps=100000!**



# General LPWAN IoT architecture

- ⦿ With increased range, LPWAN are mostly gateway-centric
  - ⦿ IoT gateways are connected to Internet
  - ⦿ They forward data from IoT device to Internet Servers



# Low-cost, general-purpose hardware



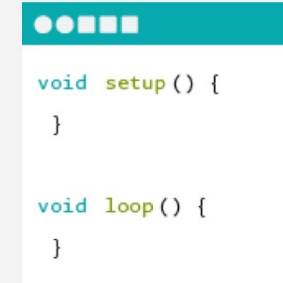
## WHAT IS ARDUINO?

Arduino is an open-source electronics platform based on easy-to-use hardware and software. It's intended for anyone making interactive projects.



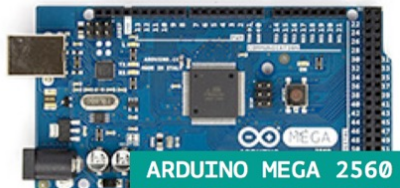
## ARDUINO BOARD

Arduino senses the environment by receiving inputs from many sensors, and affects its surroundings by controlling lights, motors, and other actuators.



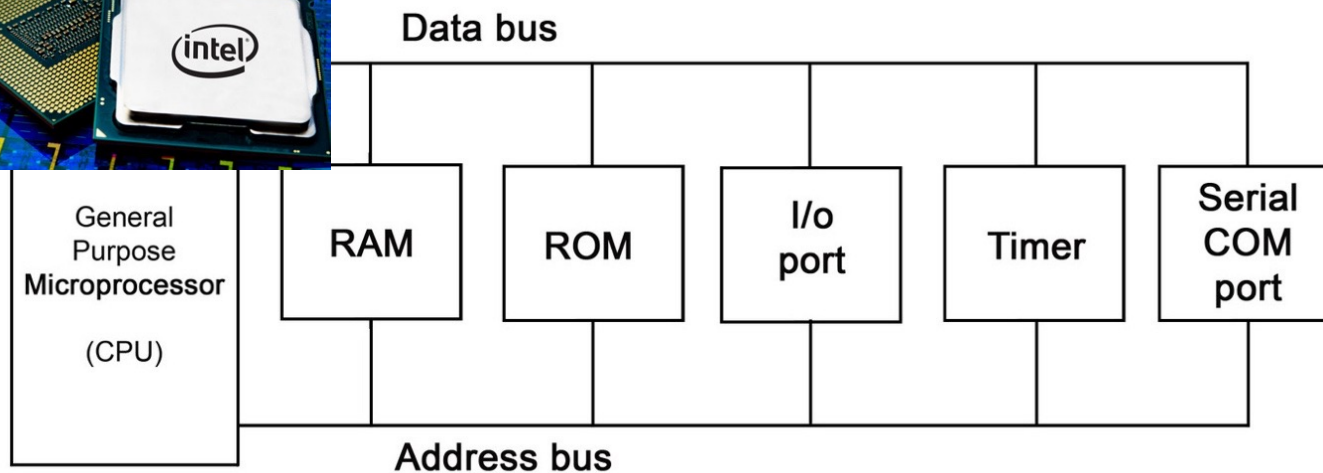
## ARDUINO SOFTWARE

You can tell your Arduino what to do by writing code in the Arduino programming language and using the Arduino development environment.

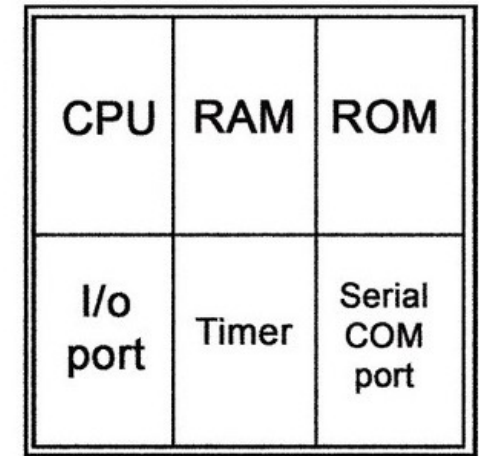




- ⦿ A microprocessor unit (MPU) is a processor on one silicon chip
- ⦿ A microcontroller unit (MCU) is a microprocessor with some added circuitry on one silicon chip
- ⦿ Microcontrollers are used in embedded computing and **most IoT devices are based on microcontrollers**



**VS**



(Single chip)

From "An Embedded System Overview" by Dr. Eng. Amr T. Abdel-Hamid

# From $\mu$ controller to $\mu$ controller board

- ⦿ A  $\mu$ controller can be standalone...

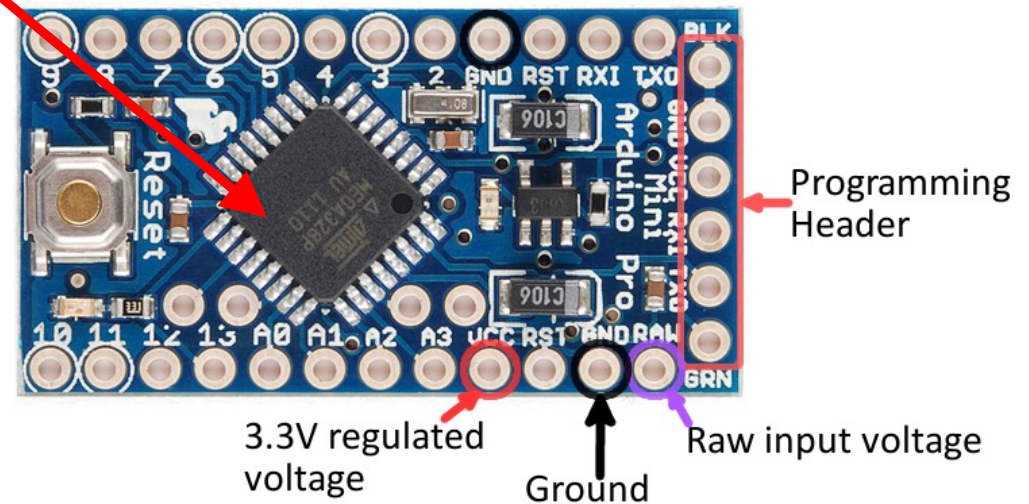
CPU	RAM	ROM
I/o port	Timer	Serial COM port

(Single chip)



- ⦿ But, it is usually mounted on a board with additional electronics parts

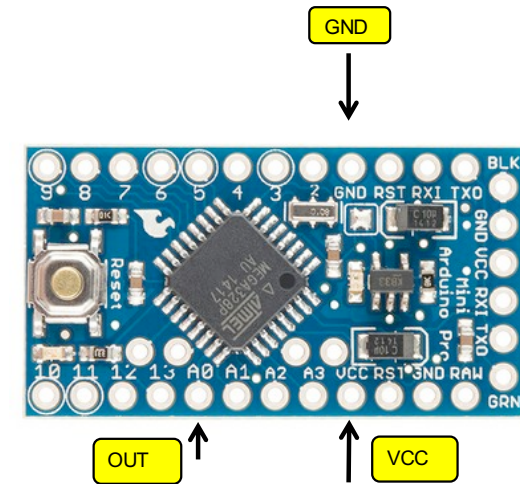
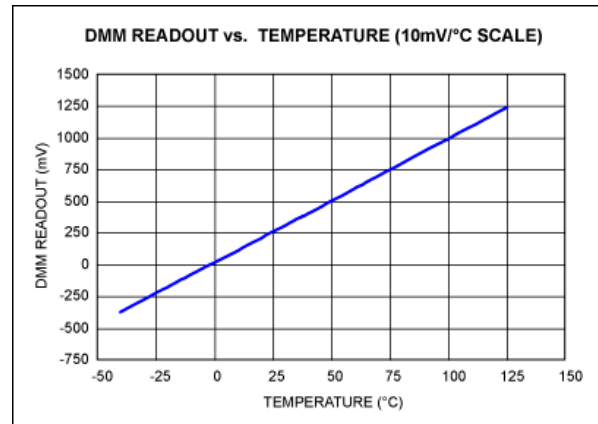
- ⦿ Leds, Voltage regulators
- ⦿ Easy access to pins
- ⦿ Reset button
- ⦿ Serial-USB interface







# Digitalizing the real world!



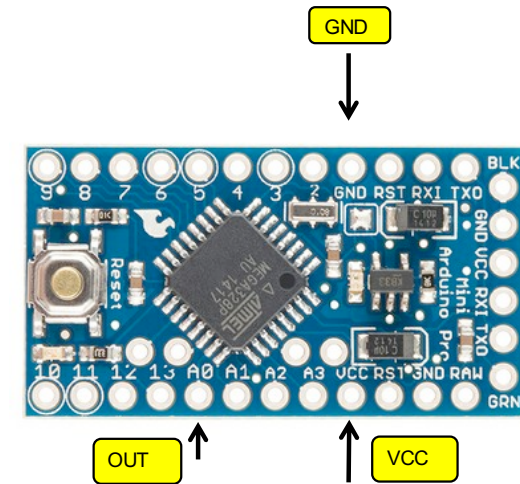
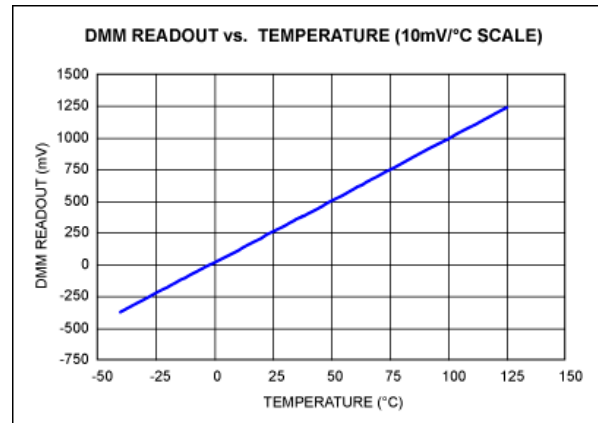
V<sub>cc</sub> is typically 3.3V. Microcontrollers have Analog/Digital (A/D) converter to map a voltage to a numerical value. **A/D with 10-bit resolution give values in  $[0, 2^{10}-1] = [0, 1023]$**

If 0=0V and 1023=3300mV then  **$3300\text{mV}/1024=3.22\text{mV}$  is the granularity of the measure**

**A digital value of 100 means  $100 \times 3.22\text{mV}=322\text{mV}$**

**If the sensor output is 10mV/1°C then the physical temperature is  $322\text{mV}/10\text{mV}=32.2^\circ\text{C}$**

# Reading analog pin value



```
// sensor output connected to A0 analog pin
value = analogRead(A0);

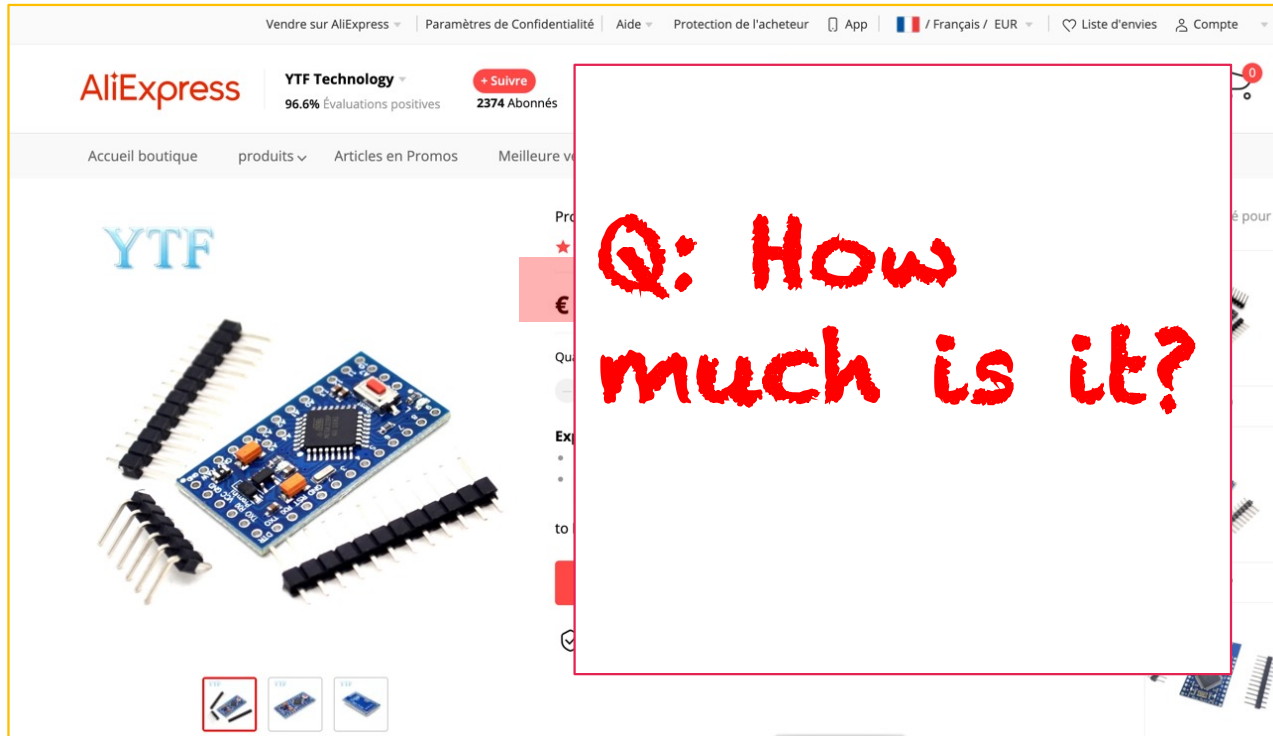
// now need to convert to Celcius degree
```

## And converting into Celcius

```
Temp = value * 3300.0/1024.0; // 3300/1024=3.22mV
Temp = Temp / 10; // 10mV means 1°C

// now process and transmit the data
```

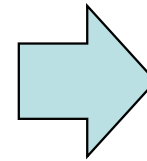
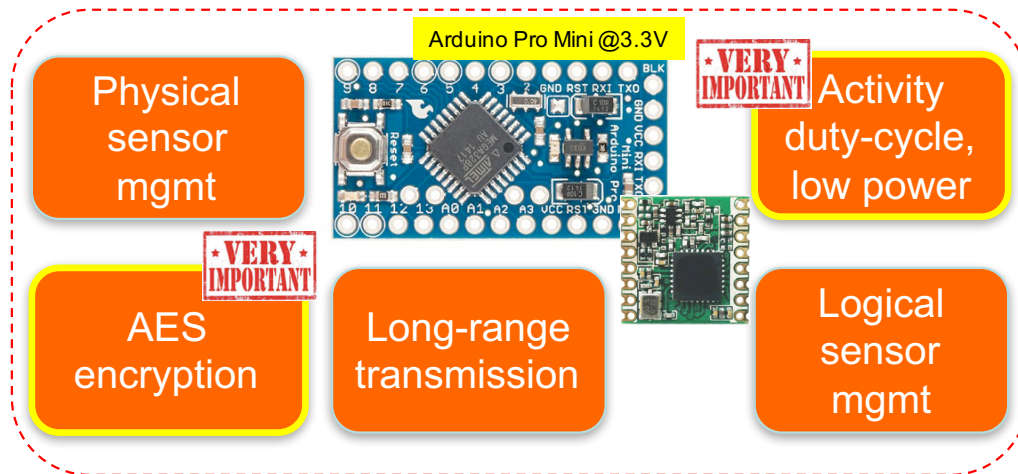
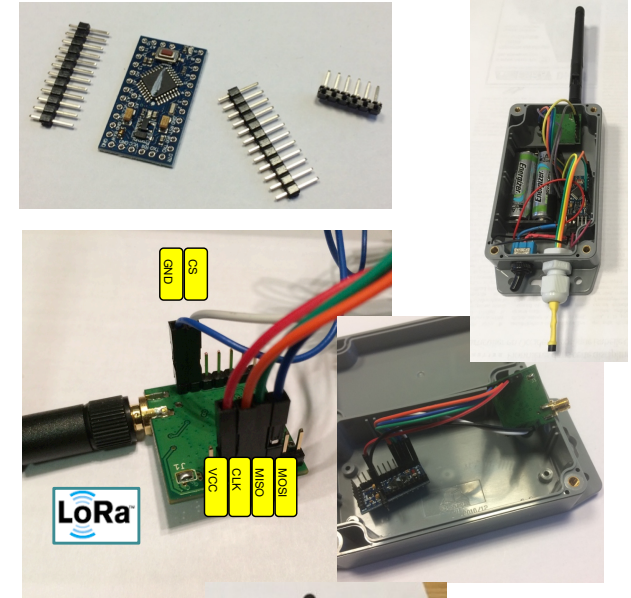
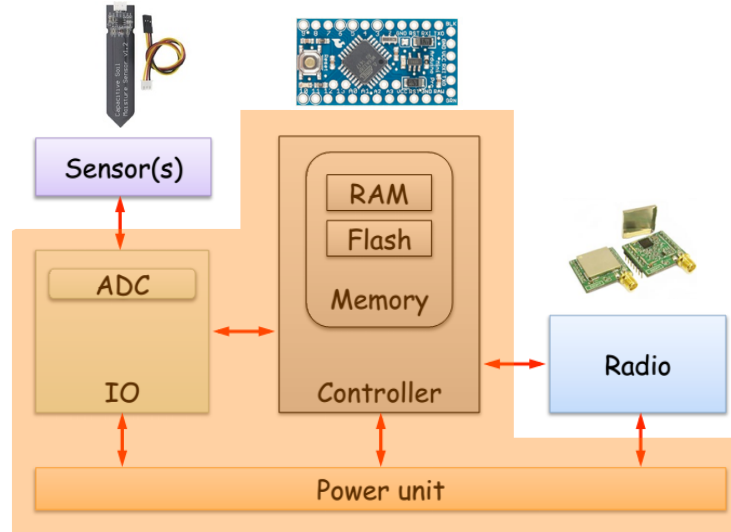
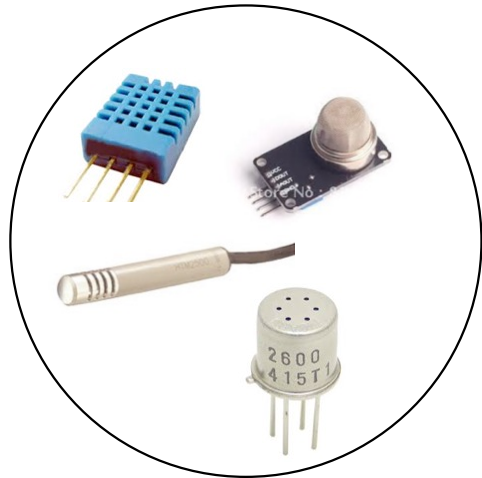
# Why go for Arduino?



- ⦿ Cheap, open, and easy to use/program
- ⦿ **Huge developer communities**
- ⦿ Hardware is not the main important issue
- ⦿ Hardware is nothing without software libraries!

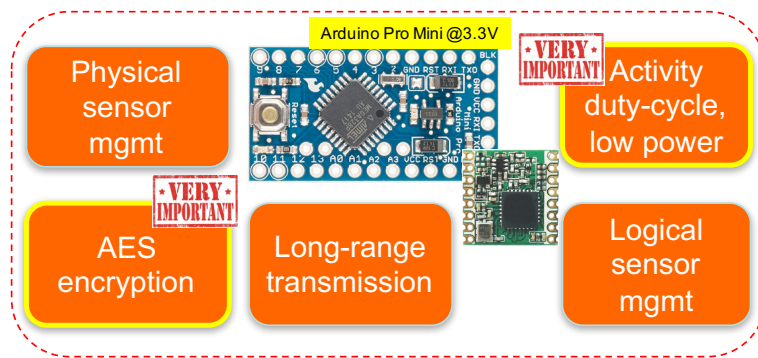


# Do-It-Yourself IoT



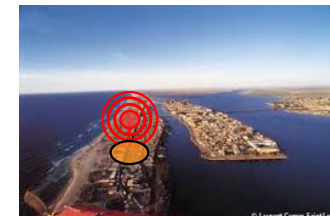
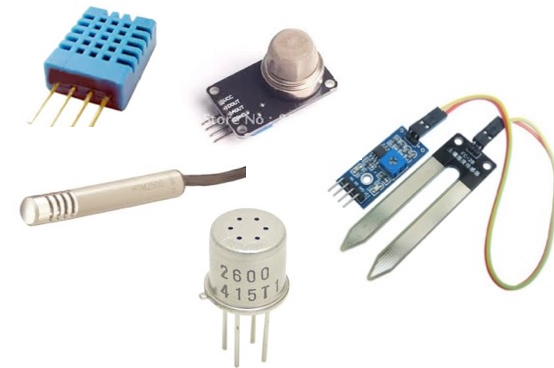
# Generic IoT v.s. highly specialized

- Build **low-cost**, **low-power**, **generic** IoT platform
- Methodology for low-cost platform design
- Technology transfers to user communities, economic actors, stakeholders,...



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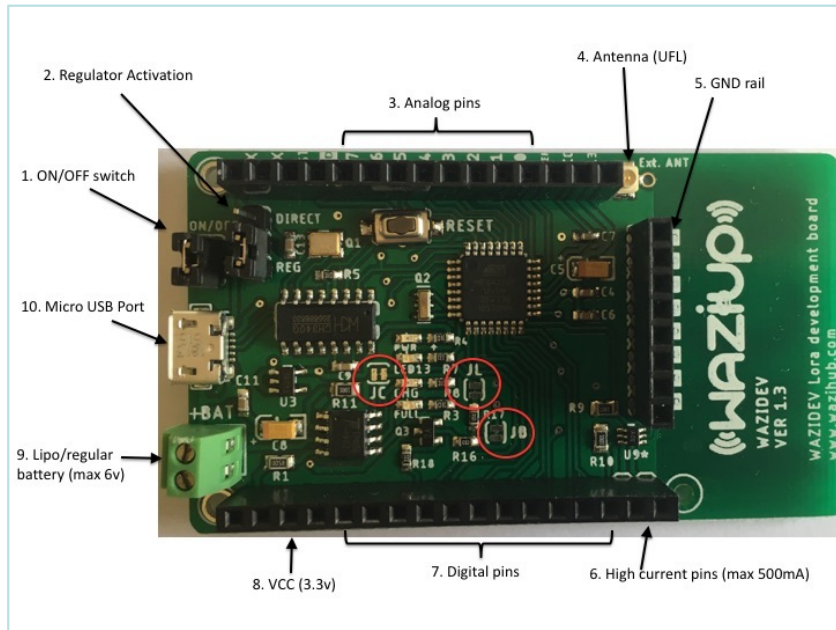
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# WaziDev kit: IoT in-a-box!



- ⦿ WaziDev
  - ⦿ ATmega328P, 8MHz, 3.3v
  - ⦿ FTDI chip
  - ⦿ RFM95W LoRa module
  - ⦿ Integrated antenna



- ⦿ Included
  - ⦿ LiPo battery regulator accepting solar panel input
  - ⦿ Battery level monitor
  - ⦿ 2 high-current control pin
  - ⦿ GND rail

# Building domain-specific sensors





# Low-cost soil moisture device



**SEN0308  
capacitive sensor**

**Watermark WM200  
Water tension sensor**



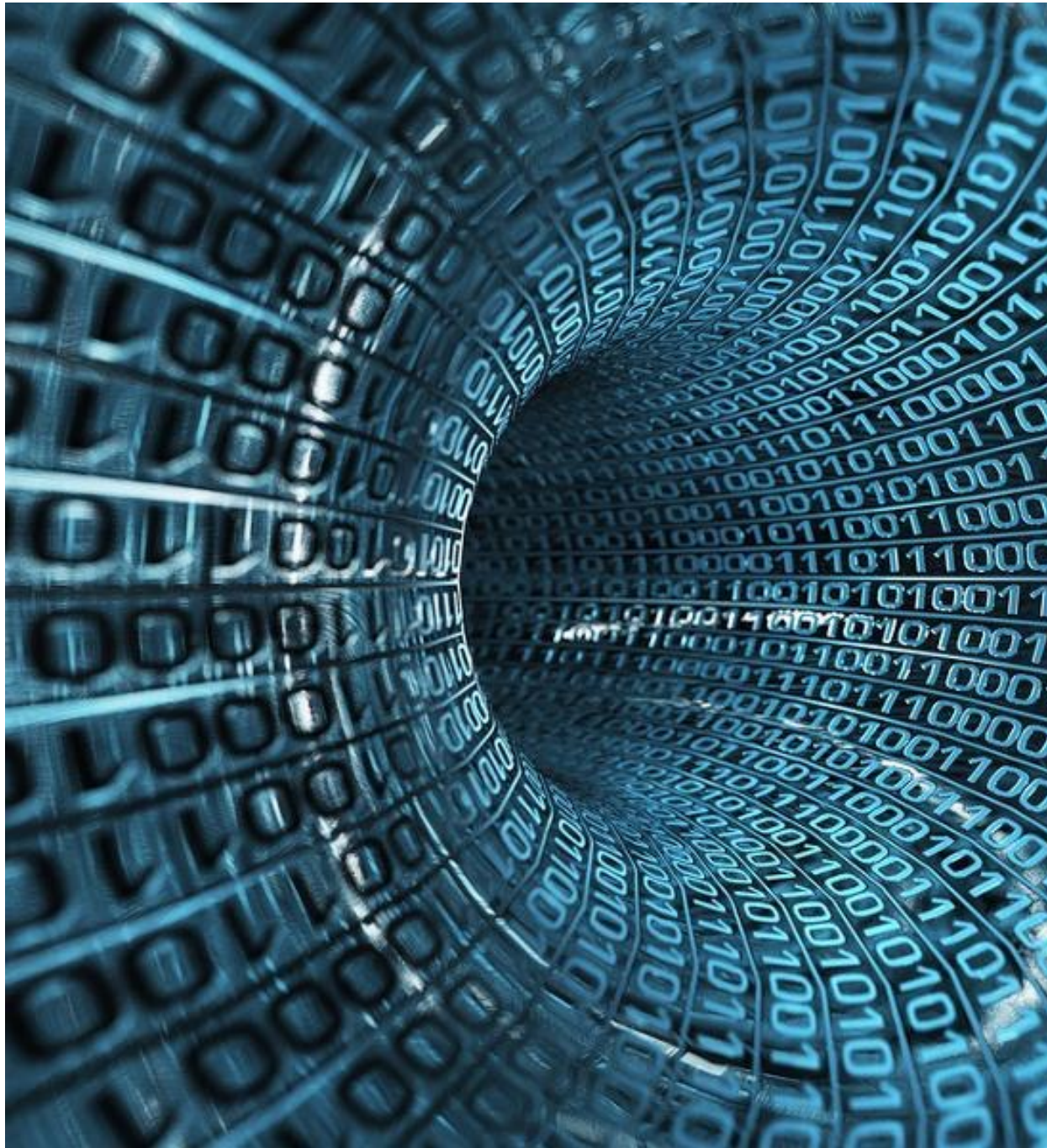
**A soil temperature  
sensor can be added**



# INTEL-IRRIS starter-kit

- "Intelligent Irrigation in-the-box", "plug-&-sense"
- From idea to reality!





# IOT

Unleash the power of  
IoT data!



The image features a cityscape at night, viewed from an elevated perspective. The sky is a vibrant mix of colors, transitioning from deep blue on the left to bright green on the right. Several stylized, colorful clouds are scattered across the sky, each containing white icons representing different IoT applications. From left to right, the clouds include: a purple cloud with icons of people, a heart, and a smartphone; a red cloud with a shopping cart, a Euro symbol, a credit card, and a dollar sign; a blue cloud with a bridge, a building, a camera, and power lines; a green cloud with wind turbines and solar panels; a blue cloud with a road, a car, a satellite, and a location pin; and a purple cloud with a factory, a truck, and gears. Numerous arrows of various colors (purple, red, blue, green, yellow) point upwards from the city towards the clouds, symbolizing the growth and deployment of IoT devices. The overall scene conveys a sense of technological advancement and global connectivity.

**2021, billions of IoT devices  
are deployed worldwide!**



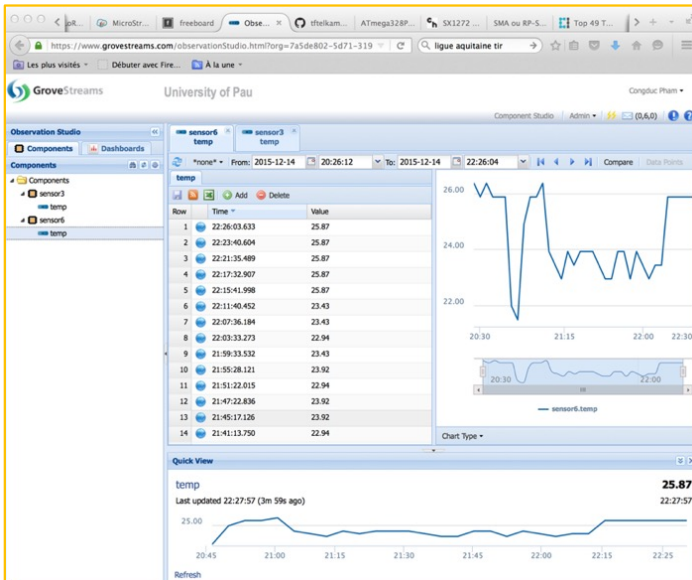
# These things talk a lot!

## Lot's of data !





# Things talks to IoT clouds

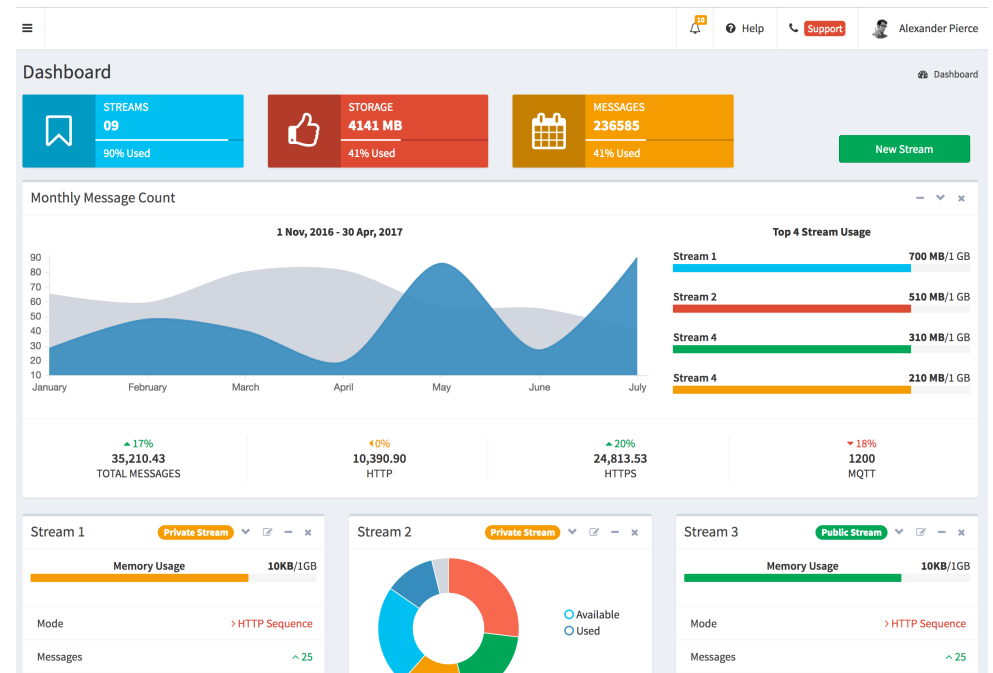
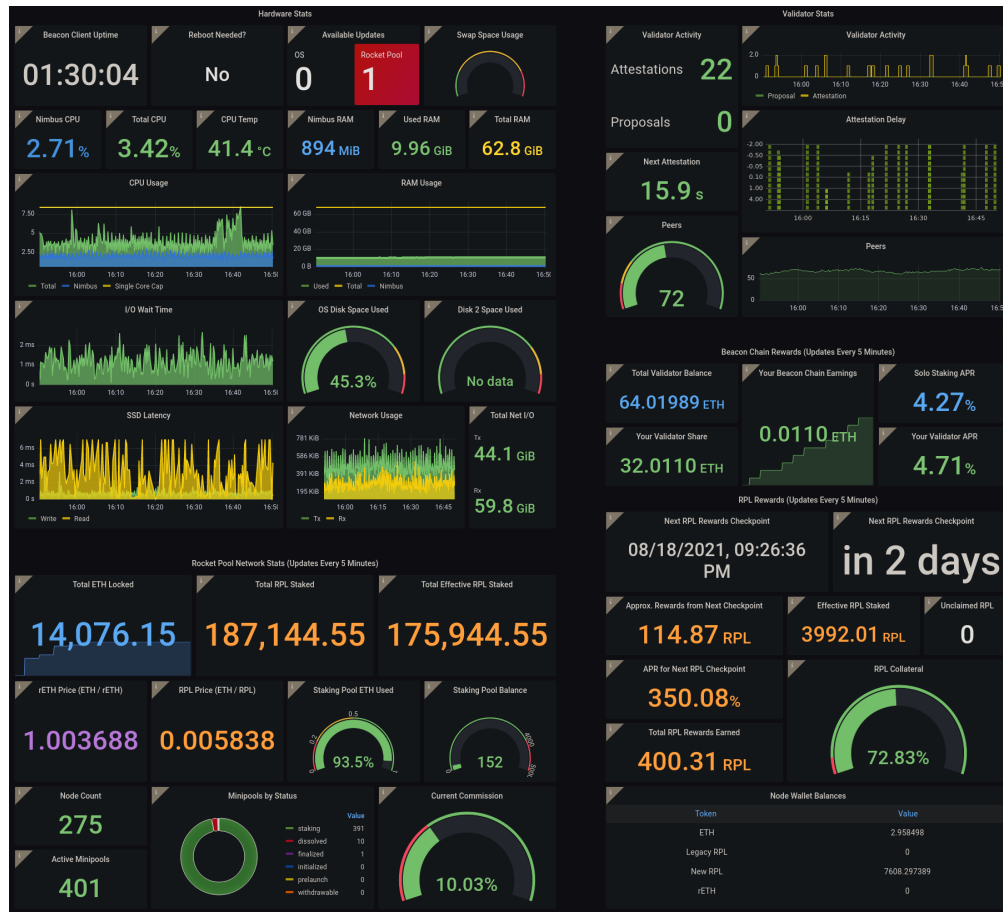


# IoT added-values come from interactions and linked data!





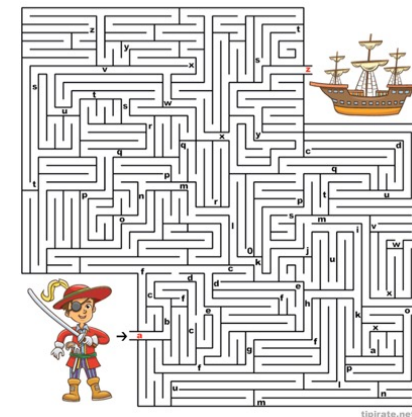
# Integrating multiple data sources





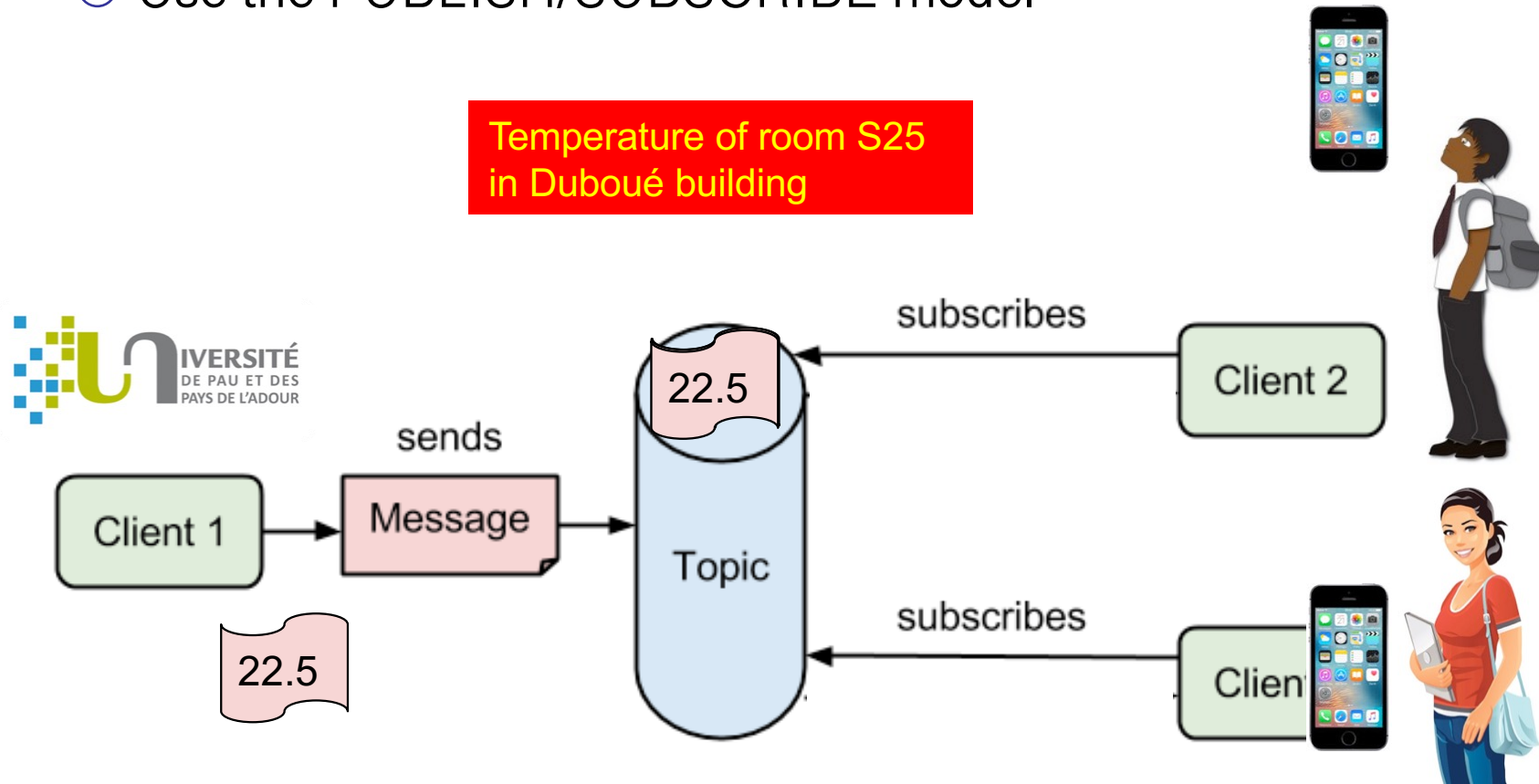
# Searching for IoT data

- Searching for information is a tough issue
  - Web search engine: Google,...
- If you seek for an information, for instance the soil humidity condition in a particular farm, then you need to know where to look
- When there can be billions of IoT nodes providing large variety of data, it is difficult to find your way!
- Although sensors' data can eventually be accessed with traditional methods (web services, HTTP/REST API, ...) IoT calls for a more "automatized" and "simplistic" approach



# From "search for info" to "get the info"

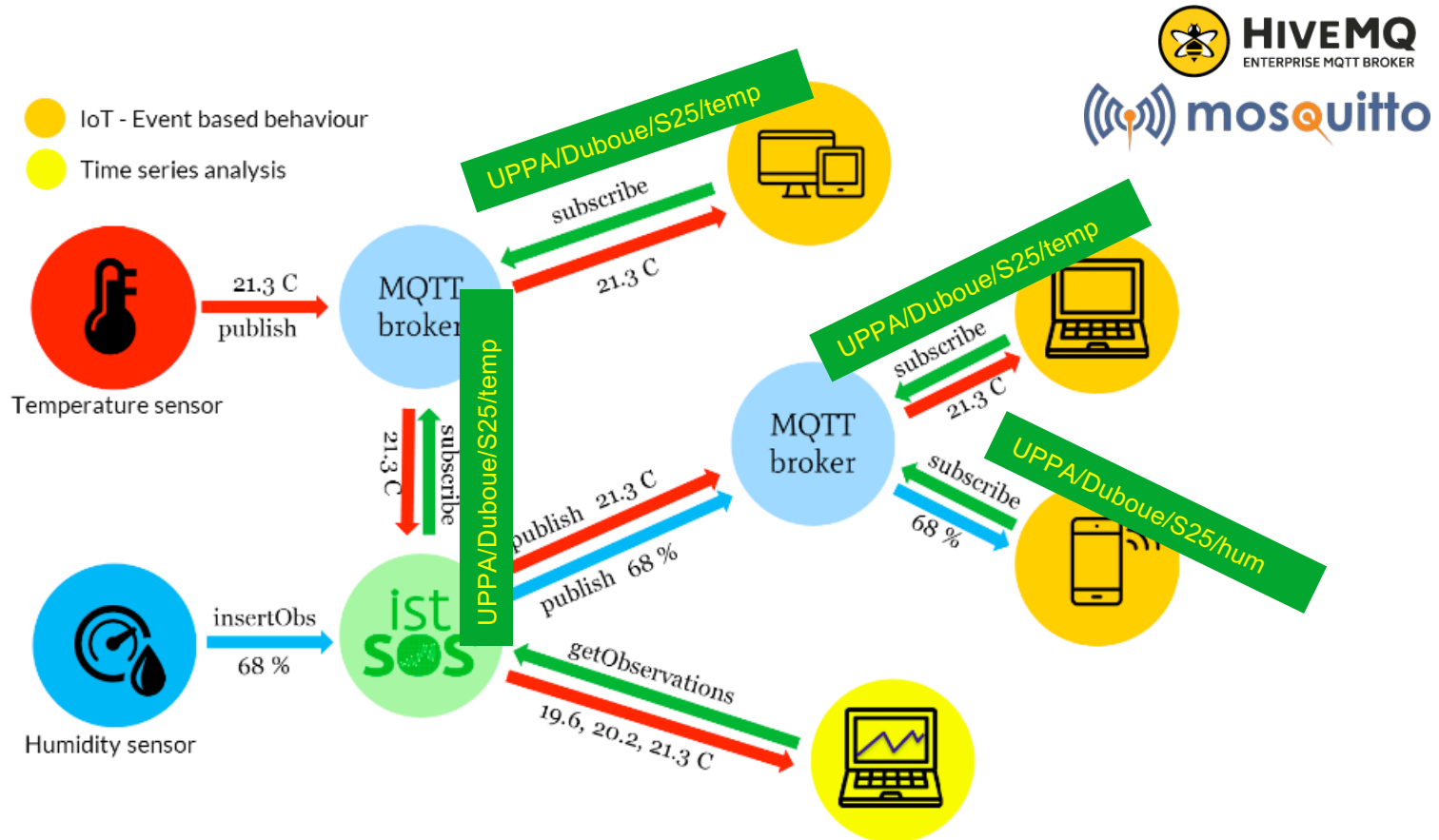
- Use the PUBLISH/SUBSCRIBE model



# MQTT

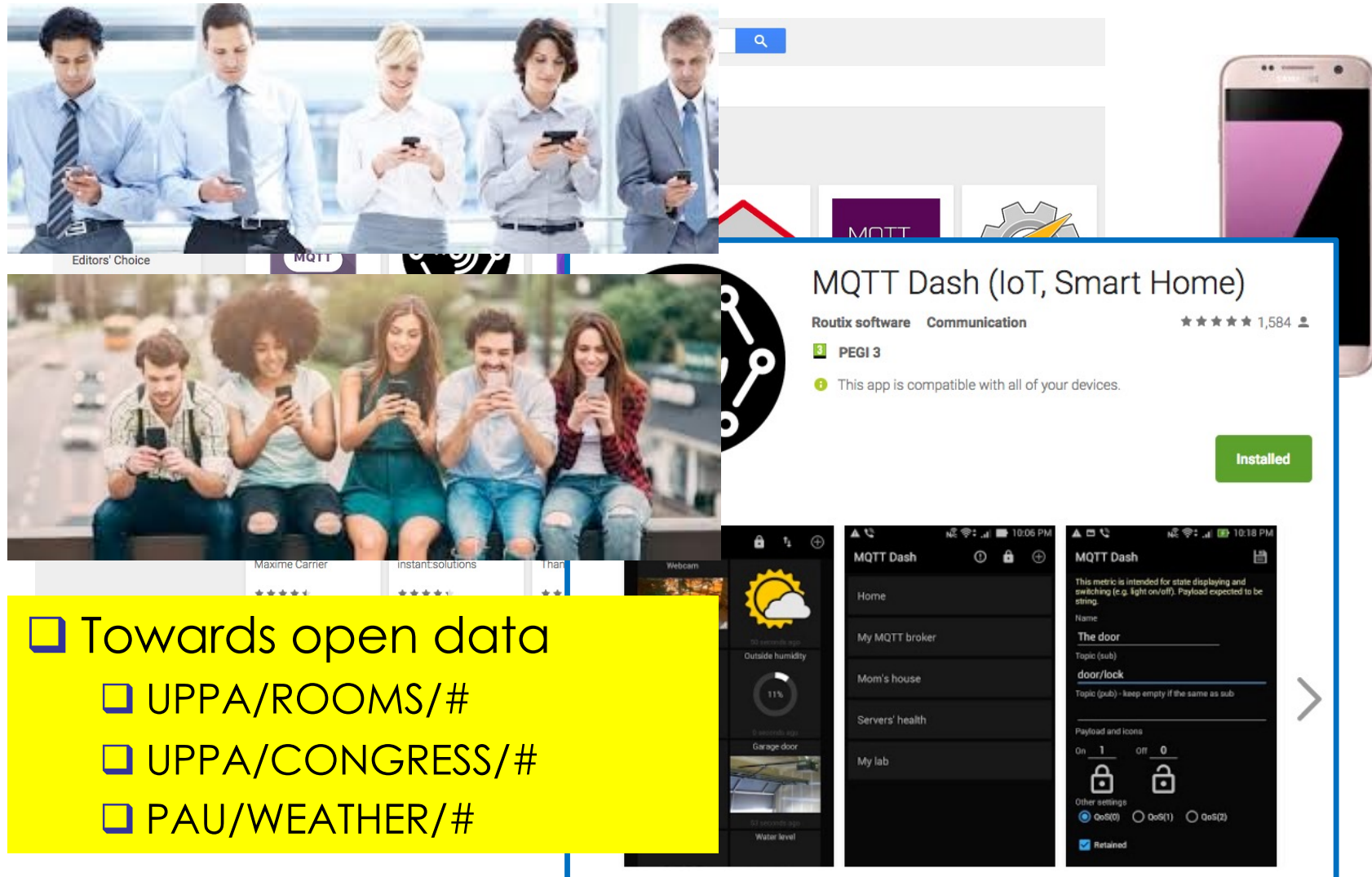
## Message Queue Telemetry Transport

- Use broker nodes to manage topics
  - UPPA/Duboue/S25/temp, UPPA/Duboue/S25/hum





# MQTT+smartphone=



Editors' Choice

MQTT Dash (IoT, Smart Home)

Routix software Communication ★★★★★ 1,584

PEGI 3

This app is compatible with all of your devices.

Installed

Maxime Carrier Instant.solutions I har Webcam

MQTT Dash

Home

My MQTT broker

Mom's house

Servers' health

My lab

MQTT Dash

This metric is intended for state displaying and switching (e.g. light on/off). Payload expected to be string.

Name

The door

Topic (sub)

door/lock

Topic (pub) - keep empty if the same as sub

Payload and icons

On 1 Off 0

Other settings

0x0(0) 0x0(1) 0x0(2)

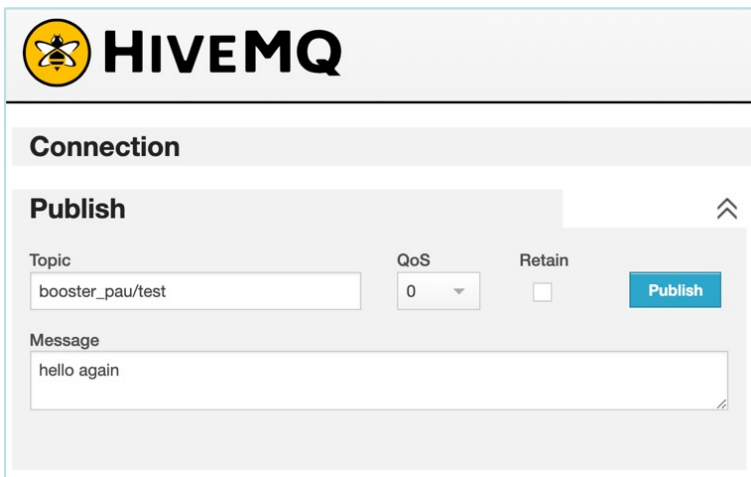
Retained

## ☐ Towards open data

- ☐ UPPA/ROOMS/#
- ☐ UPPA/CONGRESS/#
- ☐ PAU/WEATHER/#

# Want to play with MQTT?

⦿ <http://www.hivemq.com/demos/websocket-client/>



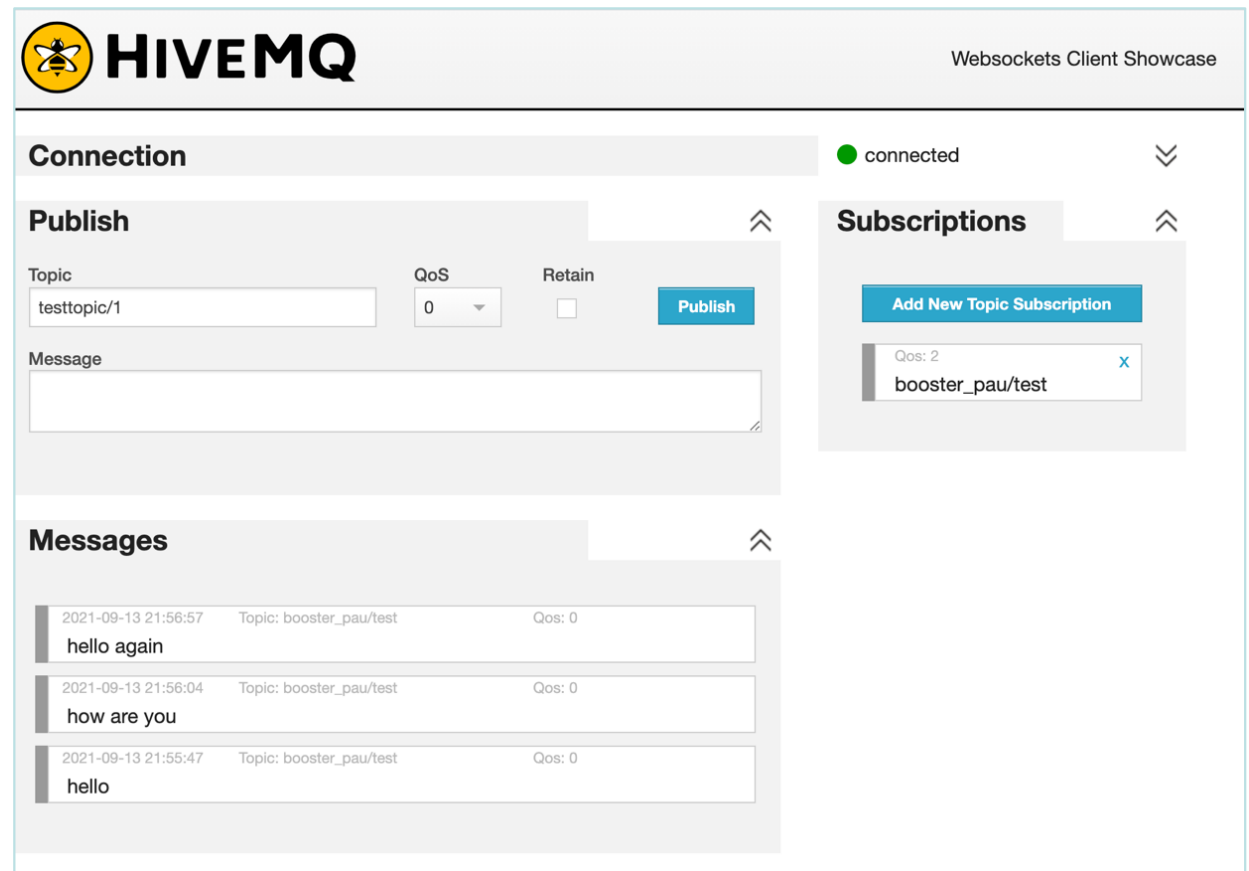
**HIVEMQ**

**Connection**

**Publish**

Topic: booster\_pau/test    QoS: 0    Retain:     **Publish**

Message: hello again



**HIVEMQ**    Websockets Client Showcase

**Connection**    ● connected

**Publish**

Topic: testtopic/1    QoS: 0    Retain:     **Publish**

Message:

**Subscriptions**

**Add New Topic Subscription**

Qos: 2    booster\_pau/test

**Messages**

2021-09-13 21:56:57	Topic: booster_pau/test	Qos: 0	hello again
2021-09-13 21:56:04	Topic: booster_pau/test	Qos: 0	how are you
2021-09-13 21:55:47	Topic: booster_pau/test	Qos: 0	hello

# MQTT implementing social media

- It is very easy to implement a social media app using MQTT

- WhatsApp-like example

- Define MQTT topic per phone number

- Alice: myWhatsApp/0655667788

- Bob: myWhatsApp/0611223344



0655667788



Alice

- To receive/send message


- Alice subscribes/publishes to myWhatsApp/0611223344

- Bob subscribes/publishes to myWhatsApp/0655667788

- To create a group

- Alice creates a group waziup-iot

- myWhatsApp/0655667788/waziup-iot



0611223344



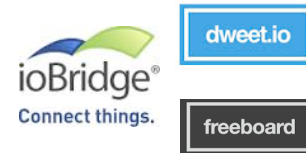
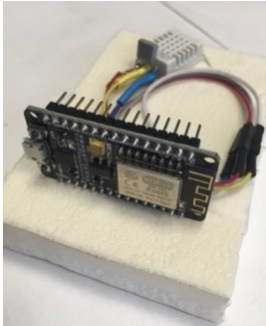
Bob

- To join(publish) on(to) the group

- Subscribe(publish) to myWhatsApp/0655667788/waziup-iot

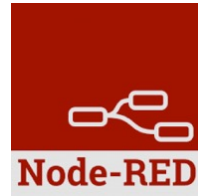


# Developing without programming?

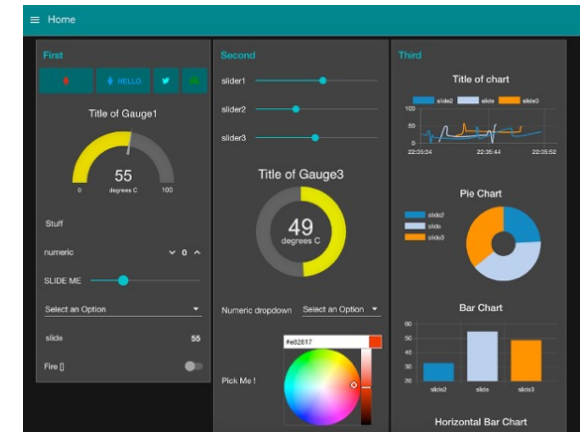
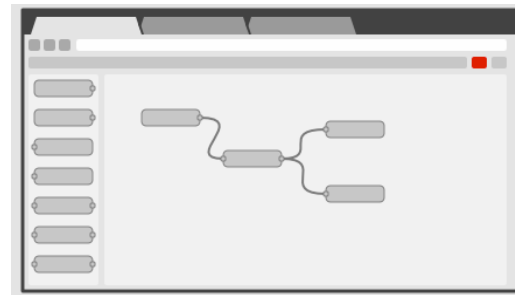


- End-users are not necessarily computer science experts nor high-skilled programmers
- Use graphical tools to build data processing flows, allowing intuitive connection from data producers to data consumers

# Node-Red

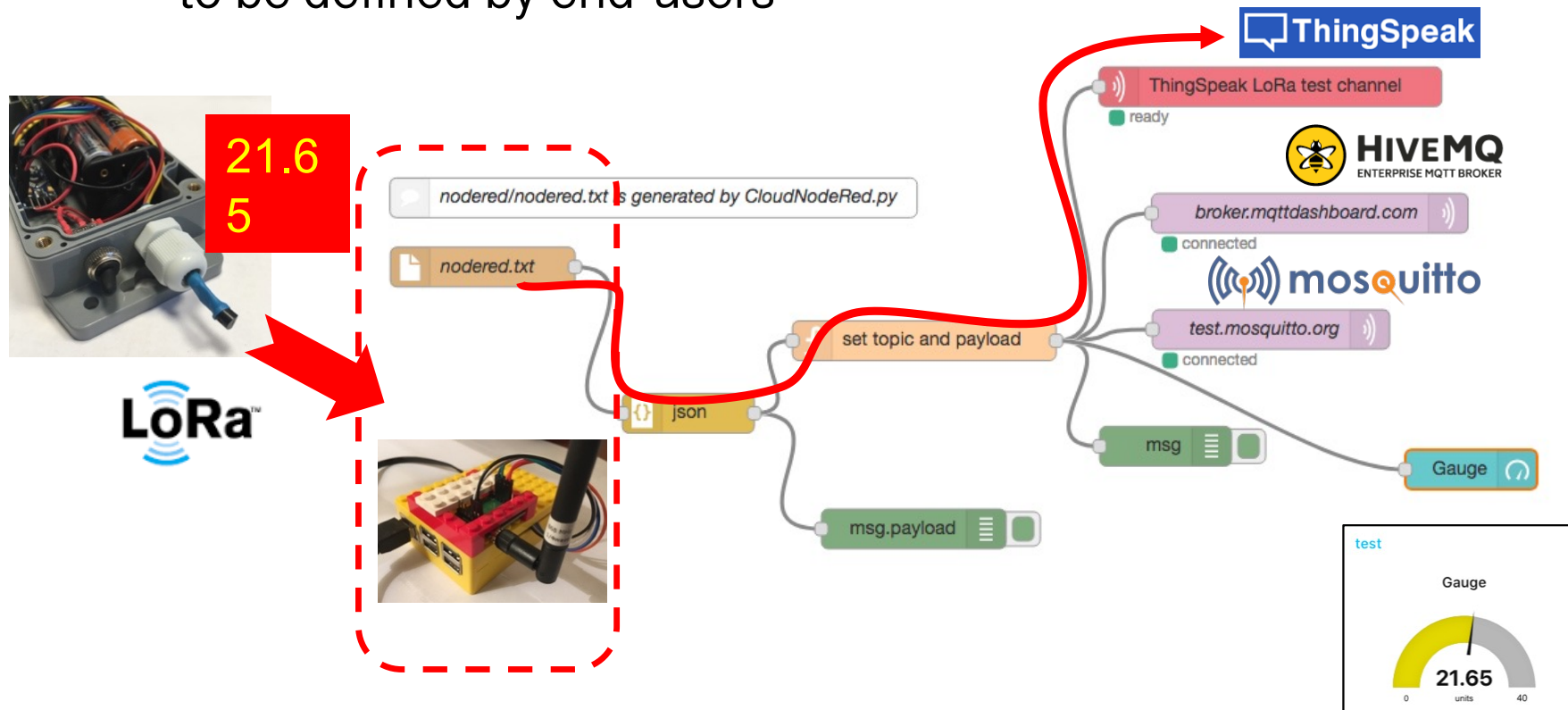


- Node-RED is a programming tool for wiring together hardware devices, APIs and online services, e.g. clouds of various types
- provides a browser-based flow editor to wire together flows with a wide range of nodes



# Node-red enabled IoT gateway

- Messages received on the IoT gateway can be injected into a Node-Red flow, allowing complex data processing to be defined by end-users

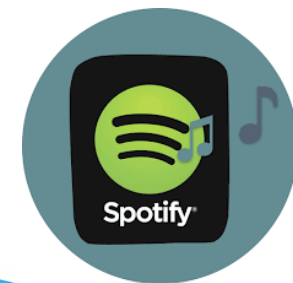
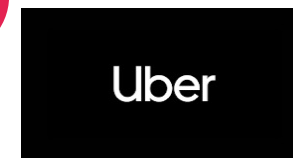




# Adding interactions?

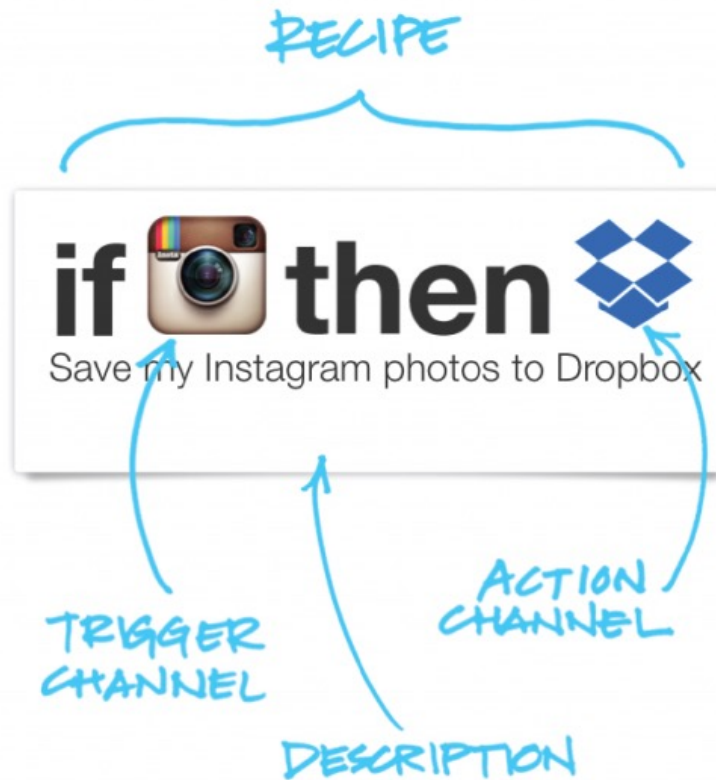


# Adding interactions?



# IF THIS THEN THAT applets

## Some example Recipes



**if**  **then**   
Nearly home? Direct message the person who should know

**if**  **then**   
Email your new iPhone photos to yourself

**if**  **then**   
Backup your contacts to a Google Spreadsheet





# IOT BACKOFFICE





# But also how to analyse the data

- ⦿ What is the meaning of the collected data?
- ⦿ Example with farming
  - ⦿ What is interesting for farmers?
    - ⦿ Fertility detection
    - ⦿ Eating/Ruminating time for welfare
  - ⦿ What data can be easily obtained?
    - ⦿ accelerometer data with neck-mounted collar
  - ⦿ How to detect relevant event from these data?

Advanced data analysis

Need of experts from the domain!

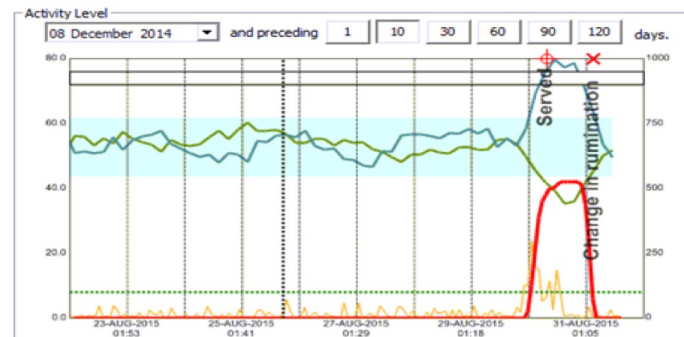
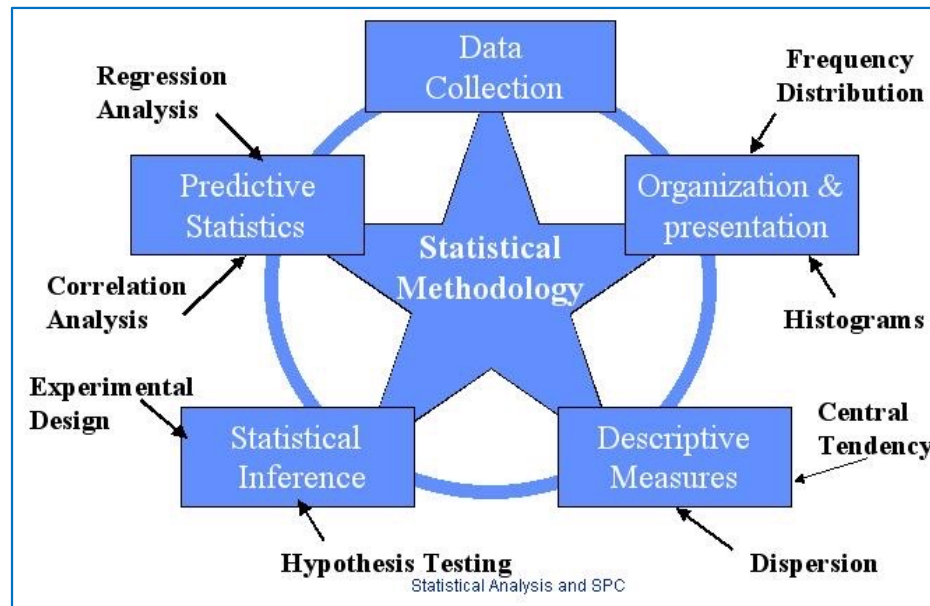


Fig. 3. Illustration of a rise in activity accompanied by a fall in rumination at the point of oestrus



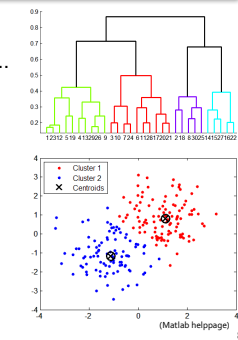
# Analysis techniques

Traditional statistic methods still valid, and useful!

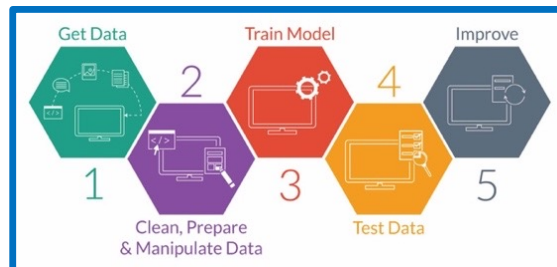


## Clustering Analysis

- Definition
  - Grouping unlabeled data into clusters, for the purpose of inference of hidden structures or information
- Dissimilarity measurement
  - Distance : Euclidean ( $L_2$ ), Manhattan ( $L_1$ ), ...
  - Angle : Inner product, ...
  - Non-metric : Rank, Intensity, ...
- Types of Clustering
  - Hierarchical
    - Agglomerative or divisive
  - Partitioning
    - K-means, VQ, MDS, ...

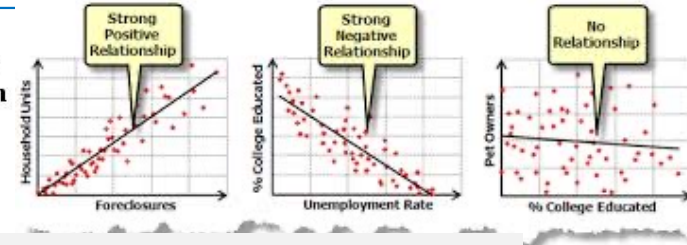
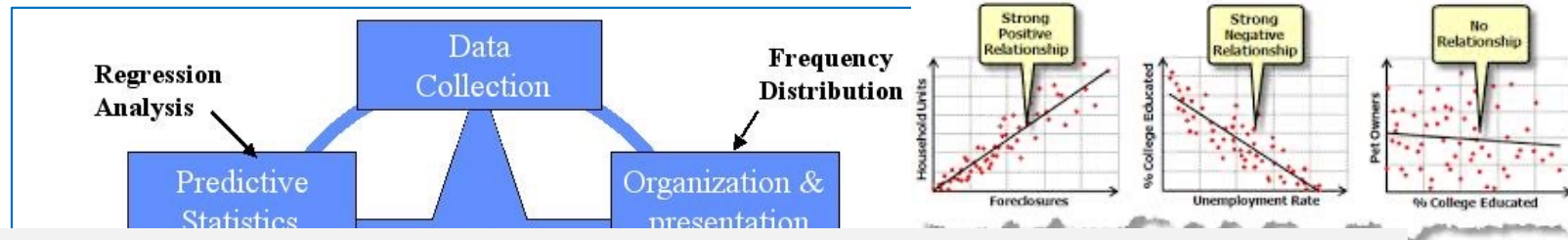


From Jong Youl Choi

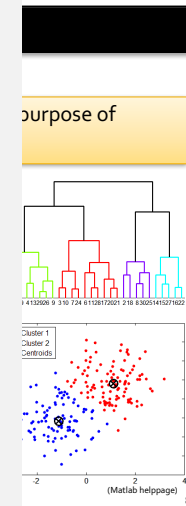


# Analysis techniques

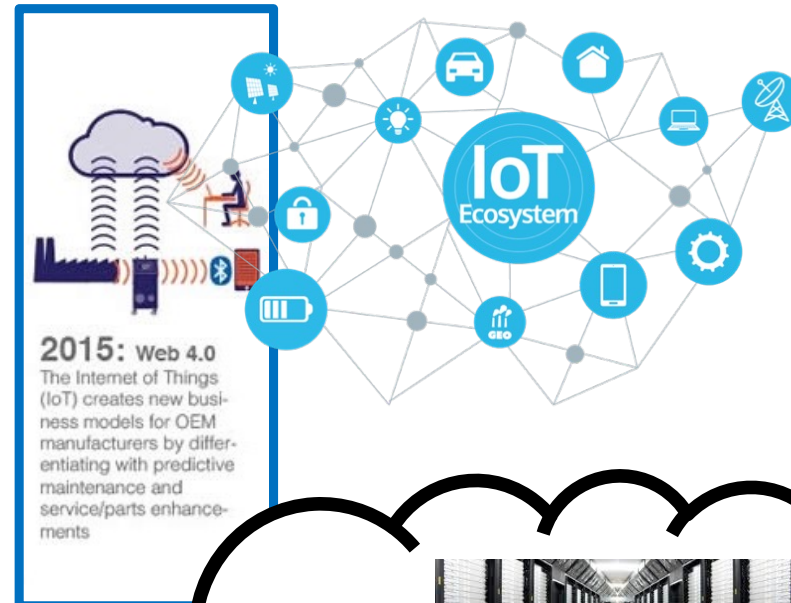
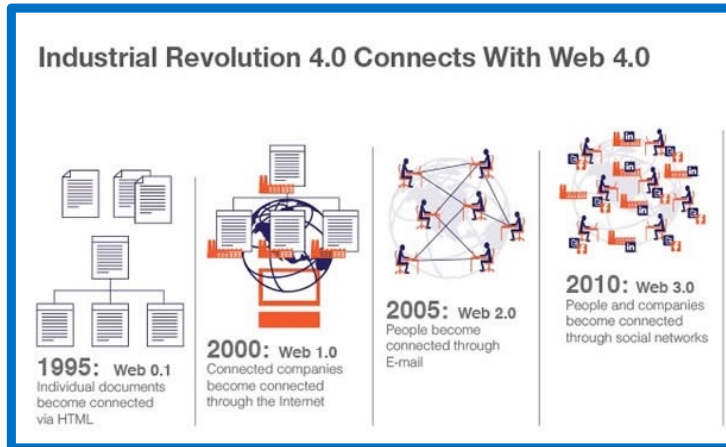
- Traditional statistic methods still valid, and useful!



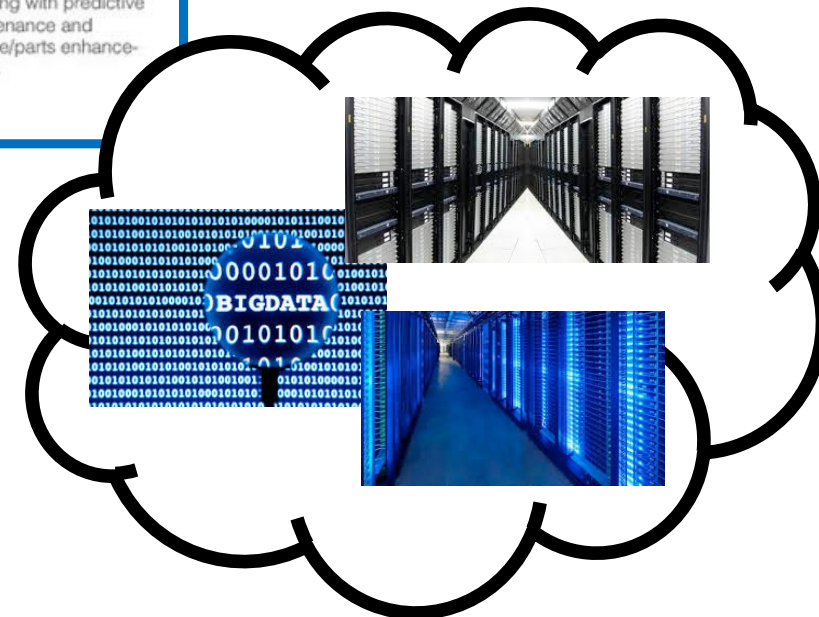
**Going old school ?**



# Use the full power of the Internet!



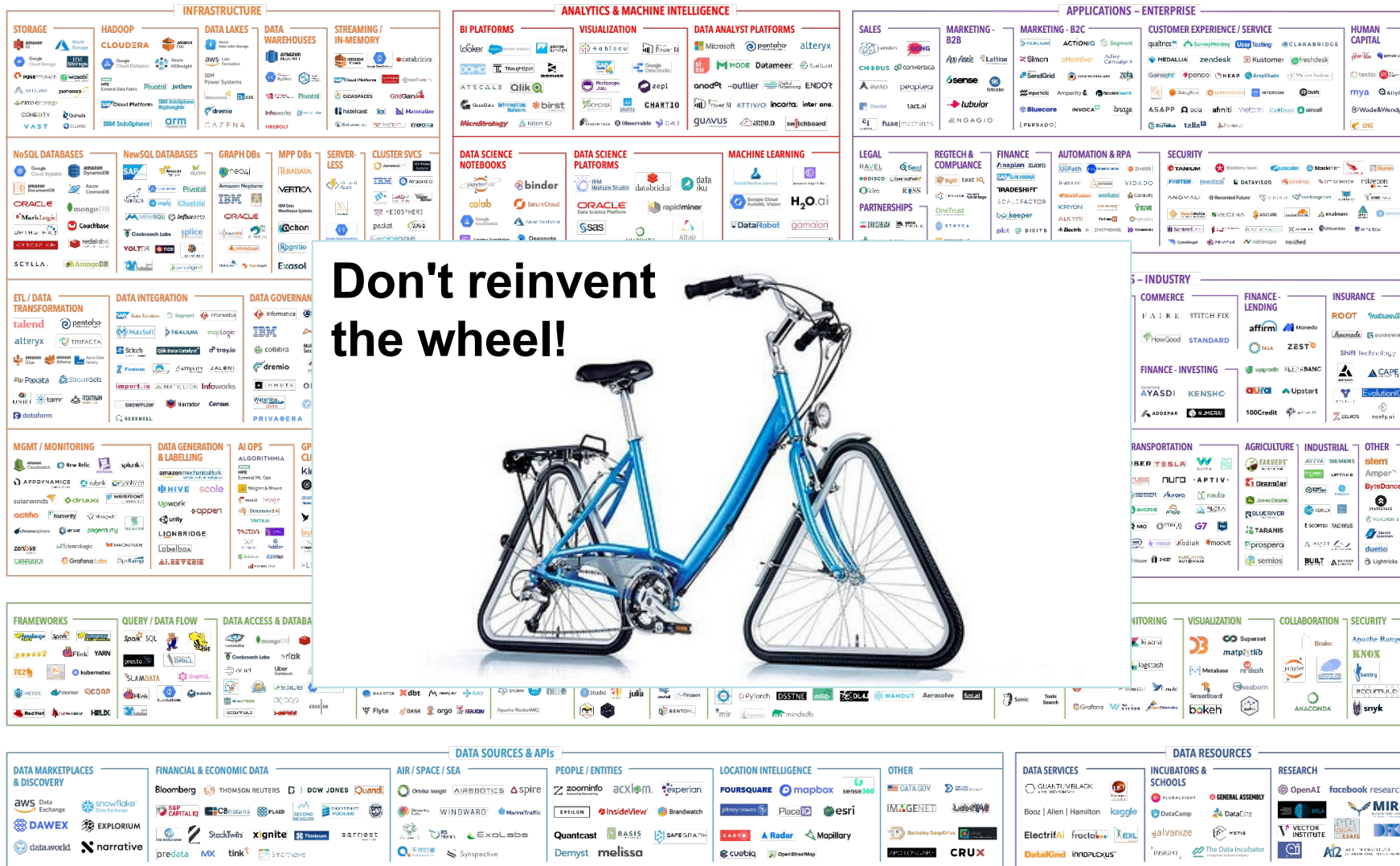
- IoT data are pushed on **Internet data clouds**
- Computing resources using Virtual Machines are obtained from **Internet Computing clouds**
- Parallel** processing
- Optimized** libraries
- Web tools to **orchestrate**





# The Big Data Landscape!

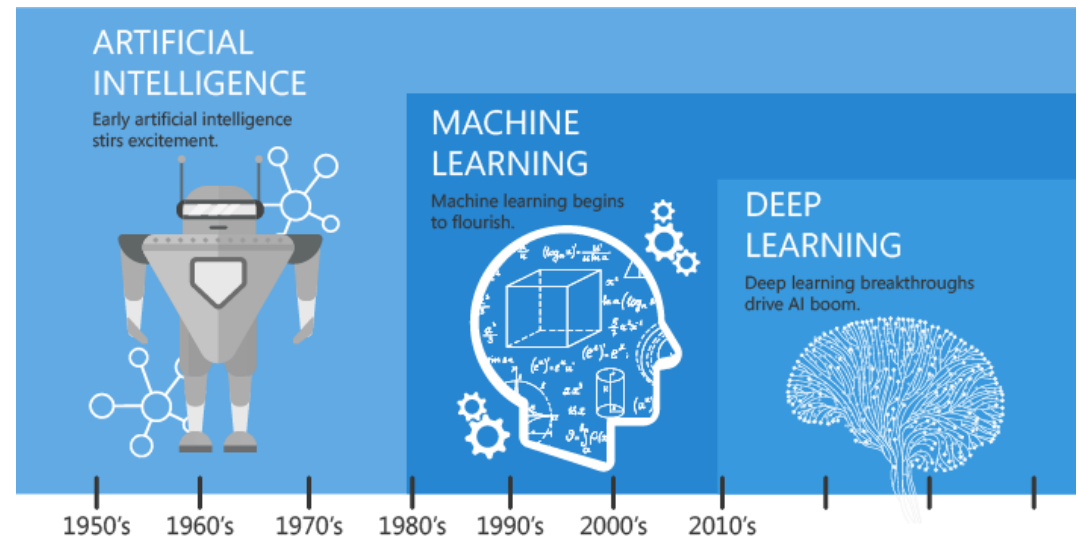
DATA & AI LANDSCAPE 2020



Prof. Congduc Pham  
http://www.univ-pau.fr/~cpham

# The raise of Artificial Intelligence

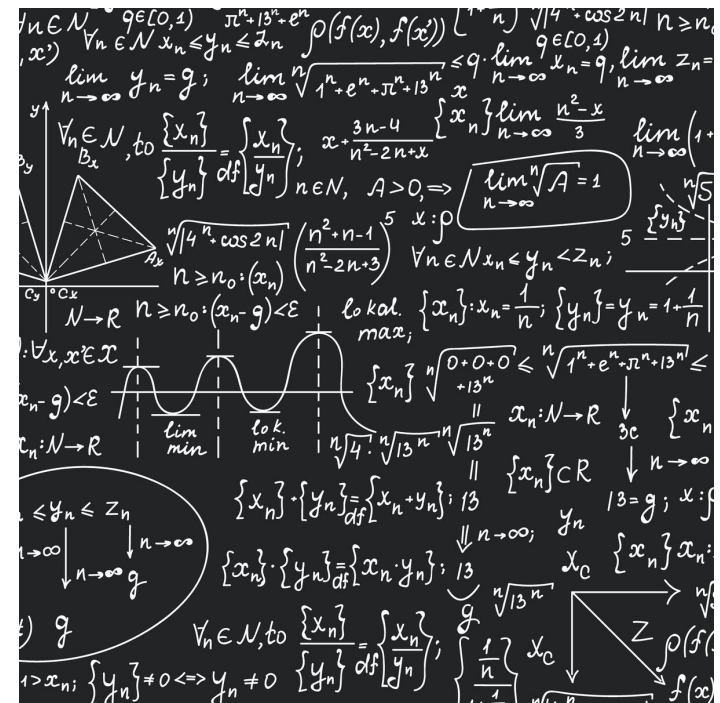
- ⦿ It is the science and engineering of making intelligent machines.
- ⦿ In Computer Science, Artificial Intelligence (AI) research is defined as the study of « intelligent agents »
- ⦿ From General AI to Narrow AI: from overhyping to fewer promises, but more realistic!



Since an early flush of optimism in the 1950's, smaller subsets of artificial intelligence - first machine learning, then deep learning, a subset of machine learning - have created ever larger disruptions.

# AI: a serious science!

- ⦿ General-purpose AI like the robots of science fiction is incredibly hard
  - ⦿ Human brain appears to have lots of special and general functions, integrated in some amazing way that we really do not understand (yet)
- ⦿ Special-purpose AI is more doable (nontrivial)
  - ⦿ E.g., chess/poker playing programs, logistics planning, automated translation, speech and image recognition, web search, data mining, medical diagnosis, keeping a car on the road.

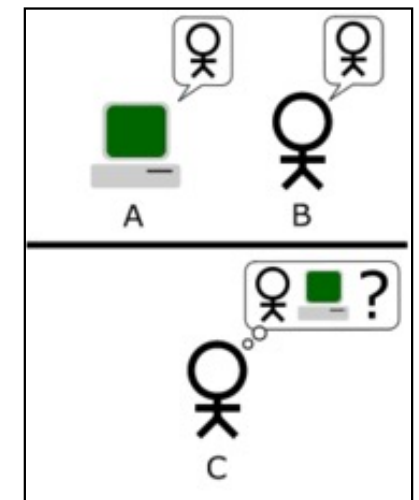




# The Turing Test

- ⦿ Proposed By Alan Turing in 1950
- ⦿ To be called intelligent, a machine must produce responses that are indistinguishable from those of a human.
- ⦿ Human judge communicates with a human and a machine over text-only channel.
- ⦿ Both human and machine try to act like a human.
- ⦿ Judge tries to tell which is which.
- ⦿ Is Turing Test the right goal?

“Aeronautical engineering texts do not define the goal of their field as making ‘machines that fly so exactly like pigeons that they can fool even other pigeons.’” [Russell and Norvig]



# Reflection

if AI can be **more rational** than humans in some cases, why not?

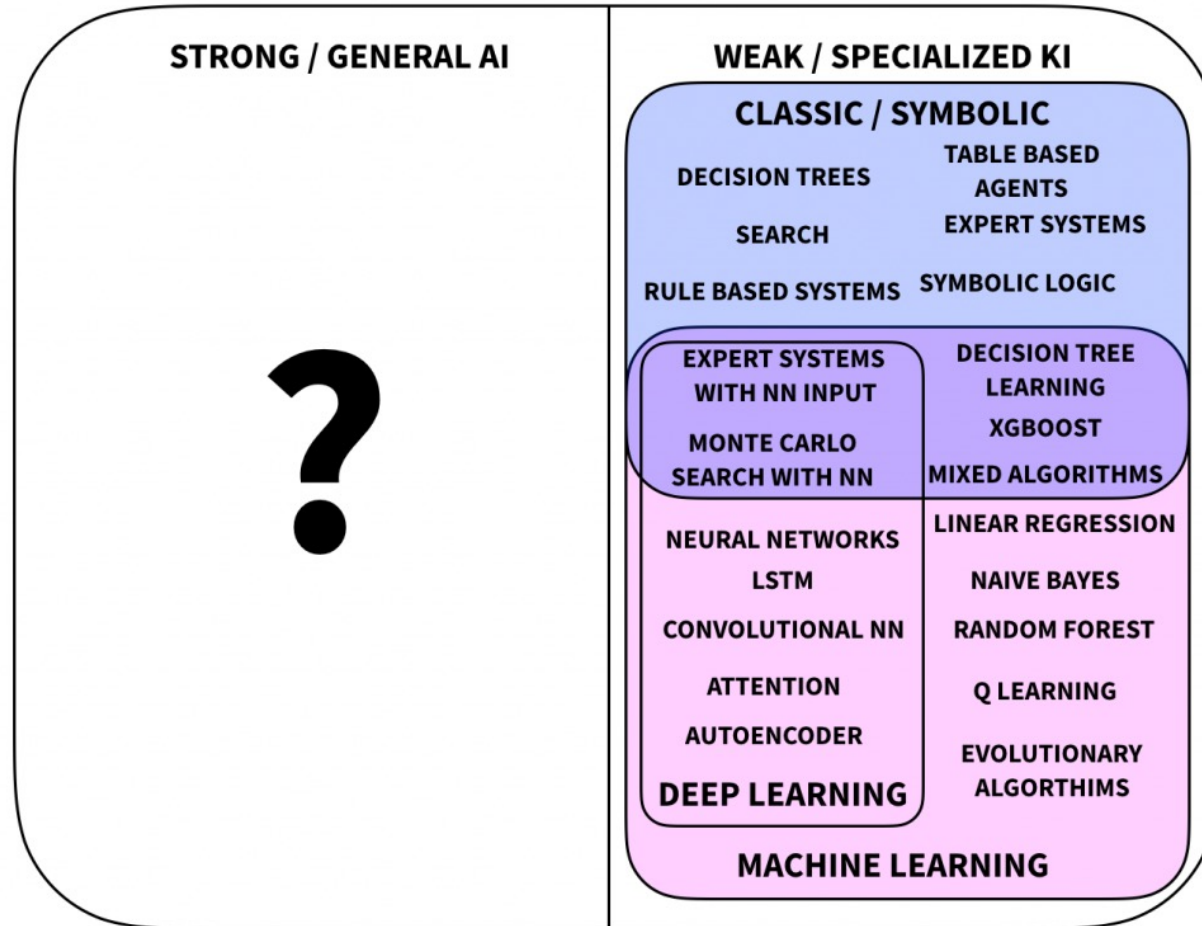


Systems that <b>think like humans</b>	Systems that <b>think rationally</b>
Systems that <b>act like humans</b>	Systems that <b><u>act rationally</u></b>

AI focus on **action**.  
 Avoids philosophical issues such as “is the system conscious” etc.

# AI Technologies

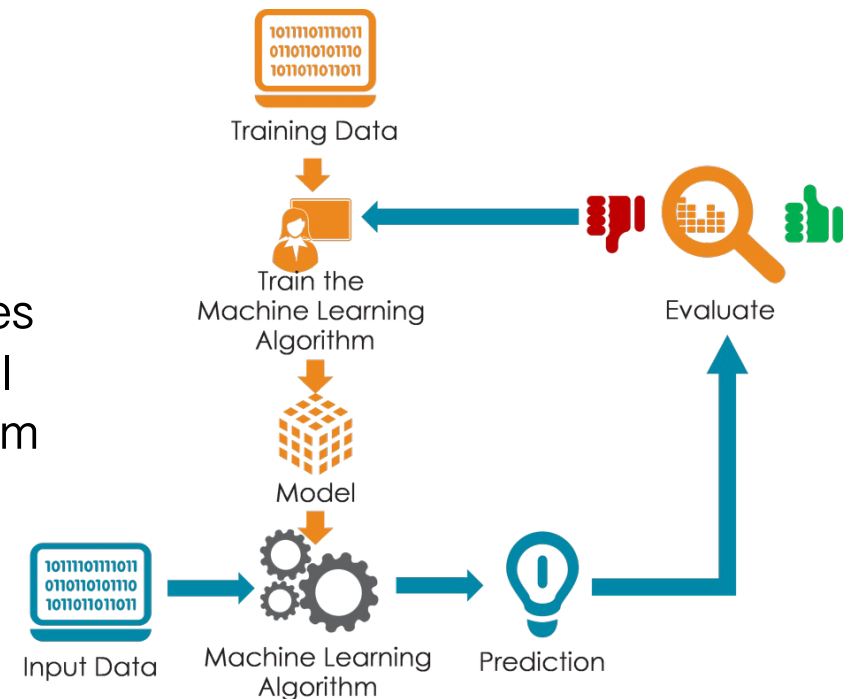
## AI TECHNOLOGIES



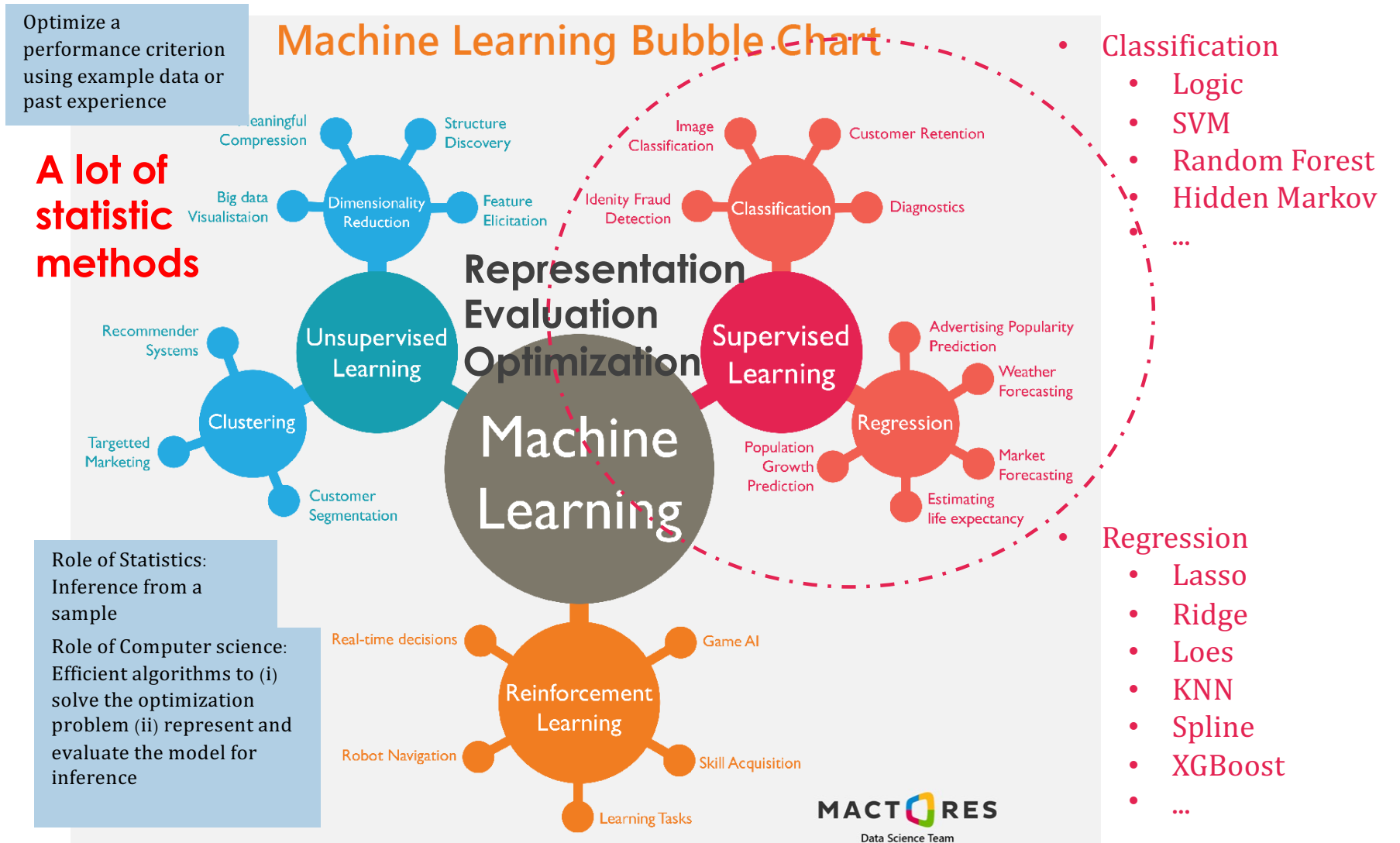


# Machine Learning

- ⦿ Develops Narrow Artificial Intelligence systems through examples
  - ⦿ A developer creates a model and then “trains” it by providing it with many examples
  - ⦿ The machine learning algorithm processes the examples and creates a mathematical representation of the data that can perform prediction and classification tasks
- ⦿ Example
  - ⦿ A machine-learning algorithm trained on thousands of bank transactions with their outcome (legitimate or fraudulent) will be able to predict if a new bank transaction is fraudulent or not

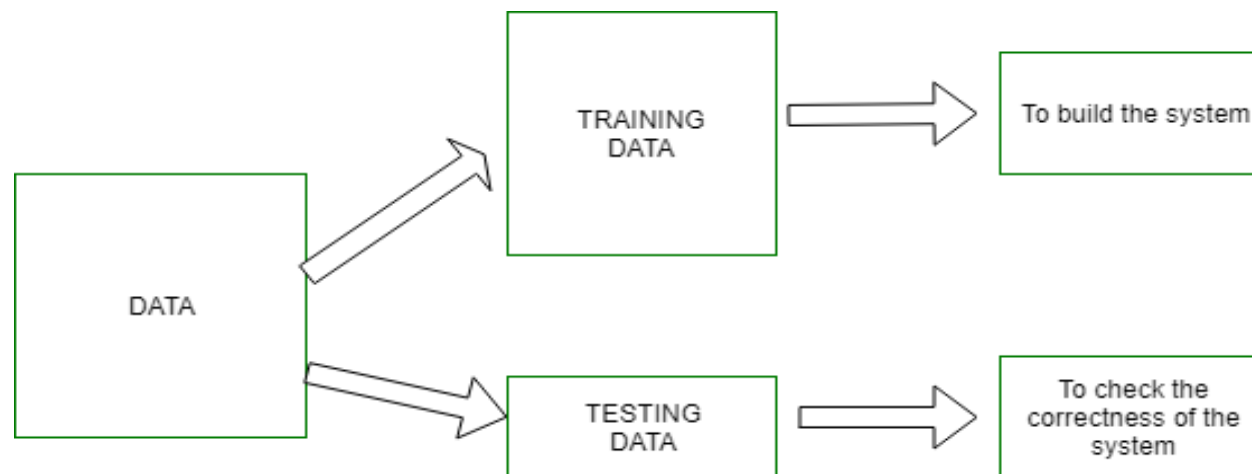


# Machine Learning Techniques



# Supervised Learning

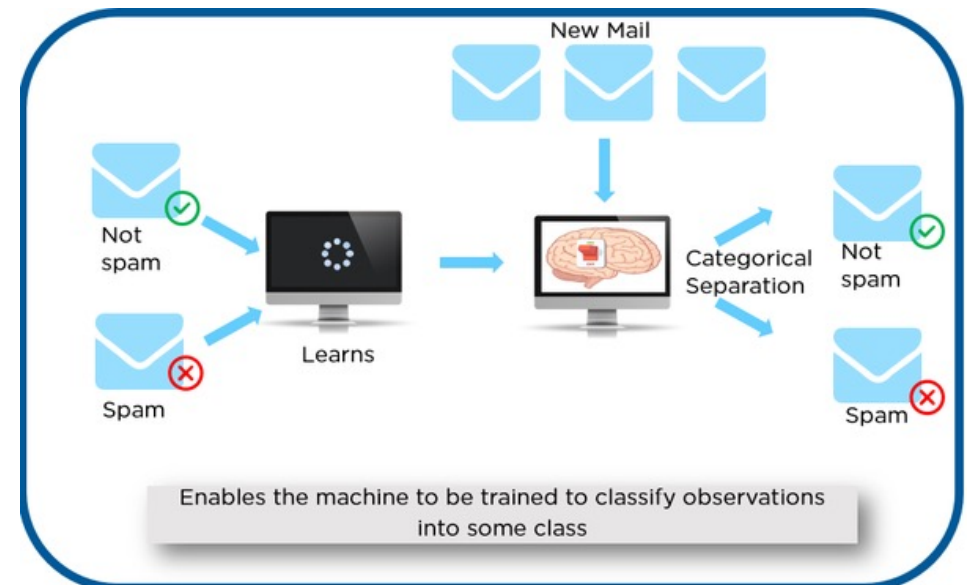
- ⦿ ML model is presented with *input data* which is labeled
  - ⦿ Each *input data* is tagged with the correct label.
- ⦿ The goal is to approximate math operations in the ML model so well that when presented with new *input data*, the ML model can **predict** the output variables for that *input data*.





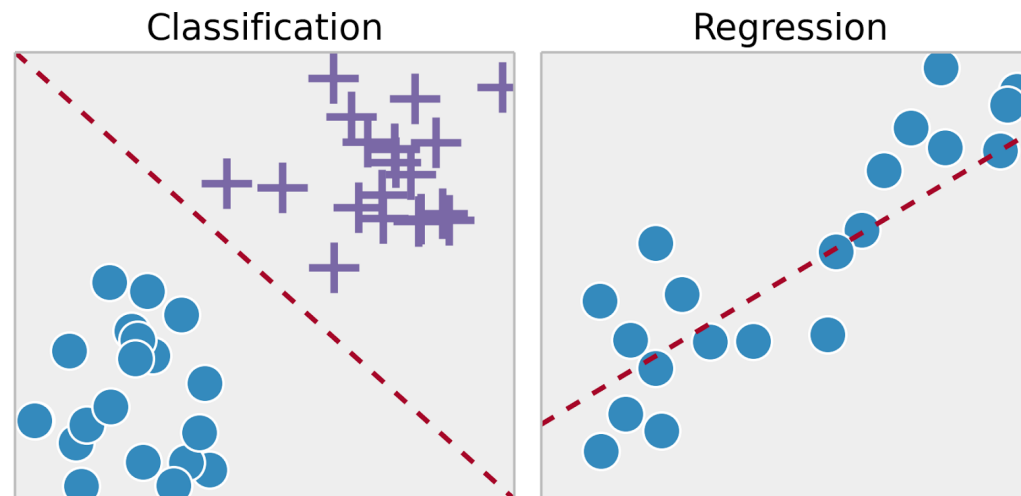
# Spam Mail Example

- On the left side of the image, some data is marked as ‘Spam’ or ‘Not Spam’. This is *labeled data*. This data is used to train the supervised model, the *intelligent* program (at center of the image).
- Trained model is tested with new mails (on the top of the image) and checking if the output of the supervised model is correct (on the right side of the image).



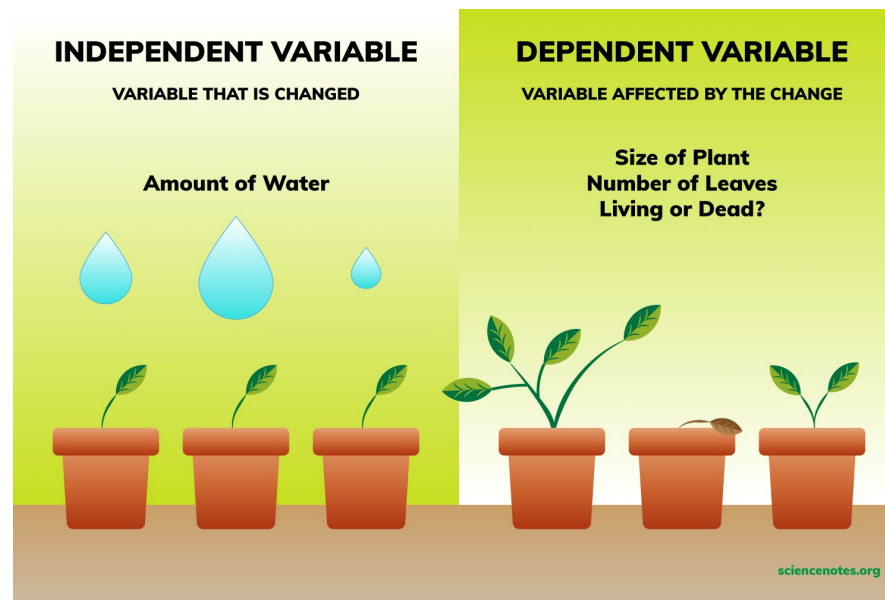
# Types of Supervised Learning

- ⦿ **Classification:** A classification problem is when the output is a category, such as “red” or “blue” or “disease” and “no disease”.
- ⦿ **Regression:** A regression problem is when the output is a real number, such as “dollars” or “weight”.



# Regression

- ⦿ **Dependent variables:** the main event or factor to understand or predict. Also known as *explanatory variable*.
- ⦿ **Independent variables:** the events or factors suspected to have an impact on the dependent variable. Also known as *response variable*.



# Types of Regression

- Simple regression:** single independent variable for a single dependent variable. It is very common to name the independent variable as  $x$  and  $Y$  as the dependent variable

$x$ : number of cricket chirps

$Y$ : temperature

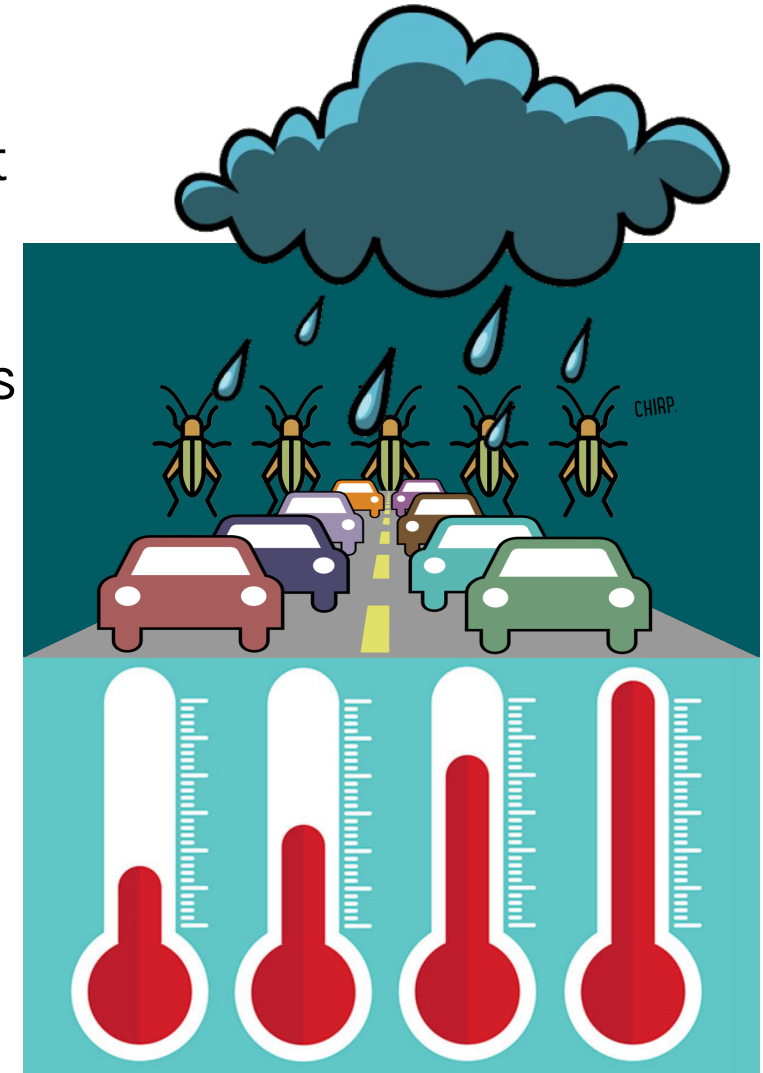
- Multivariable regression:** multiple independent variables,  $x_1, x_2, x_3$ , for a dependent variable  $Y$ .

$x_1$ : number of cricket chirps

$x_2$ : rainfall

$x_3$ : automobile traffic

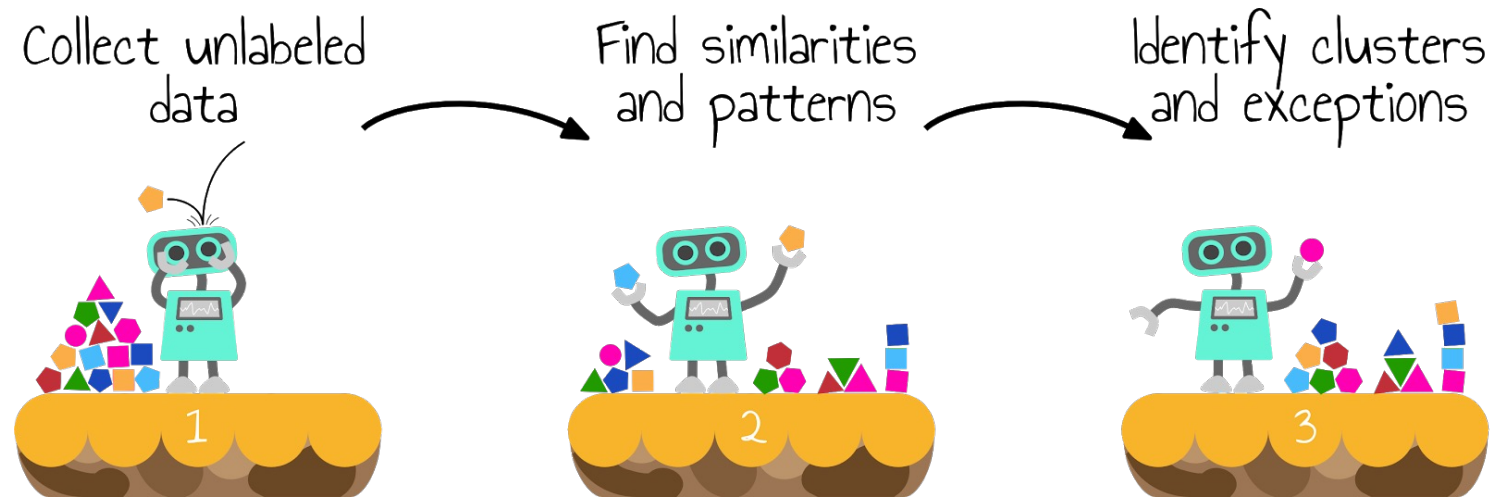
$Y$ : temperature





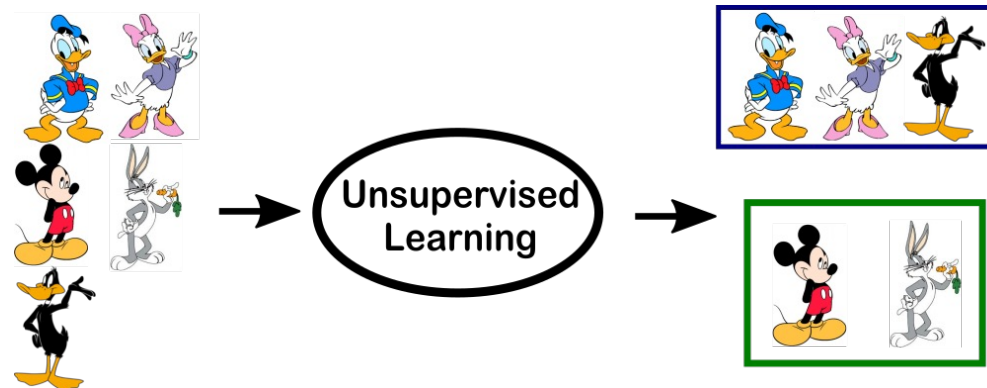
# Unsupervised Learning

- ⦿ ML model is presented with unlabeled, uncategorized data
- ⦿ ML model acts on the data without prior training.
- ⦿ The output is dependent upon the coded algorithms.
- ⦿ Is one way of testing AI.



# Ducks Example

- ⦿ In the below example, some cartoon characters are passed to the ML model. Some of them are ducks.
- ⦿ No data label provided.
- ⦿ ML model is able to separate the characters into ‘Duck’ and ‘No duck’ by looking at the type of data and models in the underlying data structure.

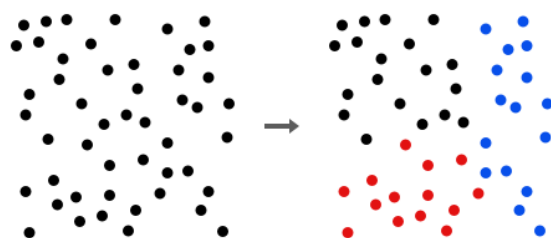


# Types of Unsupervised Learning

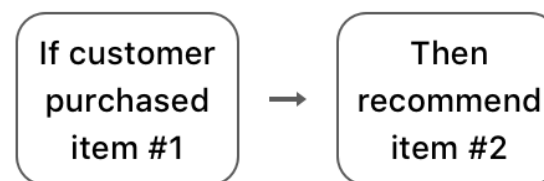
- ⦿ **Clustering:** Discovering the inherent groupings in the data, such as grouping customers by purchasing behavior.
- ⦿ **Association:** Discovering rules that describe large portions of the input data, such as people that buy X also tend to buy Y.

## UNSUPERVISED LEARNING

### Clustering



### Association



# Reinforcement Learning

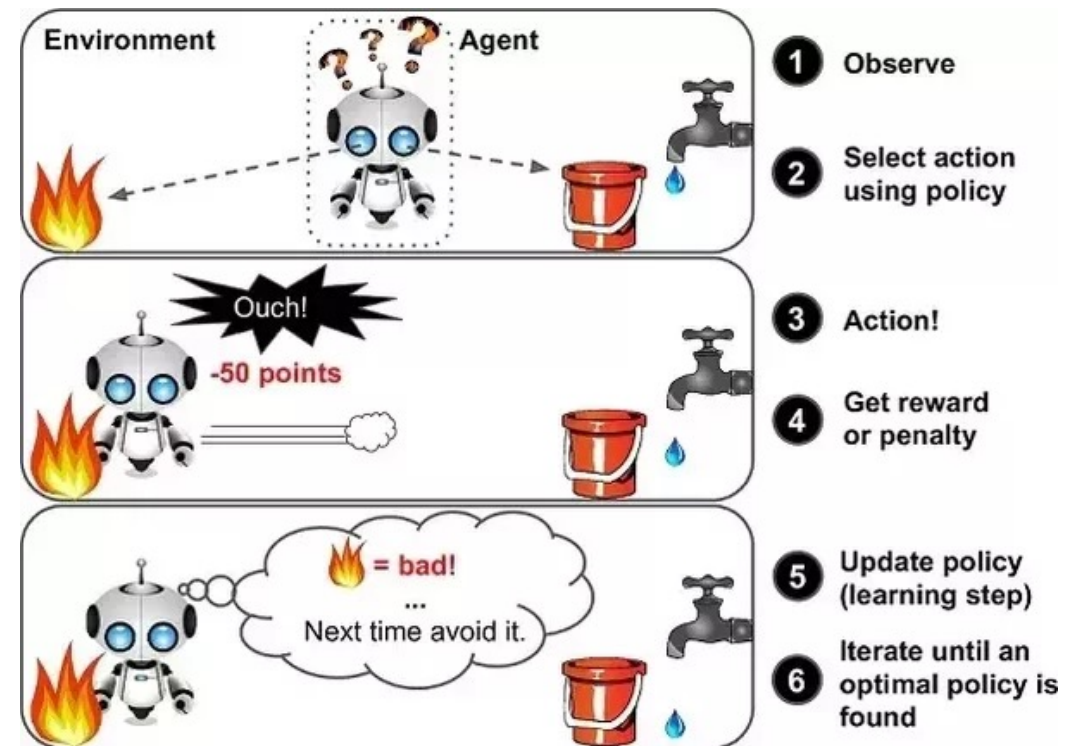
- ⦿ A reinforcement learning algorithm, or agent, learns by interacting with its environment.
- ⦿ The agent receives rewards by performing correctly and penalties for performing incorrectly.
- ⦿ The agent learns without intervention from a human by maximizing its reward and minimizing its penalty.
- ⦿ It is a type of dynamic programming that trains algorithms using a system of reward and punishment.





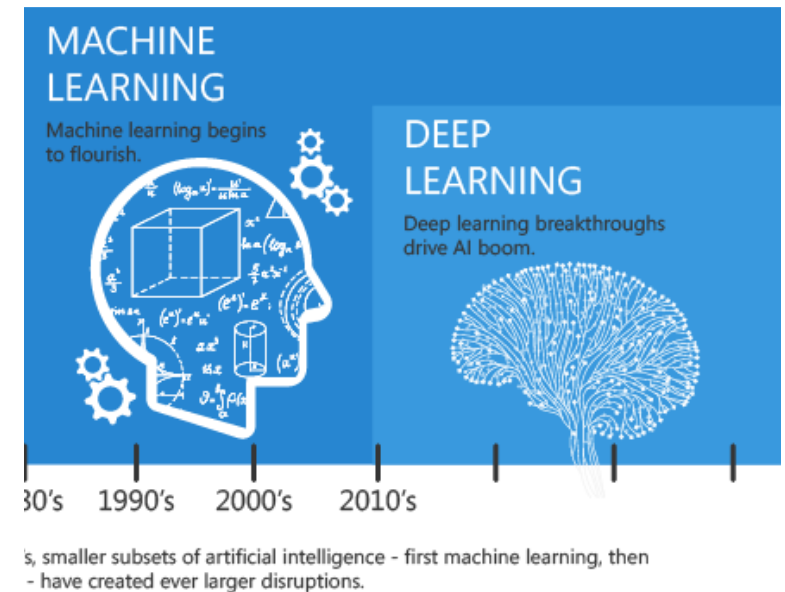
# Robot Path Example

- ⦿ The agent is given 2 options i.e. a path with water or a path with fire.
- ⦿ If agent takes the fire path then a penalty is subtracted
- ⦿ Agent learns it should avoid the fire paths.
- ⦿ If agent takes water path then some a reward is granted
- ⦿ Agent learns what path is safe and what path isn't.



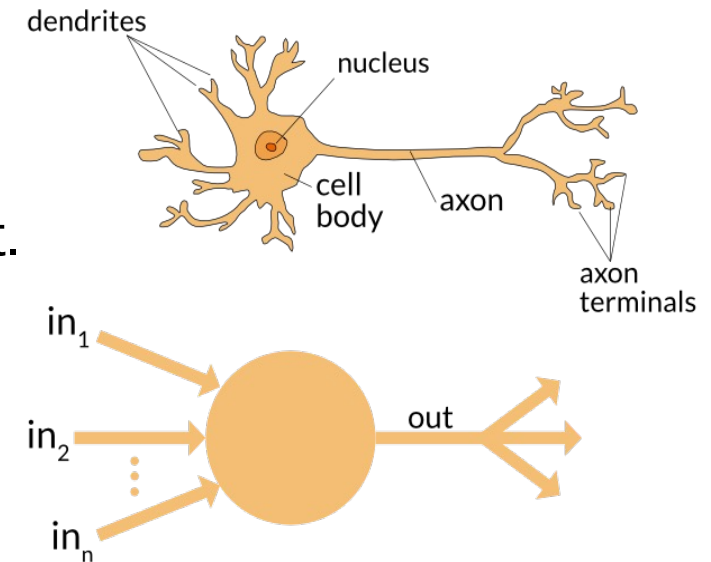
# Beyonds Machine Learning?

- ⦿ Combines advances in computing power and special types of **Neural Networks** to learn complicated patterns in large amounts of data
- ⦿ State of the art for identifying objects in images and words in sounds
- ⦿ Applied successes in pattern recognition to more complex tasks such as automatic language translation, medical diagnoses and numerous other important social and business problems



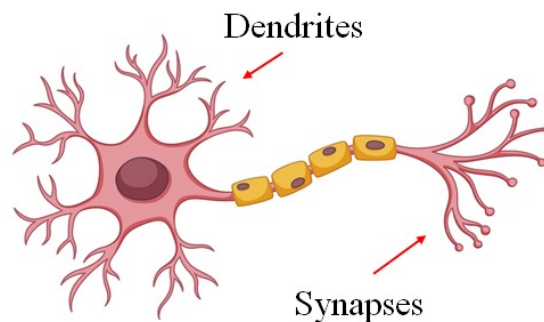
# Neural Networks: the Perceptron

- ⦿ Mathematical representation of a biological neuron
- ⦿ First implementation by Frank Rosenblatt in the 1950s
- ⦿ Rosenblatt's perceptron is activated when there is sufficient stimuli or input. (Neurons have been found to perform a similar process, in which experience strengthens or weakens dendrites' connections)

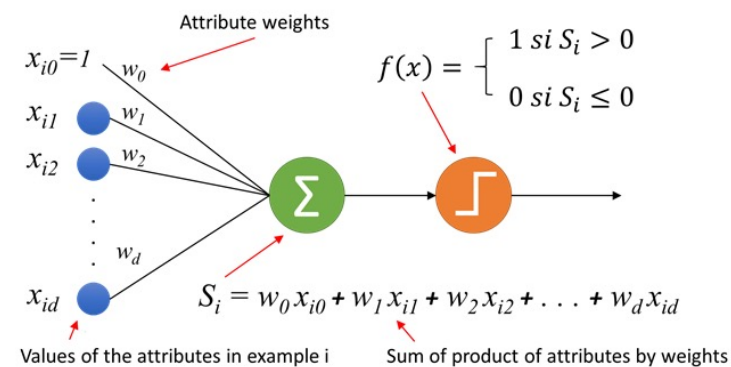


# How does a Perceptron Work?

- Perceptron receives the value of the attributes of an input, just as dendrites do in a neuron.
- Each attribute has a **weight** that measures its *contribution* to the final result, which is the sum of the multiplications of inputs of each attribute by its corresponding weight.
- If the sum is greater than zero Perceptron returns a value of 1, otherwise it yields 0.



NEURON

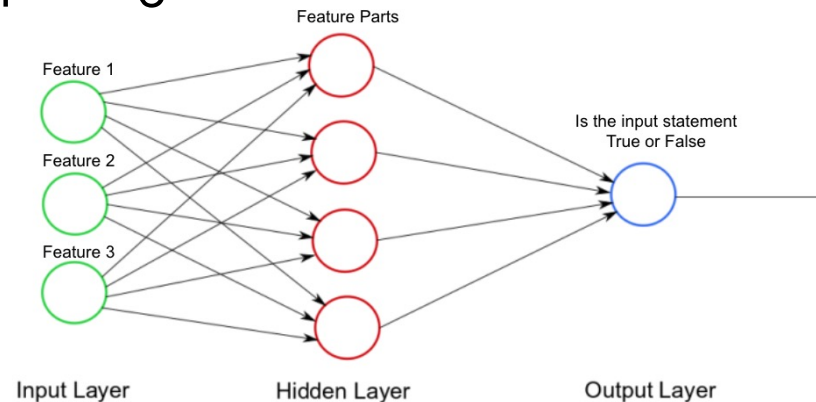


PERCEPTRON



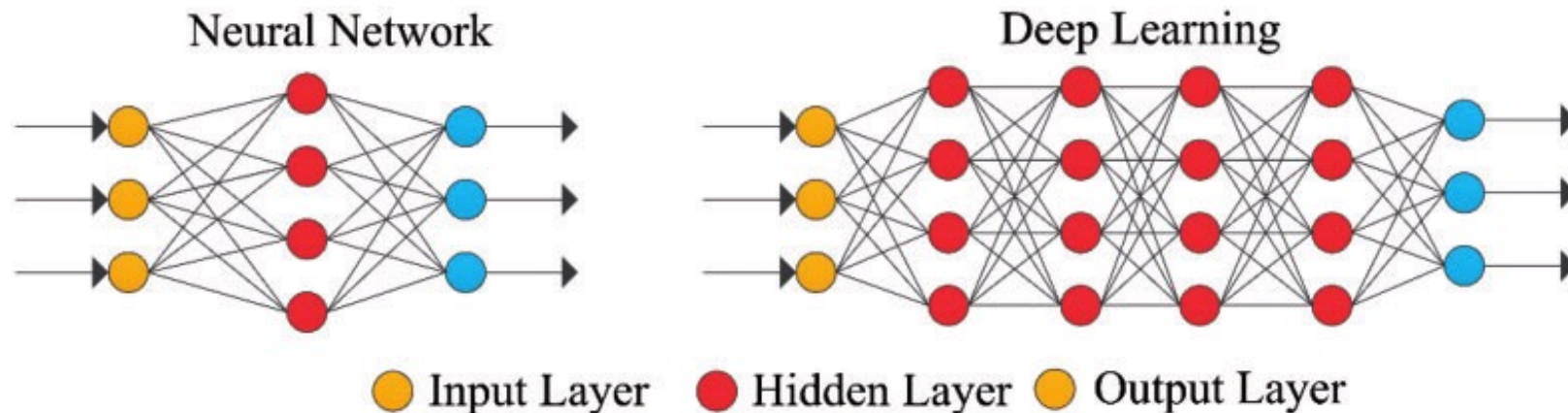
# Neural Networks

- ⦿ Neurons by themselves are kind of useless, in large groups, they work together to create some serious magic!
- ⦿ Neural Networks are no more than a **stacking** of multiple *perceptrons* in layers to produce an output.
- ⦿ Input into one layer that creates an output which in turn becomes the input for the next layer, and so on. This happens until the final output signal.



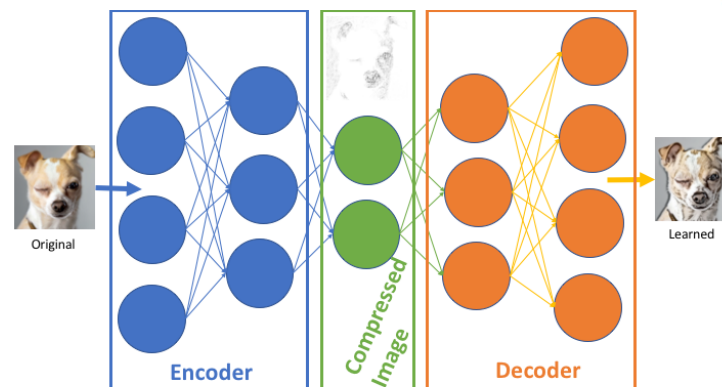
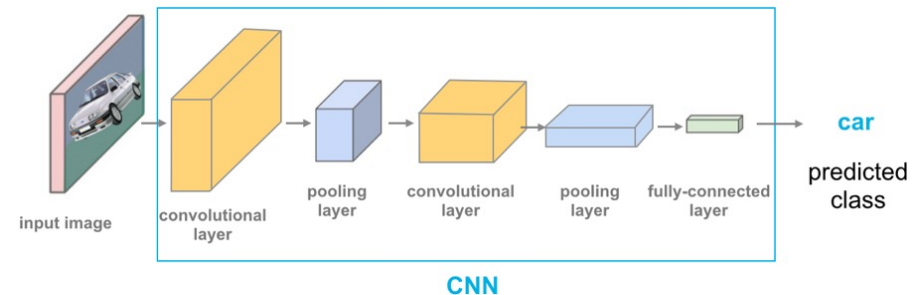
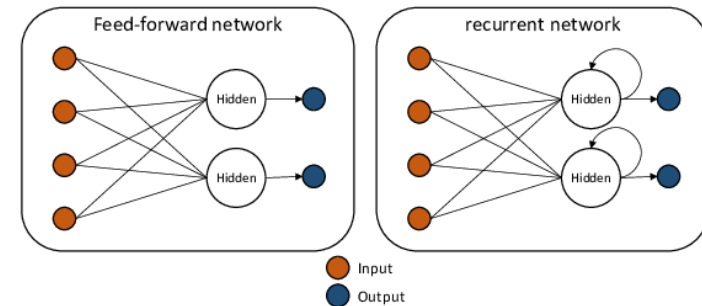
# Deep Neural Networks

- ⦿ In the 1980s, most Artificial Neural Networks (**ANN**) were single-layered due to the cost of computation and availability of data.
- ⦿ Nowadays is possible to afford more hidden layers in ANN, hence the moniker “Deep Neural Networks” (**DNN**).
- ⦿ Regained popularity since ~2006.
- ⦿ Rebranded field as Deep Learning (**DL**)



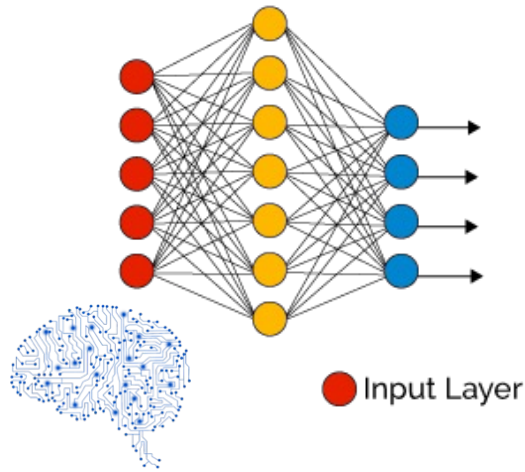
# Types of Deep Neural Networks

- Feedforward Neural Networks (**FFNs, ANNs** or **NNs**)
- Recurrent Neural Networks (**RNNs**)
- Convolutional Neural Networks (**CNNs**)
- Autoencoder Neural Networks (**AEs**)



# CNN success thanks to GAFA

Simple Neural Network

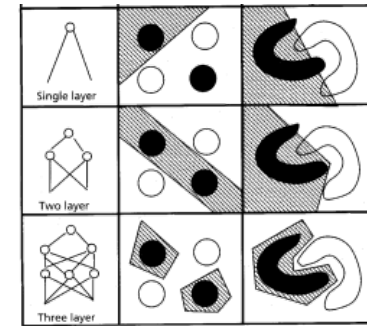
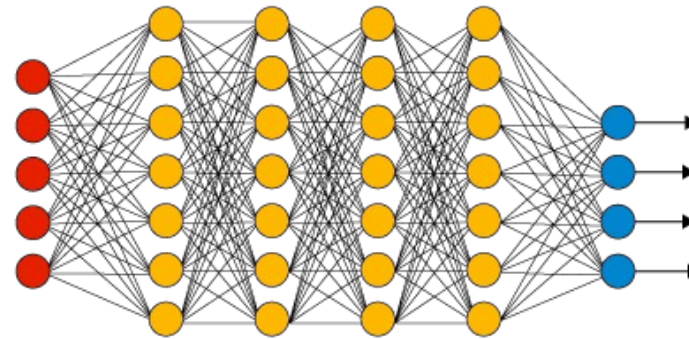


● Input Layer

● Hidden Layer

● Output Layer

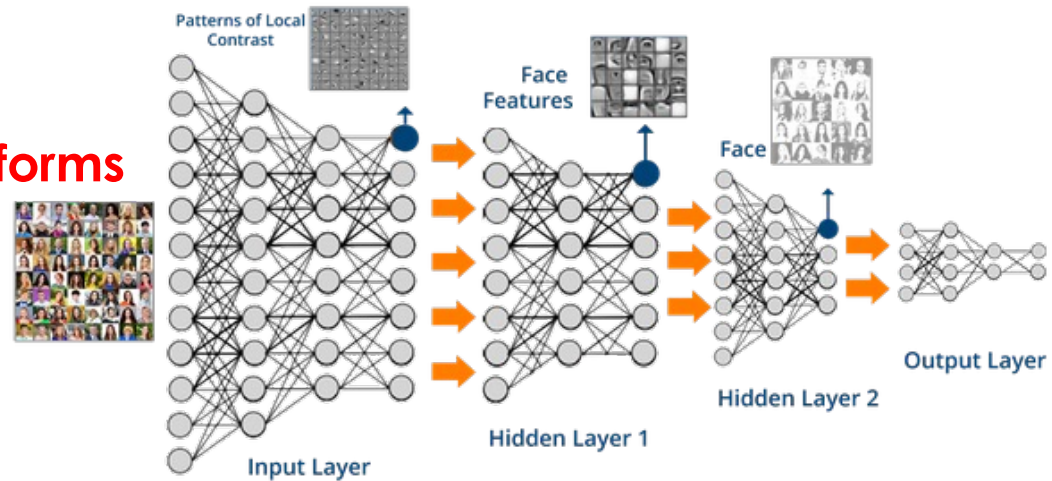
Deep Learning Neural Network



(Jain, 1996)

**Voice/Face/Patterns recognition on many platforms**

- Facebook
- Google Photos
- Twitter
- Siri
- ...

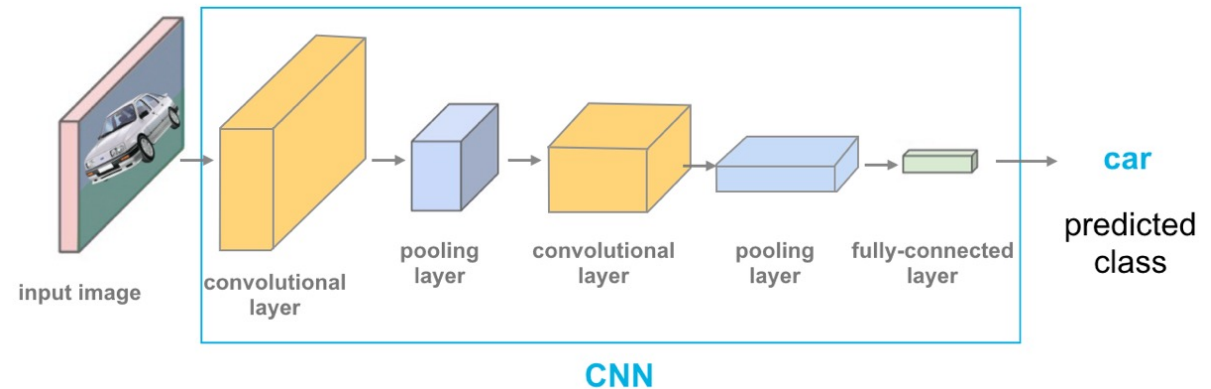




# Convolutional Neural Networks

- Contain five types of layers:

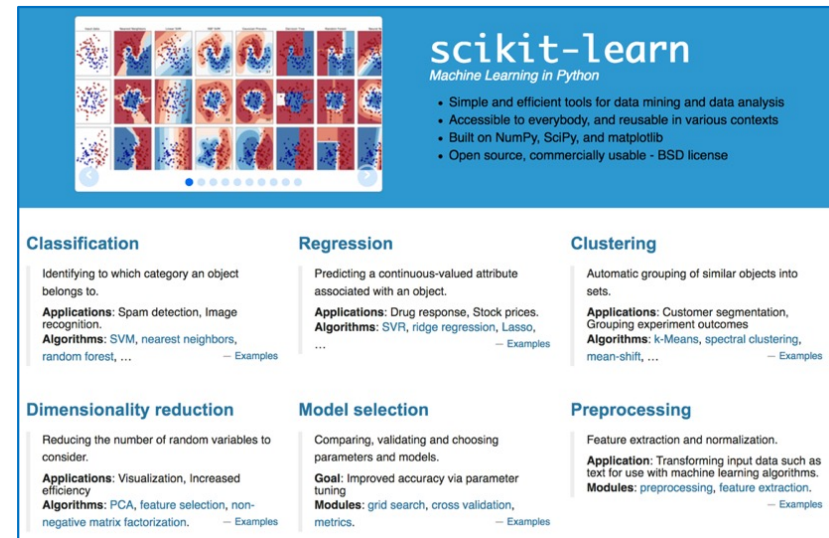
- Input
- Convolution
- Pooling
- Fully connected
- Output.



- Each layer has a specific purpose, like summarizing, connecting or activating.
- CNN have popularized image classification and object detection.
- Also applied to other areas, such as natural language processing and forecasting.

# Machine/Deep Learning for scientists

- ⦿ Large variety of supported languages
  - ⦿ Python, R, C++, Java, Scala, Javascript, Go, ...
- ⦿ Many statistical methods/algorithms are implemented in libraries
- ⦿ Examples
  - ⦿ Scikit-learn
  - ⦿ Google TensorFlow
  - ⦿ Microsoft Distributed Machine Learning Toolkit
  - ⦿ Apache Mahout
  - ⦿ ...
- ⦿ But, beware
  - ⦿ There are hundredth of tools...
  - ⦿ ...and new tools every months!



**scikit-learn**  
Machine Learning in Python

- Simple and efficient tools for data mining and data analysis
- Accessible to everybody, and reusable in various contexts
- Built on NumPy, SciPy, and matplotlib
- Open source, commercially usable - BSD license

Classification	Regression	Clustering
Identifying to which category an object belongs to. <b>Applications:</b> Spam detection, Image recognition. <b>Algorithms:</b> SVM, nearest neighbors, random forest, ...	Predicting a continuous-valued attribute associated with an object. <b>Applications:</b> Drug response, Stock prices. <b>Algorithms:</b> SVR, ridge regression, Lasso, ...	Automatic grouping of similar objects into sets. <b>Applications:</b> Customer segmentation, Grouping experiment outcomes <b>Algorithms:</b> k-Means, spectral clustering, mean-shift, ...
Dimensionality reduction	Model selection	Preprocessing
Reducing the number of random variables to consider. <b>Applications:</b> Visualization, Increased efficiency <b>Algorithms:</b> PCA, feature selection, non-negative matrix factorization. ...	Comparing, validating and choosing parameters and models. <b>Goal:</b> Improved accuracy via parameter tuning <b>Modules:</b> grid search, cross validation, metrics. ...	Feature extraction and normalization. <b>Application:</b> Transforming input data such as text for use with machine learning algorithms. <b>Modules:</b> preprocessing, feature extraction. ...

# Want to try DeepLearning?

🕒 <https://playground.tensorflow.org/>

Tinker With a **Neural Network** Right Here in Your Browser.  
Don't Worry, You Can't Break It. We Promise.

The screenshot shows the TensorFlow Playground interface. At the top, there are controls for Epoch (000,000), Learning rate (0.03), Activation (Tanh), Regularization (None), Regularization rate (0), and Problem type (Classification). Below this, the interface is divided into several sections:

- DATA:** Which dataset do you want to use? (Icons for various datasets)
- FEATURES:** Which properties do you want to feed in? (List of features:  $X_1$ ,  $X_2$ ,  $X_1^2$ ,  $X_2^2$ ,  $X_1X_2$ ,  $\sin(X_1)$ ,  $\sin(X_2)$ )
- NEURAL NETWORK:** A diagram showing 2 HIDDEN LAYERS. The first hidden layer has 4 neurons, and the second has 2 neurons. Lines of varying thickness represent weights between neurons.
- OUTPUT:** Test loss 0.522, Training loss 0.508. A scatter plot showing data points (orange and blue) and neuron/weight values (color scale from -1 to 1).

Annotations in the diagram include: "The outputs are mixed with varying weights, shown by the thickness of the lines." and "This is the output from one neuron. Hover to see it larger."

INTEL-IRRIS

A PRIMA PROJECT FOR LOW-COST  
SMART IRRIGATION

OBJECTIVES

METHODOLOGY

CONSORTIUM

PILOTS

# INTEL-IRRIS

Intelligent Irrigation System for Low-cost Autonomous Water Control  
in Small-scale Agriculture

## IOT+AI ILLUSTRATION





# Smallholders & Smart Agriculture?



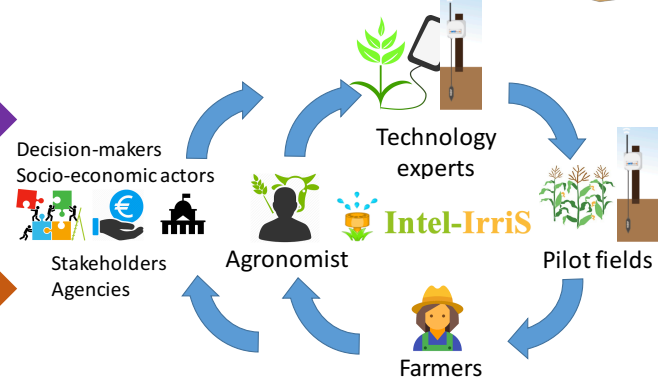
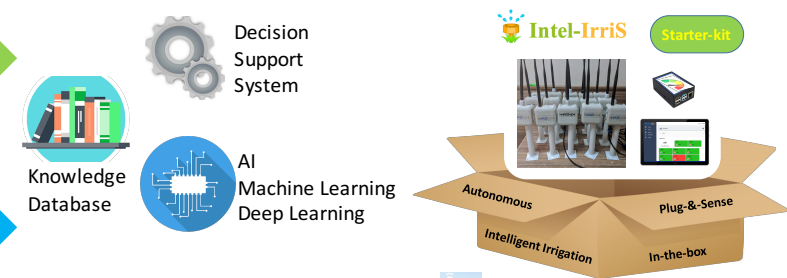
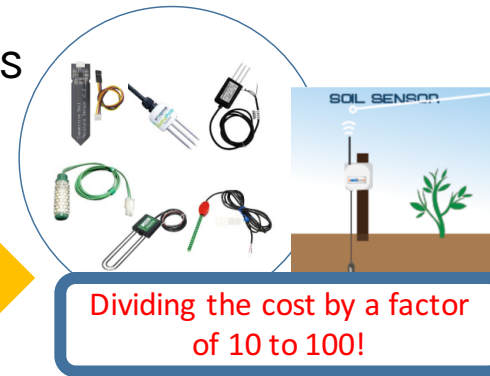
Too expensive  
Too integrated  
Highly specialized  
Difficult to customize  
Difficult to upgrade



# Illustration with Intel-IrriS

## Intelligent Irrigation System for Low-cost Autonomous Water Control in Small-scale Agriculture

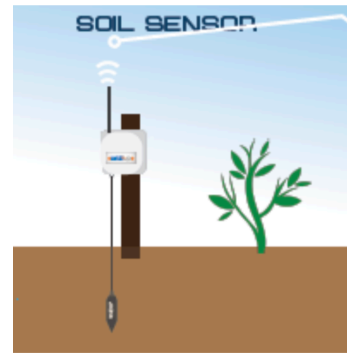
- 1** Propose low cost but highly efficient water control systems for irrigation optimization
- 2** Use cutting-edge technologies to propose highly innovative systems yet simple to deploy and adapted to smallholders
- 3** Seamless integration into existing irrigation system and/or local customs and practices
- 4** Improve farmer's knowledge on water-related issues, foster local adaptation of technologies, increase local innovation capacity and facilitate technology appropriation
- 5** Large-scale adoption of low cost smart irrigation system by smallholders, stimulating synergies between various local actors



# Low-cost sensors: accuracy?

Sensor part

Intel-IrriS



- Build on low-cost, low-power IoT expertise
- Increase accuracy of low-cost sensors by **advanced calibration**
- Enable deployment of several complementary low-cost sensors: soil conductivity, volumetric water content, ...
- Include **agricultural models / knowledge with corrective & predictive analytics**



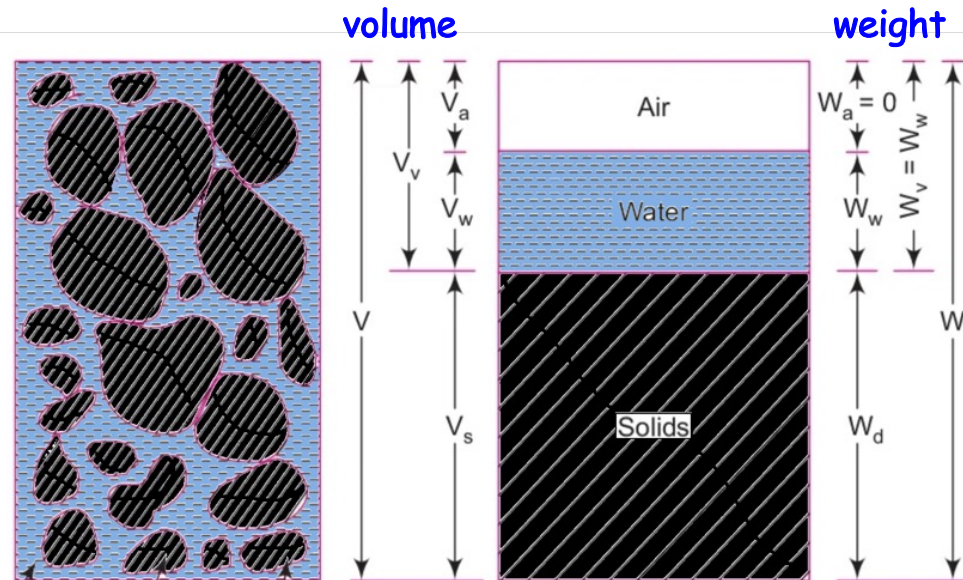
# Understanding soil water

Source: Christian Hartmann, IRD

- Low-cost sensors usually measure soil water content
- Soil = a pile of aggregates → 3 phases: solid + air & water

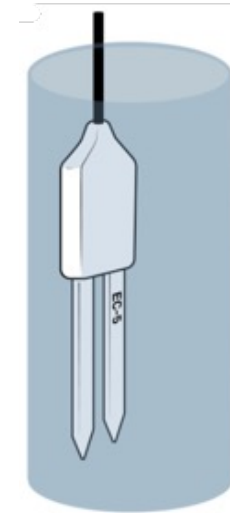
Geometry of the aggregates & pores

Schematical view of the 3 phases



Saturated soil

## water volume capacitive sensors



Decagon EC5  
**120 euros**

accurate



Gravity SEN193  
**6 euros**

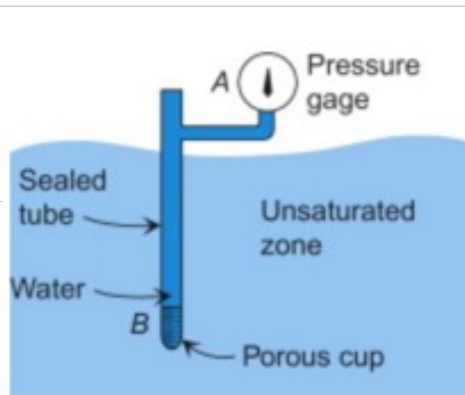
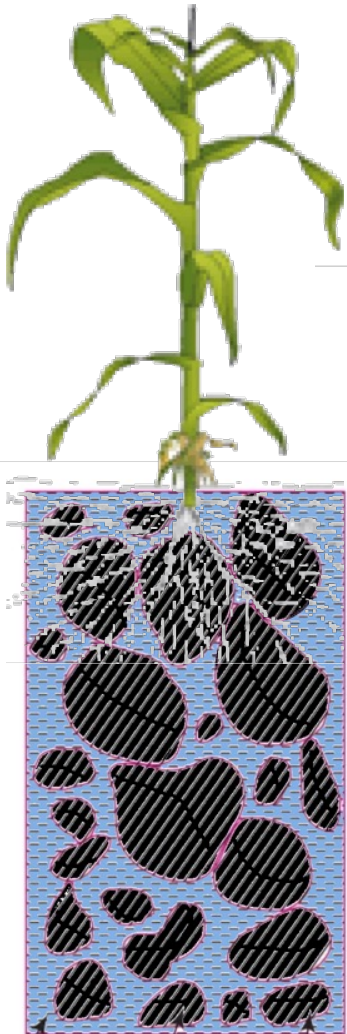
under test



# Soil water? Not enough!

Source: Christian Hartmann, IRD

- in the soil, the water is UNDER TENSION = it is hold by CAPILLARY FORCES
- Water tension is also needed!



SDEC  
100 euros



WATERMARK  
40 euros

IRD  
< 5 euros?



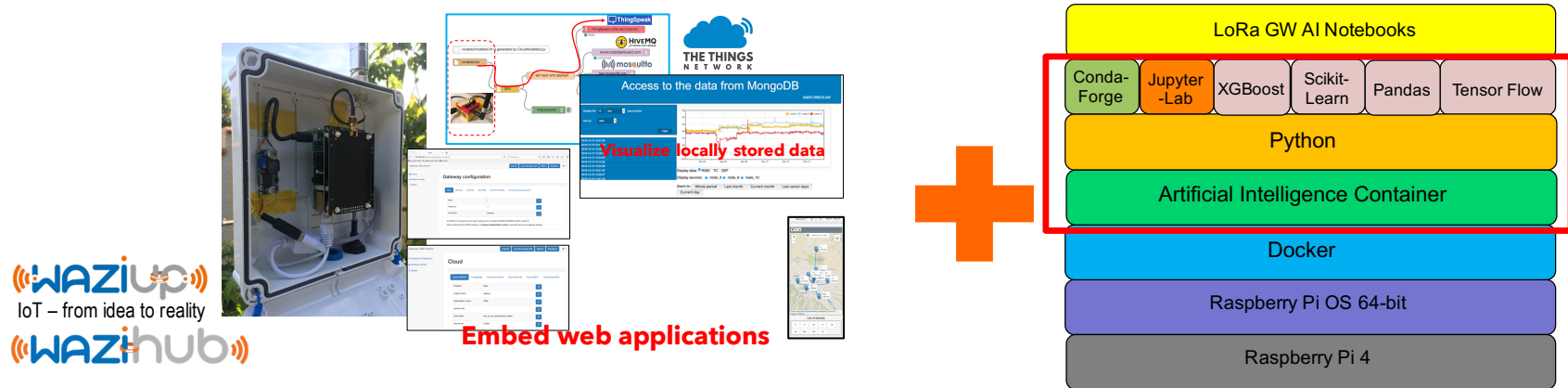
# Smart embedded control

- Build on low-cost embedded & open IoT gateway expertise
- Implement the “Intelligent Irrigation in-the-box” vision
- Model **complex interactions**: water-soil-plant interaction, evapotranspiration,...
- Embed **Decision Support System (DSS)** and **disruptive Artificial Intelligence (AI)**
- Integration of **multiple knowledge streams**
- Fully **autonomous**

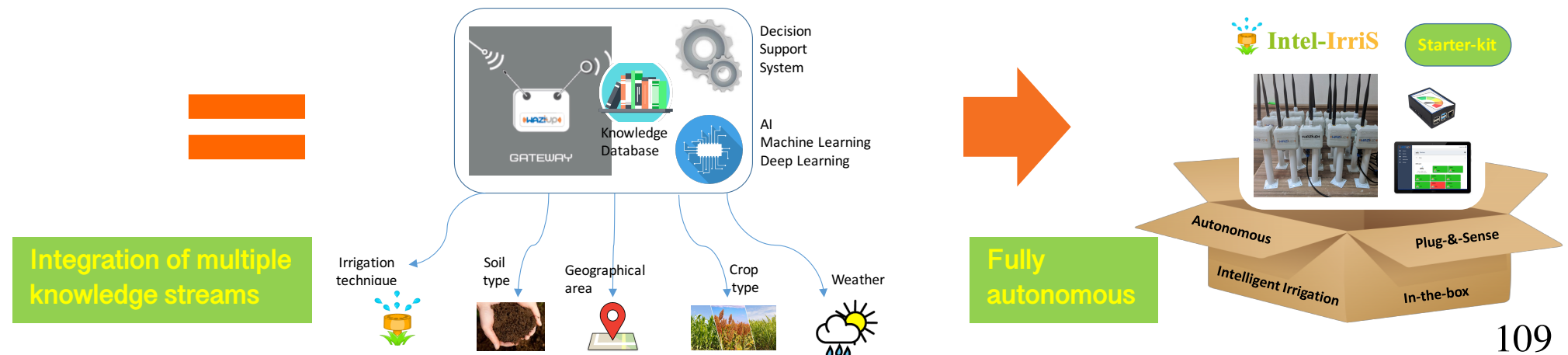


# Edge-AI for fully autonomous system

- Embed every thing on the IoT gateway to provide a fully autonomous system for the "Intelligent Irrigation-in-the-box"



  
IoT – from idea to reality  





# Edge-AI integration



Gateway Web Admin WAZIUP 2021-05-15T19:31:19 [offline] Test

## Cloud

Cloud WAZIUP ThingSpeak Cloud No Internet Cloud Gps File Cloud MQTT Cloud Node-RED

When enabling a new cloud, you need to reboot for changes to take effect.  
It is possible to change a cloud parameter at run-time although it is recommended to reboot.  
Date/Time: 2021-05-15T19:31:19  
**no upload with CloudWAZIUPpy found**

Enabled [server offline]

project name

organization name

service tree

username

password

Gateway Web Admin WAZIUP 2021-05-15T21:17:54 [offline] Test Internet pkt logger Reboot Shutdown

File Edit View Run Kernel Tabs Settings Help

WAZIUP Competition

Name	Last Modified
predictions	9 months ago
Wazihub_competition.ipynb.invalid	9 months ago
Wazihub_competition.ipynb	a day ago
Wazihub_competition_workingcopy.py	9 months ago
Wazihub_competition_workingcopy.nbc...	9 months ago
Wazihub_competition_workingcopy.ipynb	9 months ago
Wazihub_competition_save_model.ipynb	9 months ago
Wazihub_competition_process_time.ipy...	9 months ago
Wazihub_competition_perf_counter.ipynb	9 months ago
Wazihub_competition_load_predict.ipynb	9 months ago
Wazihub_competition_fetch_predict.py	9 months ago
Wazihub_competition_fetch_predict.ipy...	9 months ago
Wazihub_competition_fetch_predict_be...	9 months ago
VariableDefinitions.csv	10 months ago
Train.csv	10 months ago
submission.csv	9 months ago
SampleSubmission.csv	10 months ago
populate_mongo.ipynb	9 months ago
list_coll_mongo.ipynb	9 months ago
Hamadi_field4.model	9 months ago
Hamadi_field3.model	9 months ago
Hamadi_field2.model	9 months ago

```
[1]: #matplotlib notebook
      %matplotlib inline
      %matplotlib widget
      import pandas as pd
      from numpy import array
      import numpy as np
      import math
      from xgboost import XGBRegressor
      from sklearn.metrics import mean_absolute_error
      from sklearn.model_selection import train_test_split
      from sklearn.impute import SimpleImputer
      import matplotlib.pyplot as plt
```

Gateway Web Admin WAZIUP 2021-05-15T21:17:54 [offline] Test Internet pkt logger Reboot Shutdown

File Edit View Run Kernel Tabs Settings Help

WAZIUP Competition

Name	Last Modified
predictions	9 months ago
Wazihub_competition.ipynb.invalid	9 months ago
Wazihub_competition.ipynb	a day ago
Wazihub_competition_workingcopy.py	9 months ago
Wazihub_competition_workingcopy.nbc...	9 months ago
Wazihub_competition_workingcopy.ipynb	9 months ago
Wazihub_competition_save_model.ipynb	9 months ago
Wazihub_competition_process_time.ipy...	9 months ago
Wazihub_competition_perf_counter.ipynb	9 months ago
Wazihub_competition_load_predict.ipynb	9 months ago
Wazihub_competition_fetch_predict.py	9 months ago
Wazihub_competition_fetch_predict.ipy...	9 months ago
Wazihub_competition_fetch_predict_be...	9 months ago
VariableDefinitions.csv	10 months ago
Train.csv	10 months ago
submission.csv	9 months ago
SampleSubmission.csv	10 months ago
populate_mongo.ipynb	9 months ago
list_coll_mongo.ipynb	9 months ago
Hamadi_field4.model	9 months ago
Hamadi_field3.model	9 months ago
Hamadi_field2.model	9 months ago

```
[2]: init = time.perf_counter()
      # Read Training data
      train = pd.read_csv('Train.csv')
      # Plot Training data
      plt.plot(train.index, train[['Soil humidity 2', 'Irrigation field 2']])
      plt.show()
      data_io.append(time.perf_counter() - init)
```

```
[3]: init = time.perf_counter()
      # Extract pressures
      pressure_list = train['Pressure (KPa)'].tolist()
      pressure_list_without_nan = []
```

Prof. Congduc Pham  
<http://www.univ-pau.fr/~cpham>





# Conclusions

- Internet-of-Things provides the unique feature to make things "talk" to us: localisation, surrounding environmental conditions, particular events, ...
- It has huge potential into helping humanity to reach the UN SDG (Sustainable Development Goals)
- With more complex sensors such as cameras, spectrometers, hyperspectral cameras,... we can get better knowledge to further optimize a number of processes for sustainable development
- LIUPPA works for more than 8 years to develop & deploy low-cost IoT in Africa with 4 EU H2020/PRIMA projects



# IOT Online Course

## Fundamentals of IoT

Continue with

F-IOT-2c: Introduction to IoT hardware



IoT – from idea to reality

