IOT_2: Unleash the power of IoT data

protocols, analysis, artificial intelligence, machine learning,...

Booster Pau – Learning Capsule – 2022

Prof. Congduc Pham

http://cpham.perso.univ-pau.fr

IoT – from idea to reality

Paving for the next 10 years of innovation in IoT and AI

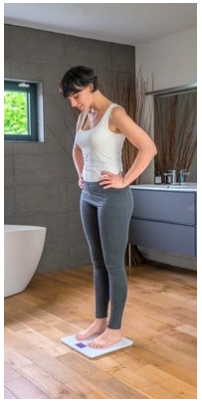
BoosterPau program

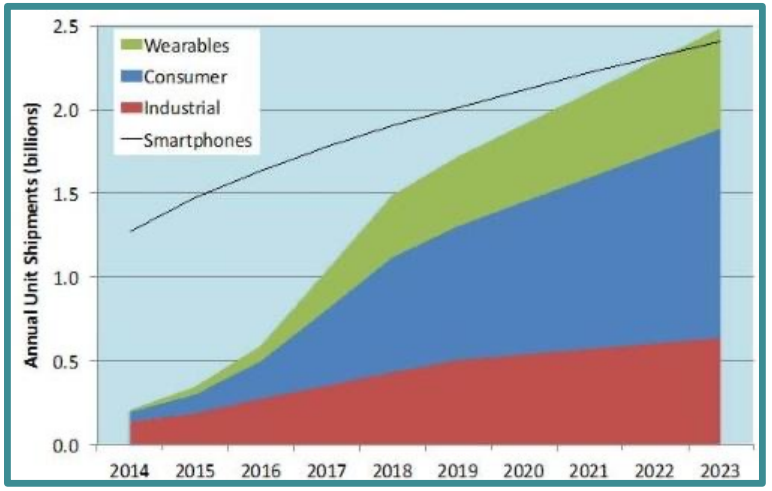
IOT

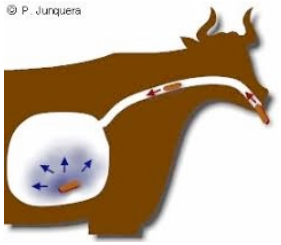
TECHNOLOGY ?

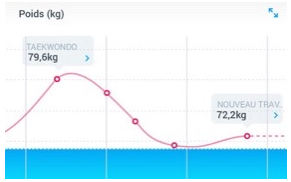
CONCEPT ?

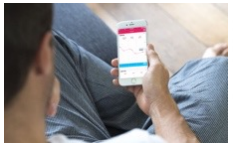
IoT=communicating objects











IoT=interactions with physical world

IoT added-values come from interactions and linked data!

Sense, Monitor, Optimize & Control

DATA ANALYSIS, OPTIMIZATION & CONTROL

Monitoring

Sensing
Physical world interaction

APPLICATION DOMAINS

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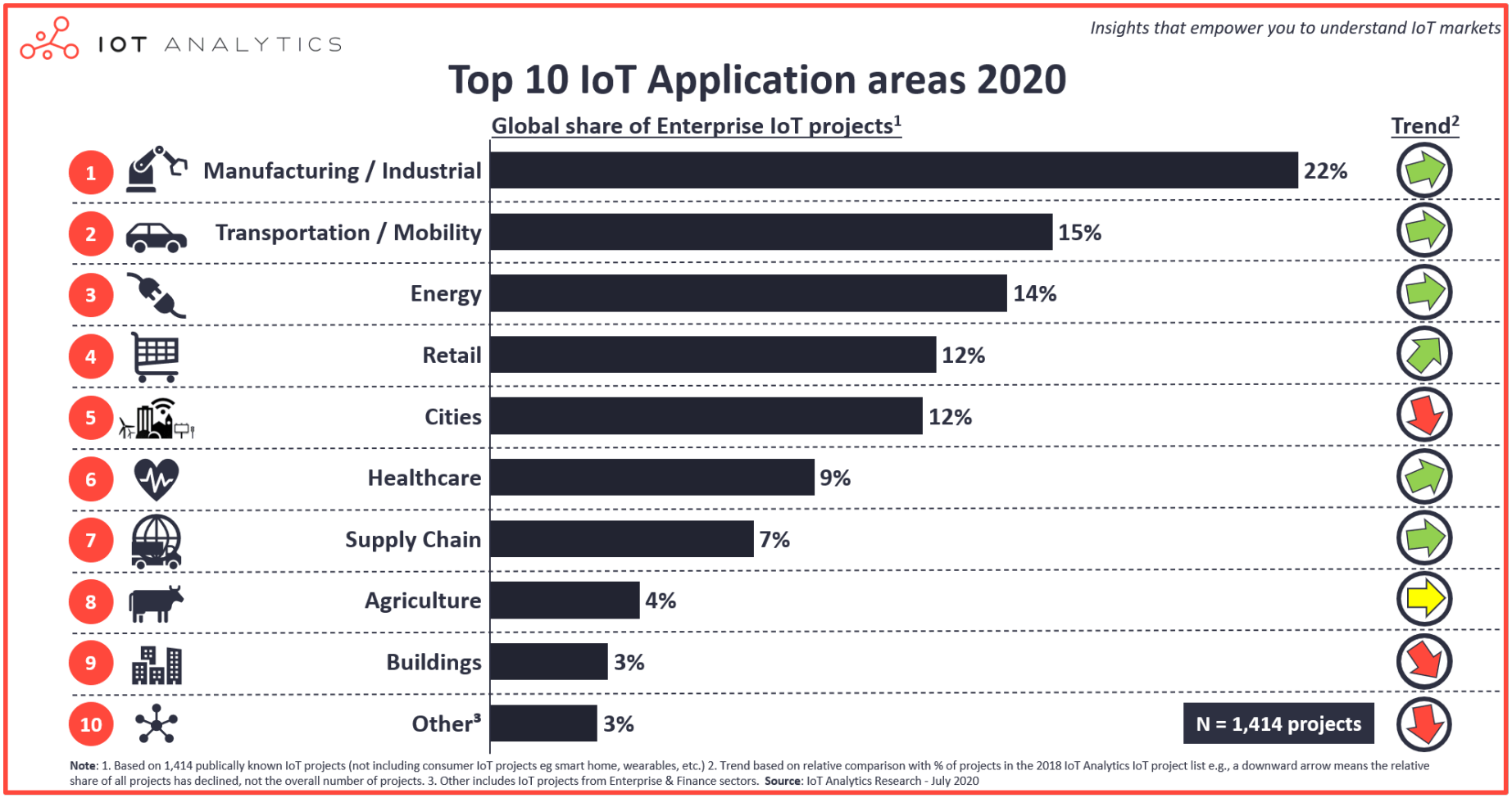
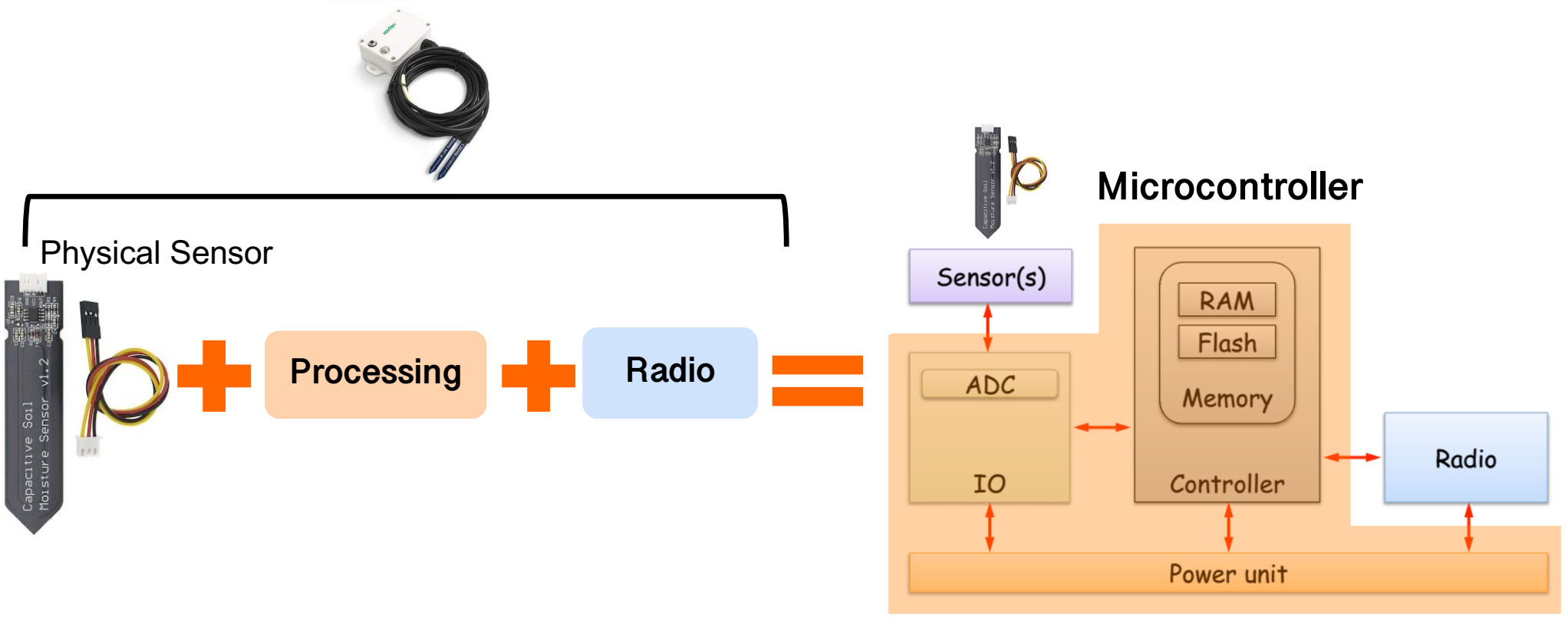
Top IoT applications, 2020



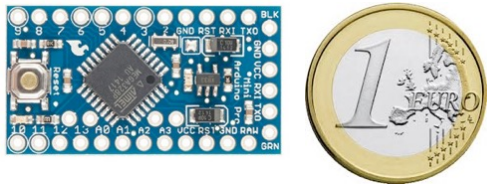
Typical IoT device

- IoT device can be viewed as a simple Embedded System



Low-cost microcontroller boards

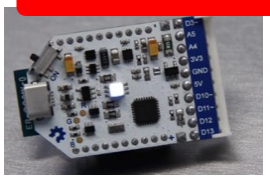
Arduino Pro Mini



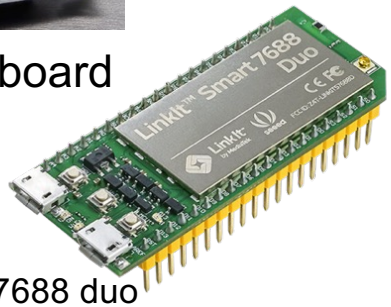
LoPy

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

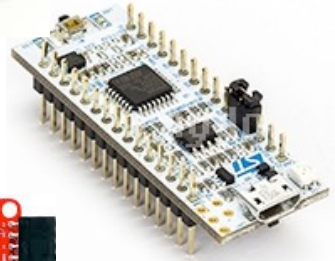


LinkIt Smart7688 duo

Expressif ESP32

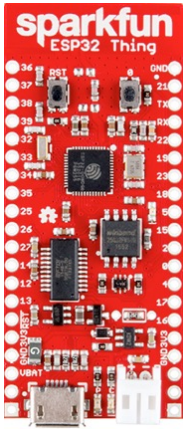
Teensy 3.2

STM32 Nucleo-32



Heltec ESP32 + OLED

Adafruit Feather



Sparkfun ESP32 Thing

Tessel

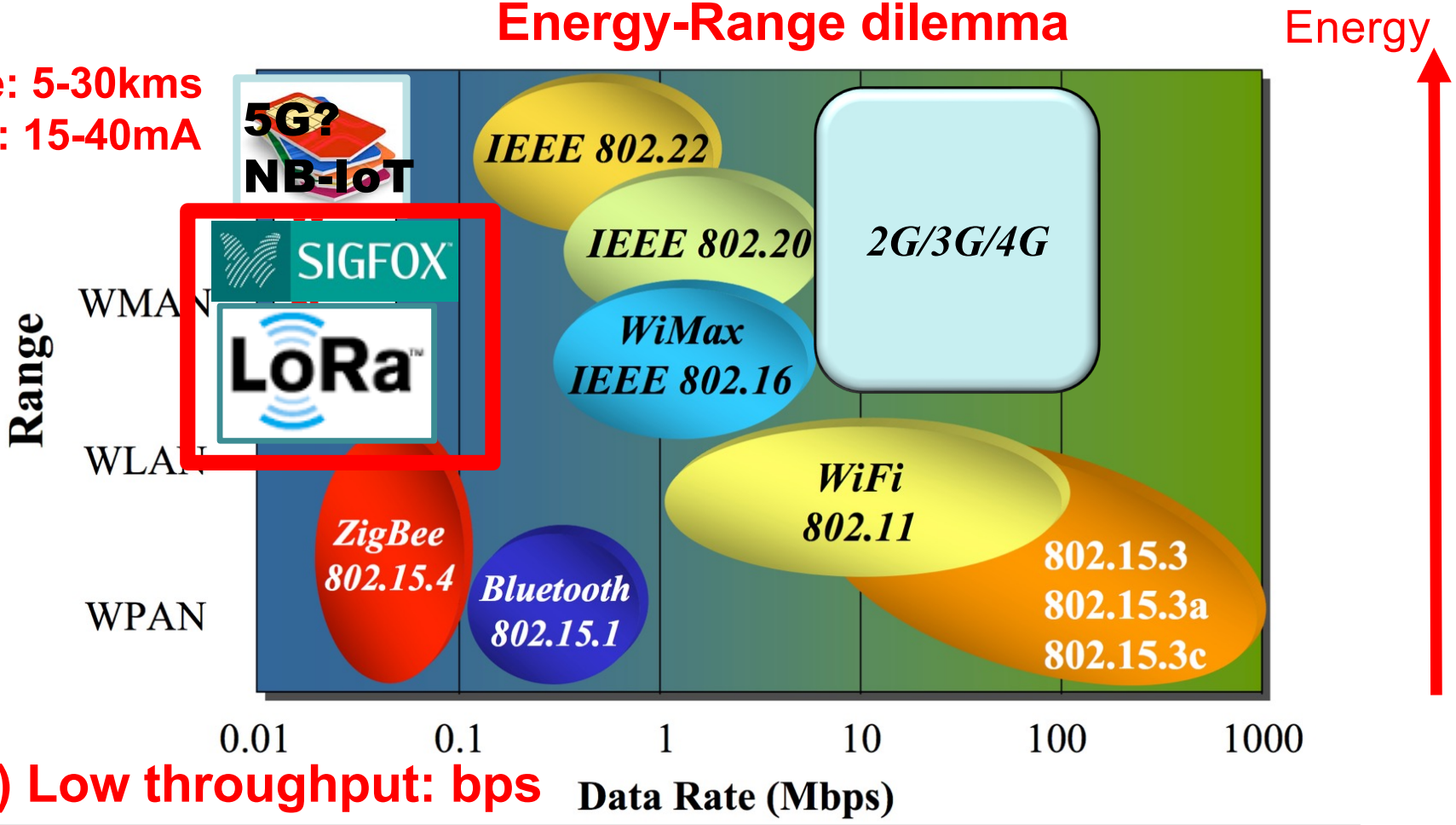
SodaqOnev2

Tinyduino

Low-power & long-range radios

Energy-Range dilemma

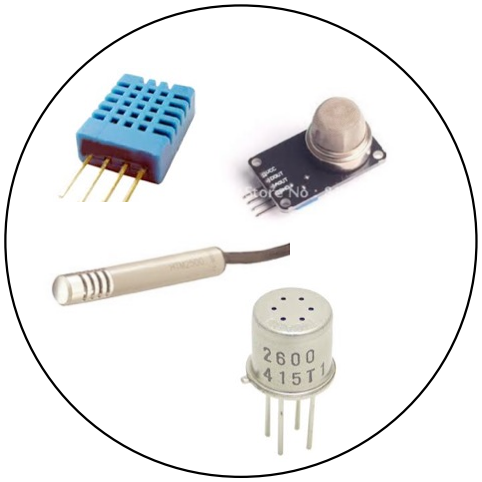
Long-range: 5-30kms
Low-power: 15-40mA

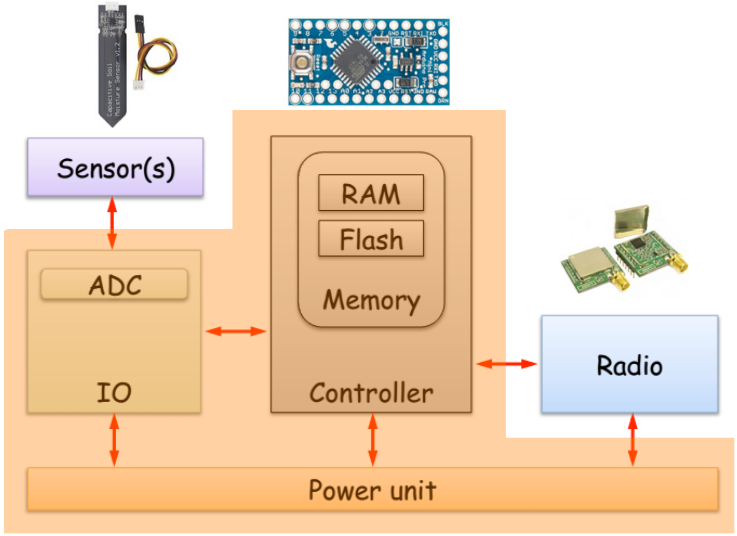


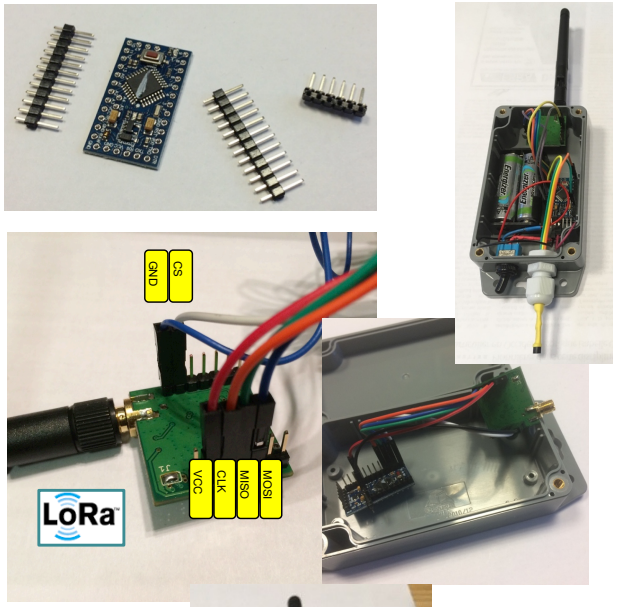
(Very) Low throughput: bps

Transmitting: `TC/22.5/HUM/67.7` ; about 20 bytes with packet header
Time on air can be 1.44s with LoRa

Do-It-Yourself IoT

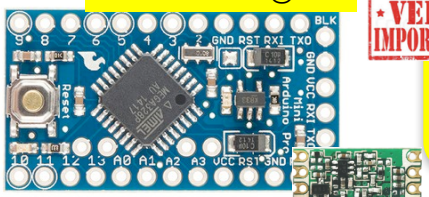






Physical sensor mgmt

Arduino Pro Mini @3.3V



VERY IMPORTANT

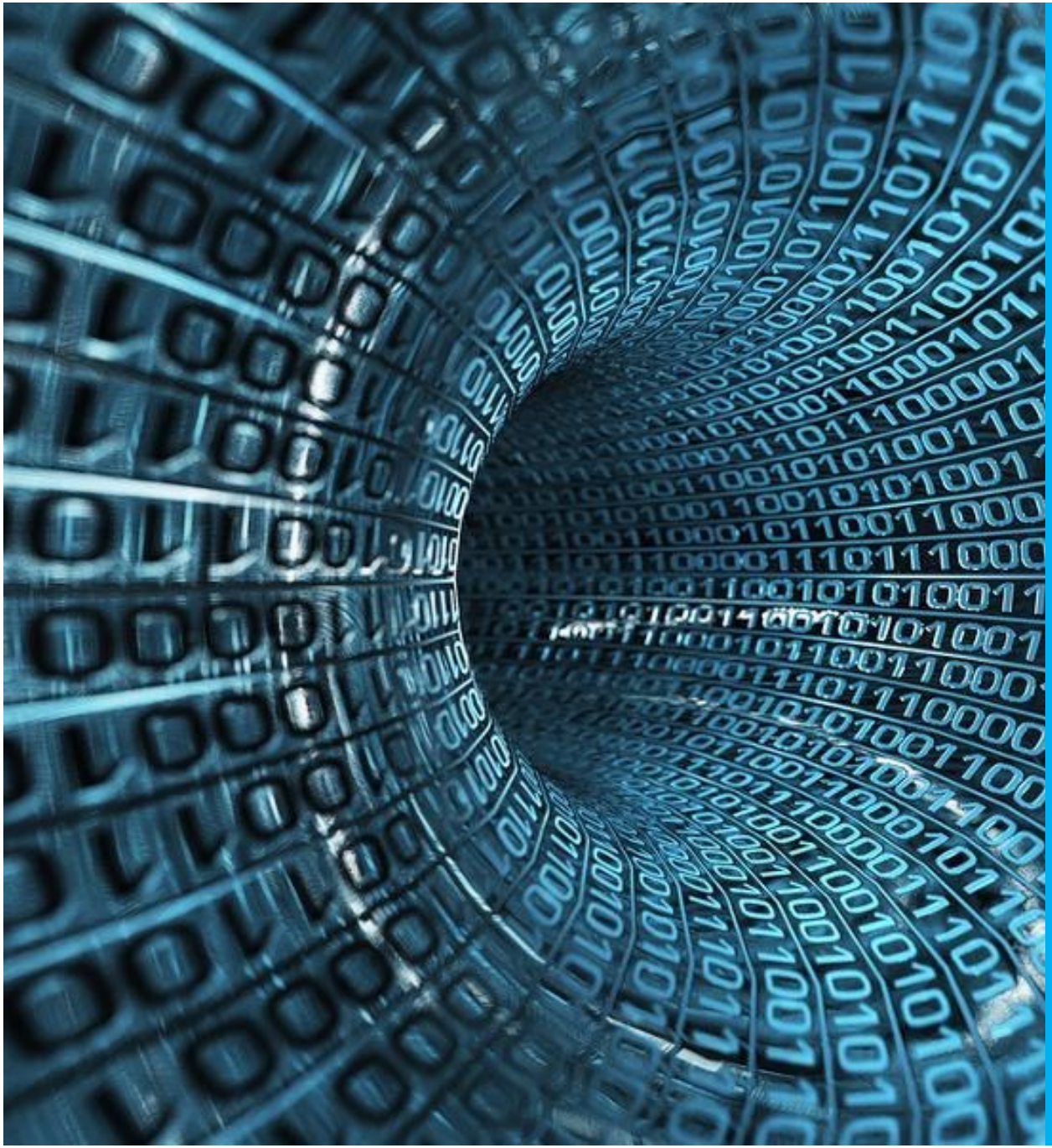
Activity duty-cycle, low power

VERY IMPORTANT

AES encryption

Long-range transmission

Logical sensor mgmt

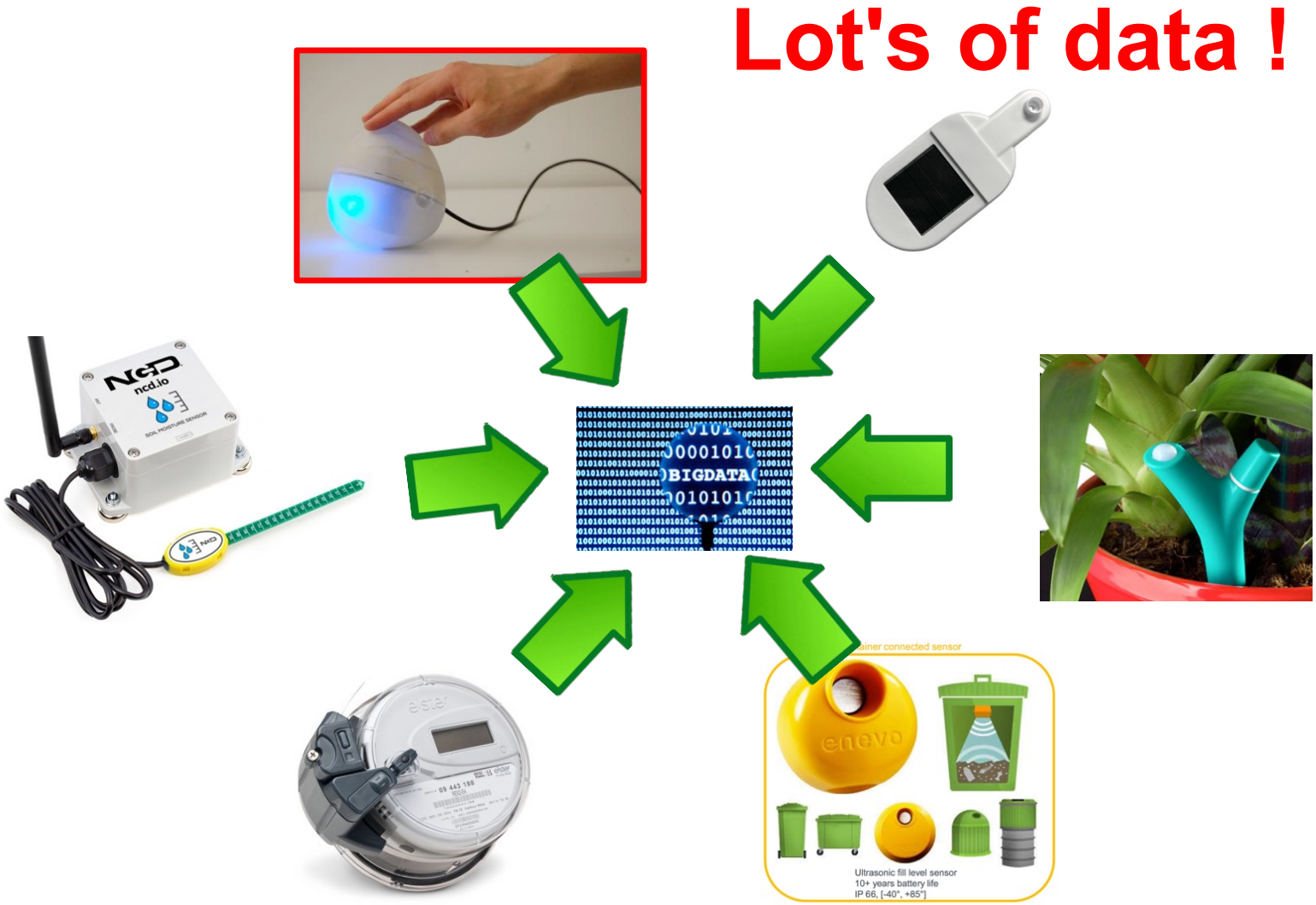


IOT

Unleash the power of IoT data !

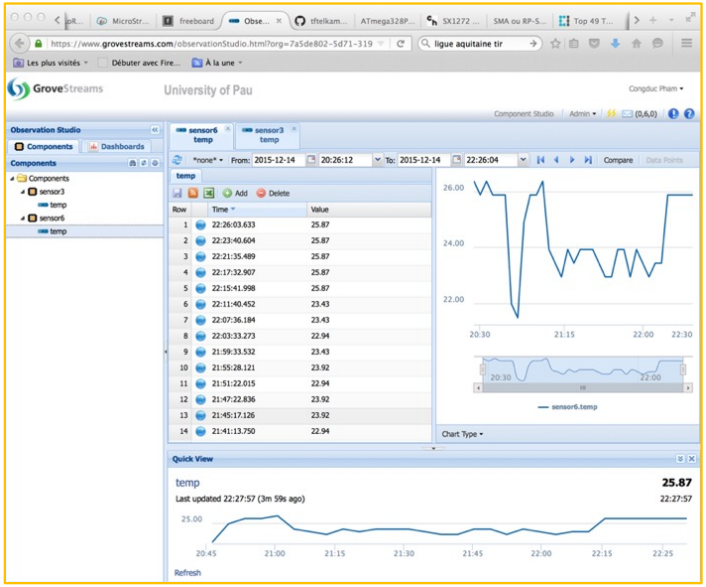

2021, billions of IoT devices
are deployed worldwide !

These things talk a lot!



Things talks to IoT clouds

Firebase
FIWARE
Axēda
ioBridge
Connect things.
ThingSpeak
GroveStreams
SensorCloud™
freeboard
dweet.io
OpenRemote
TempoIQ



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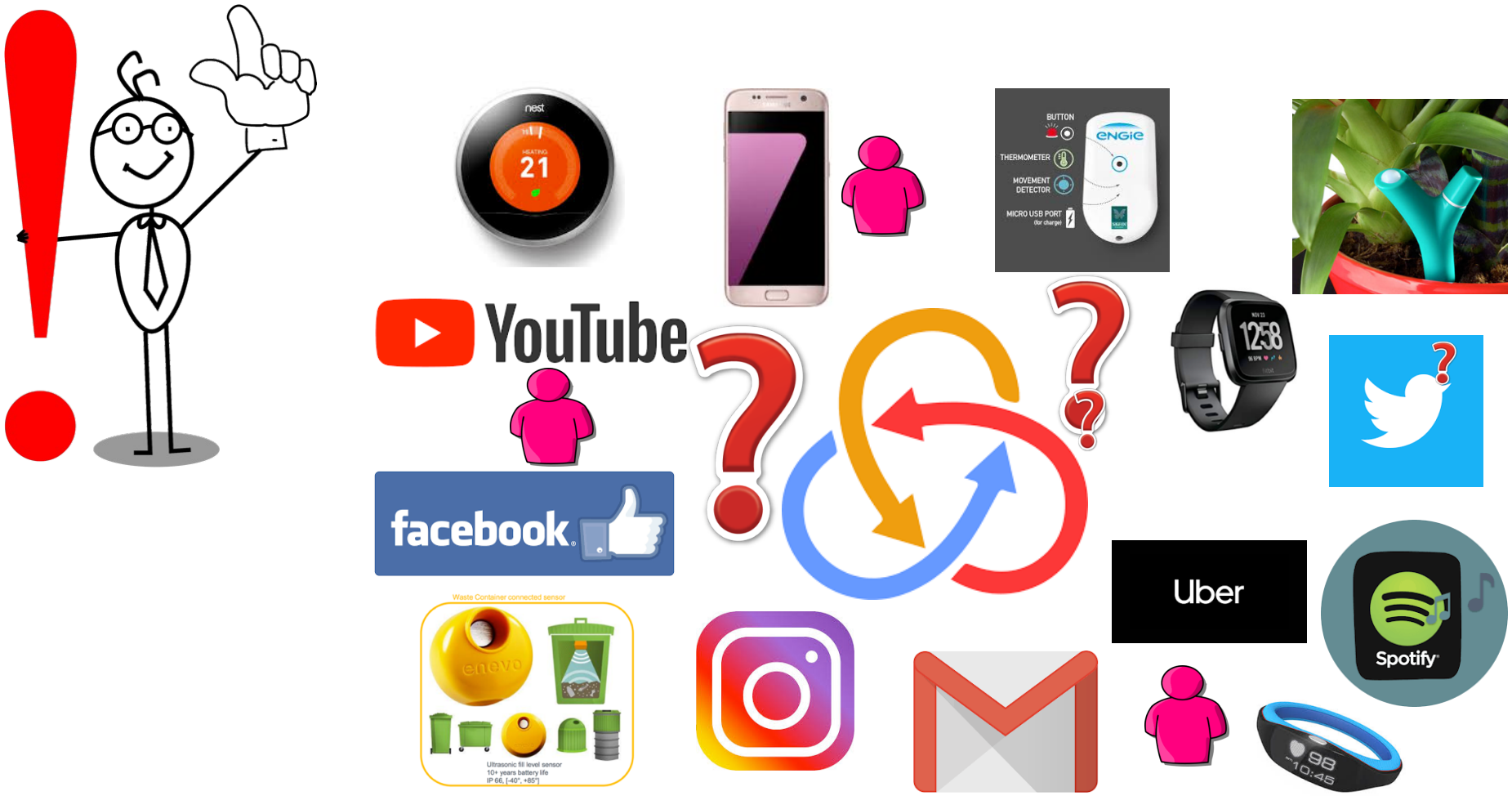
IoT added-values come from interactions and linked data!



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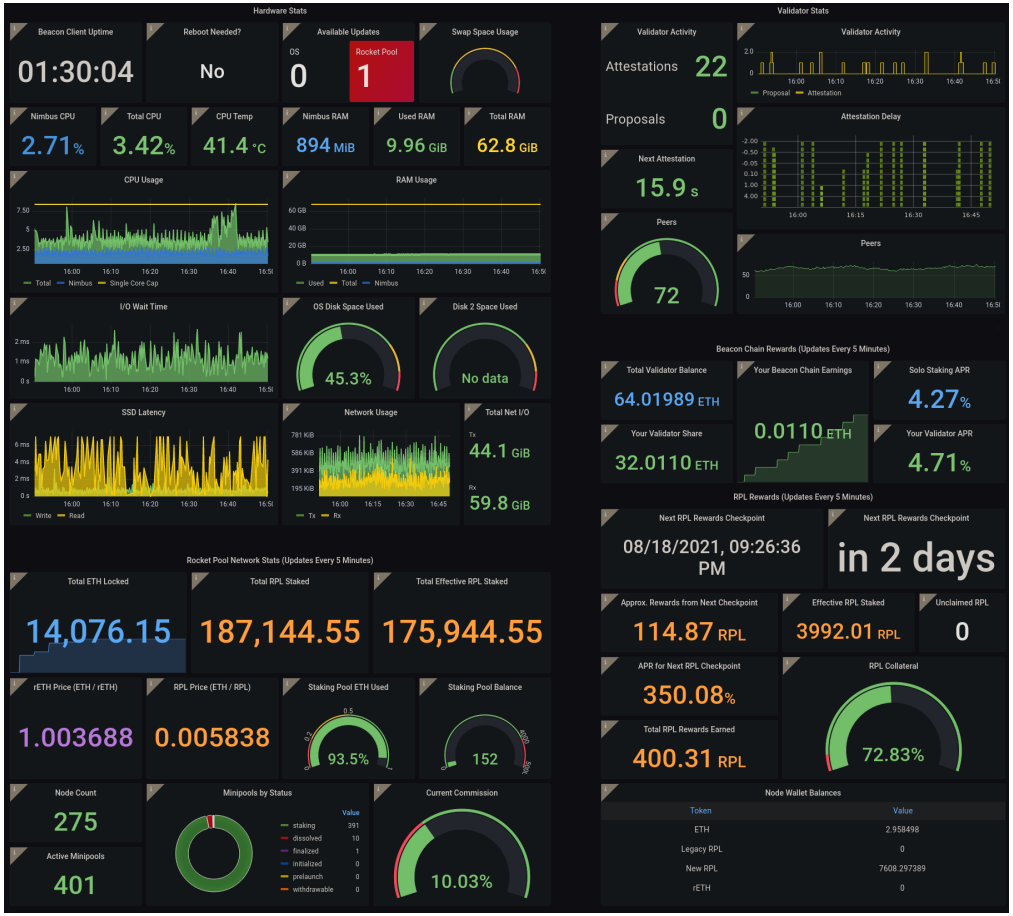
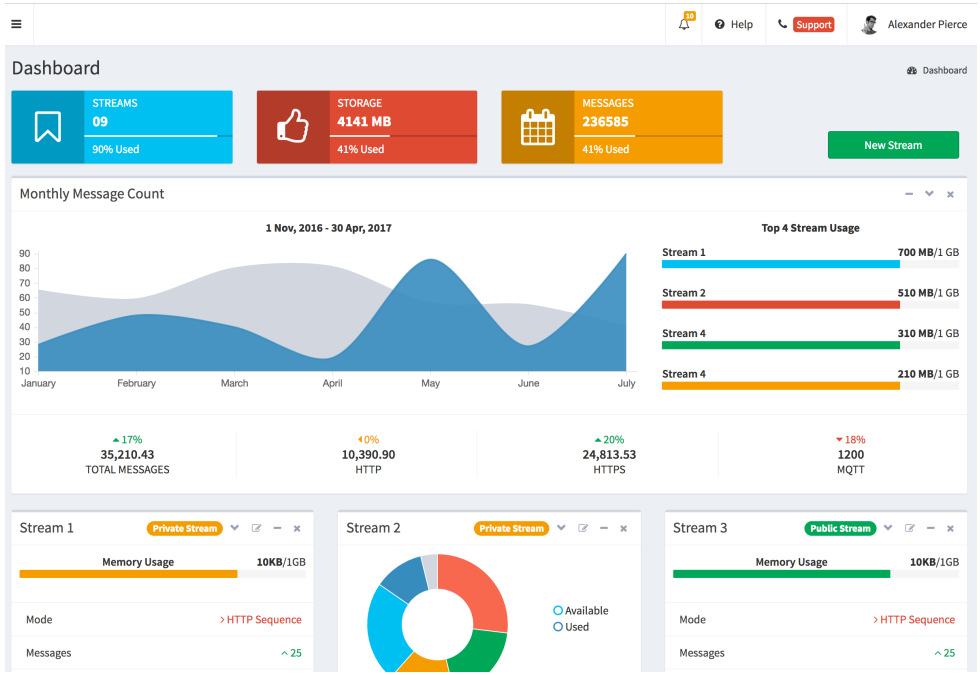
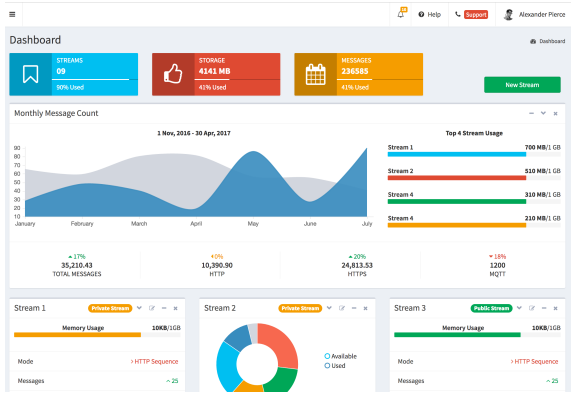
Integrating multiple data sources

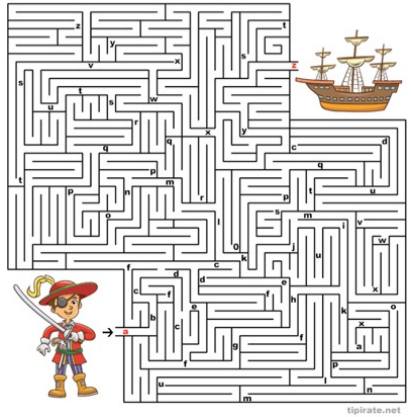




Searching for IoT data

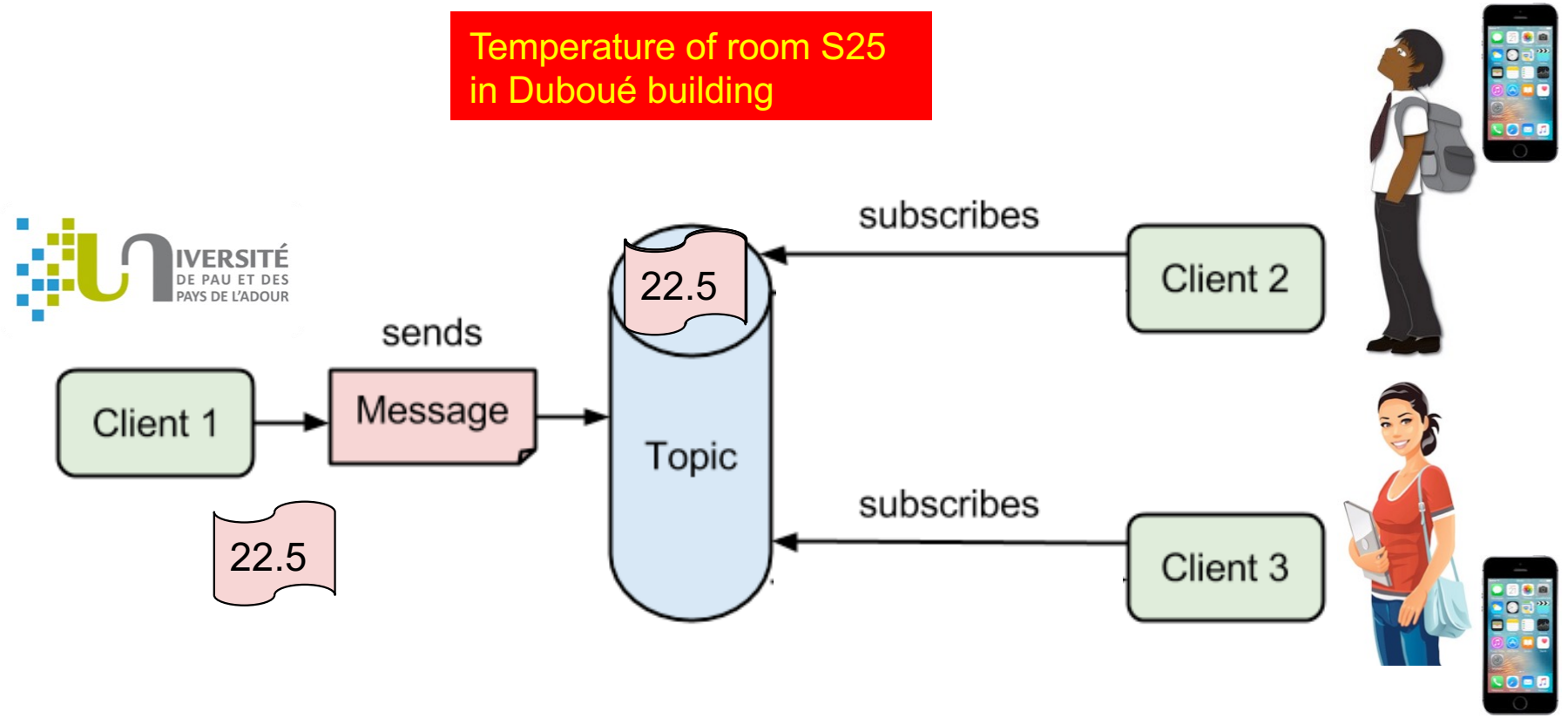
- Searching for information is a tough issue
  - Web search engine: Google,…
- If you seek for an information, for instance the soil humidity condition in a particular farm, then you need to know where to look
- When there can be billions of IoT nodes providing large variety of data, it is difficult 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"

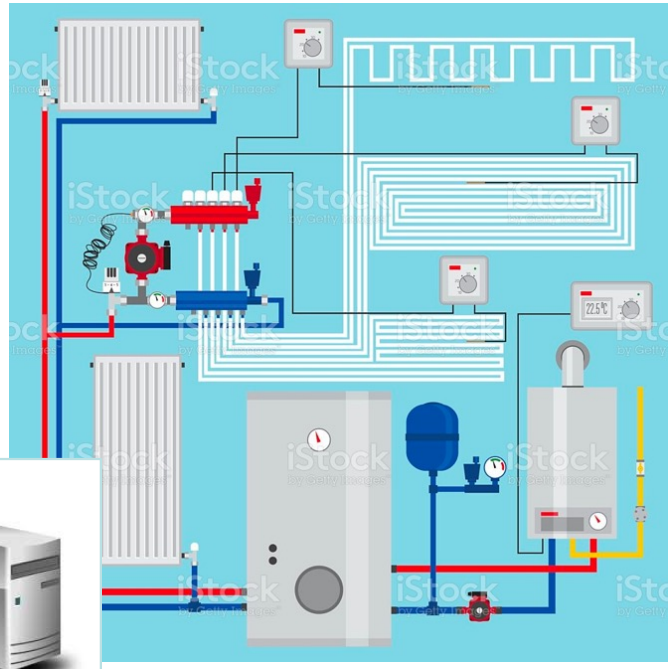
- Use the PUBLISH/SUBSCRIBE model

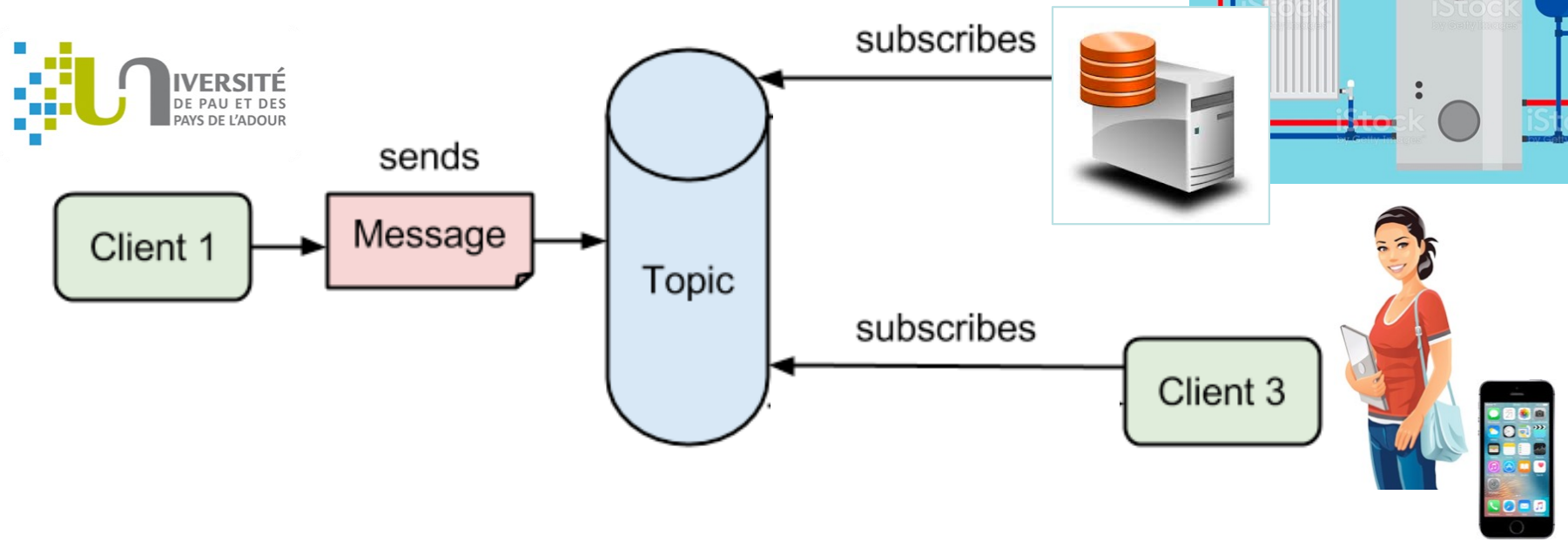


Automatization made simpler

- Use the PUBLISH/SUBSCRIBE model

Temperature of room S25
in Duboué building

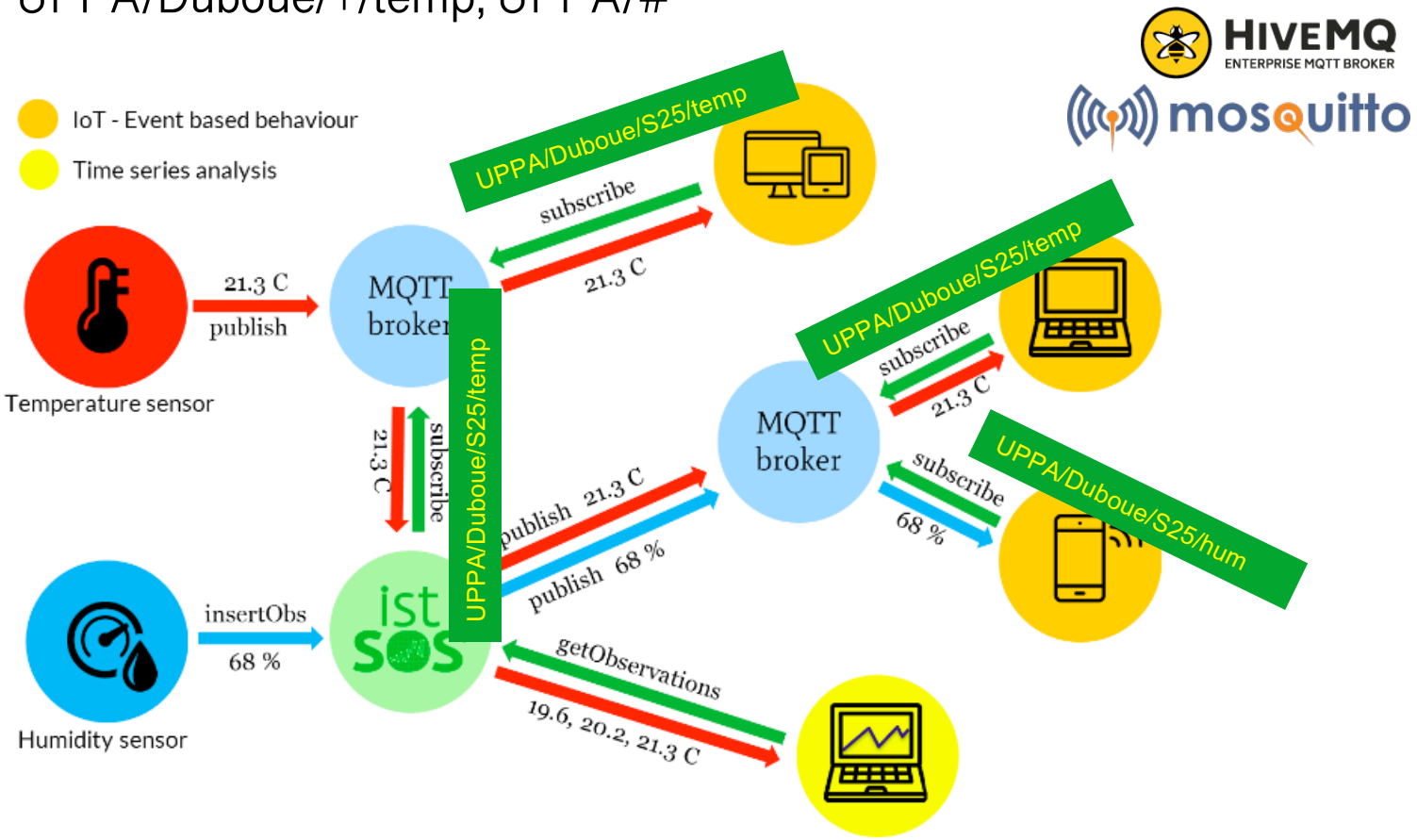




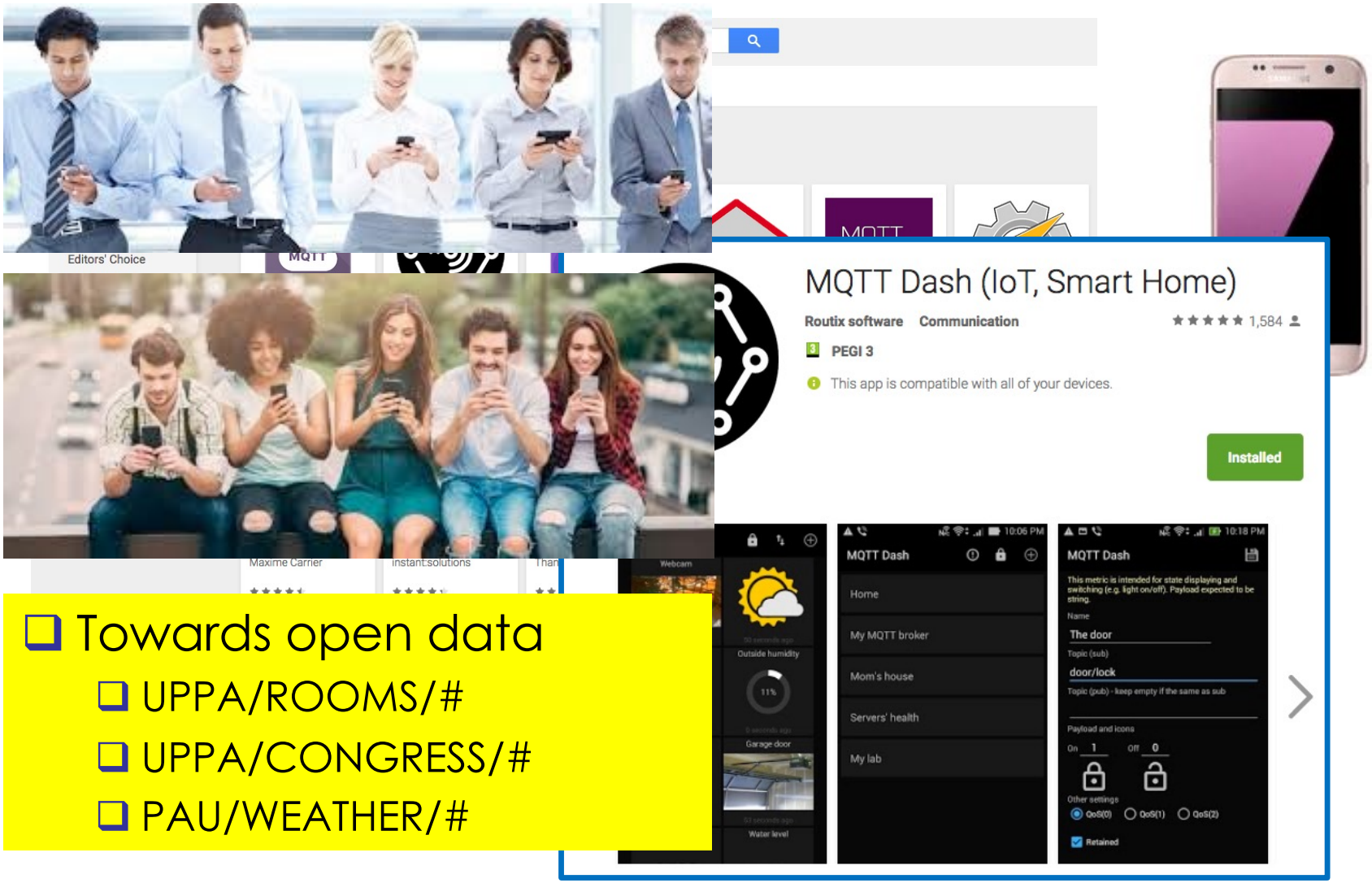
MQTT

Message Queue Telemetry Transport

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



MQTT+smartphone=



- Towards open data
  - UPPA/ROOMS/#
  - UPPA/CONGRESS/#
  - PAU/WEATHER/#

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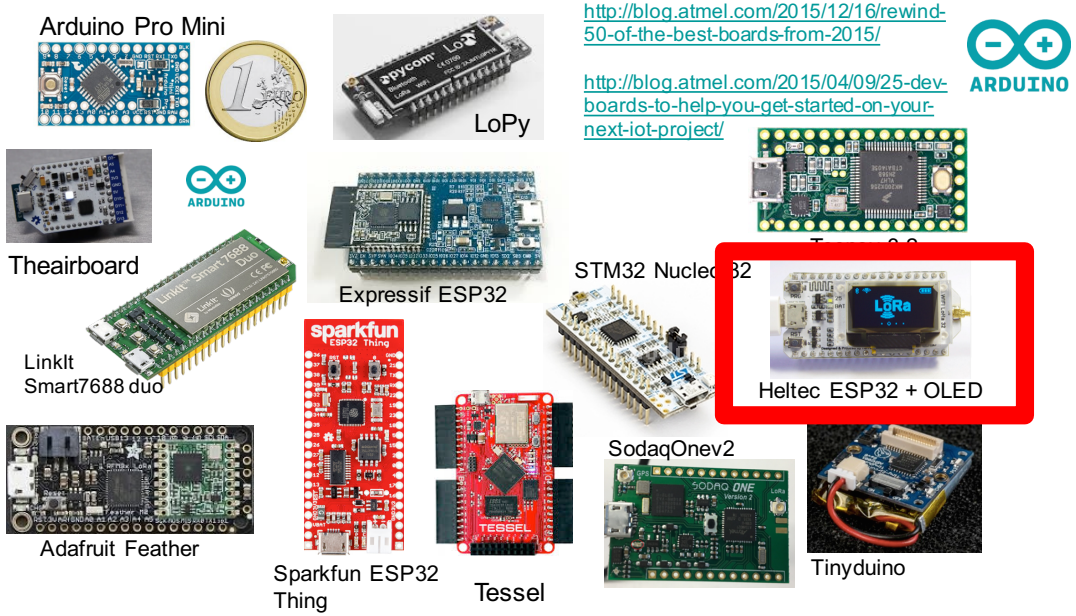
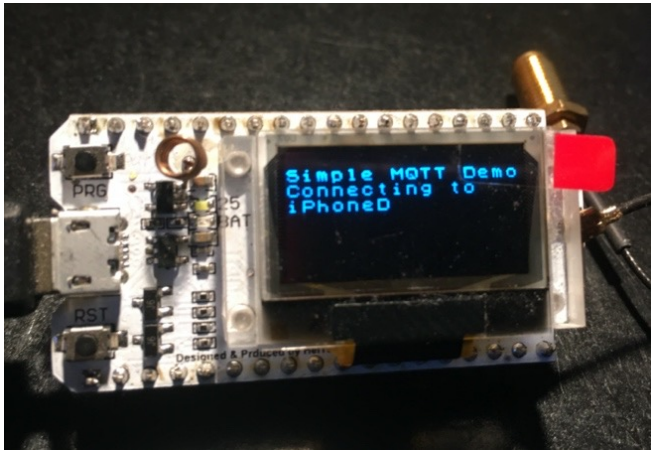
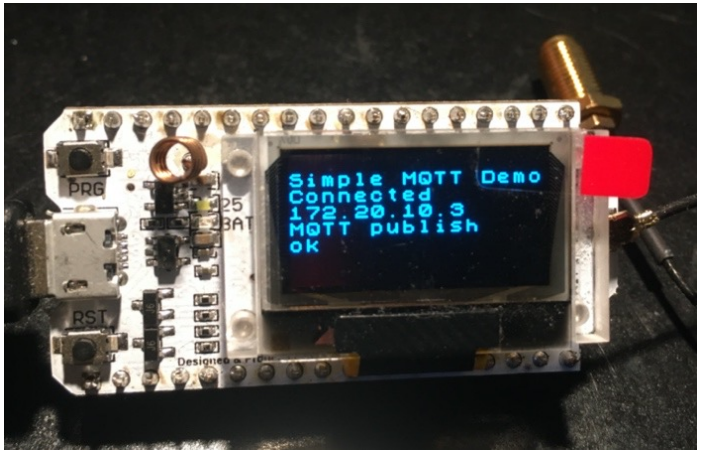
MQTT is very lightweight

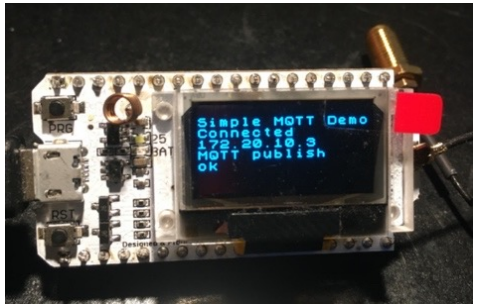
- MQTT can run on small IoT devices
- Heltec WiFi ESP32
  - Device connects to WiFi network
  - Then will publish data to MQTT topic







Ex: Mosquitto MQTT broker



- Eclipse Mosquitto is an open-source MQTT broker
- MQTT test broker: `test.mosquitto.org`
- IoT device will publish to topic UPPA/Duboue/S25/temp
- On a computer, use `mosquitto_sub` to subscribe
  - **`mosquitto_sub`** `-v -h test.mosquitto.org -t UPPA/Duboue/#`
  - -v ➠ to display information in detailed mode
  - -h ➠ the MQTT broker: `-h test.mosquitto.org`
  - -t ➠ the MQTT topic: `-t UPPA/Duboue/#`

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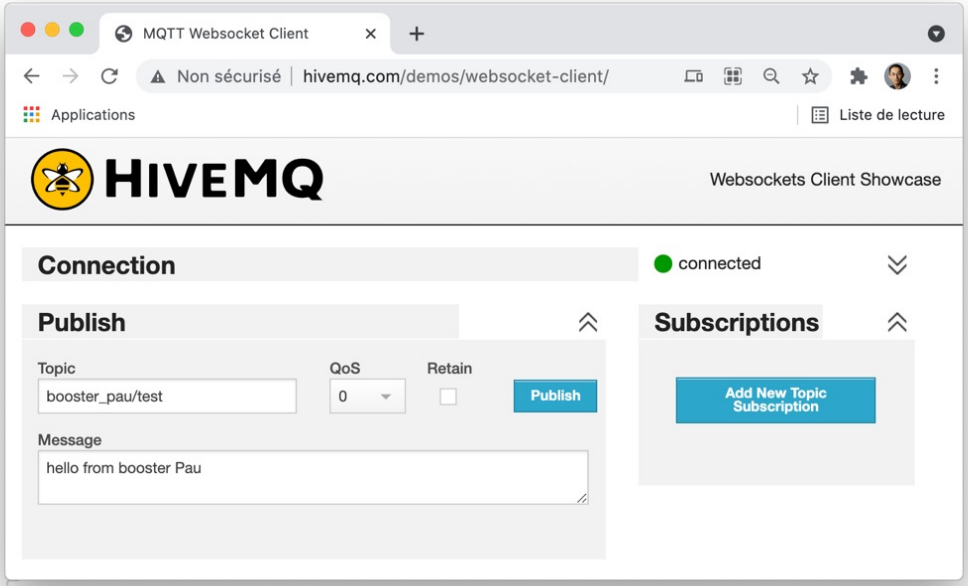
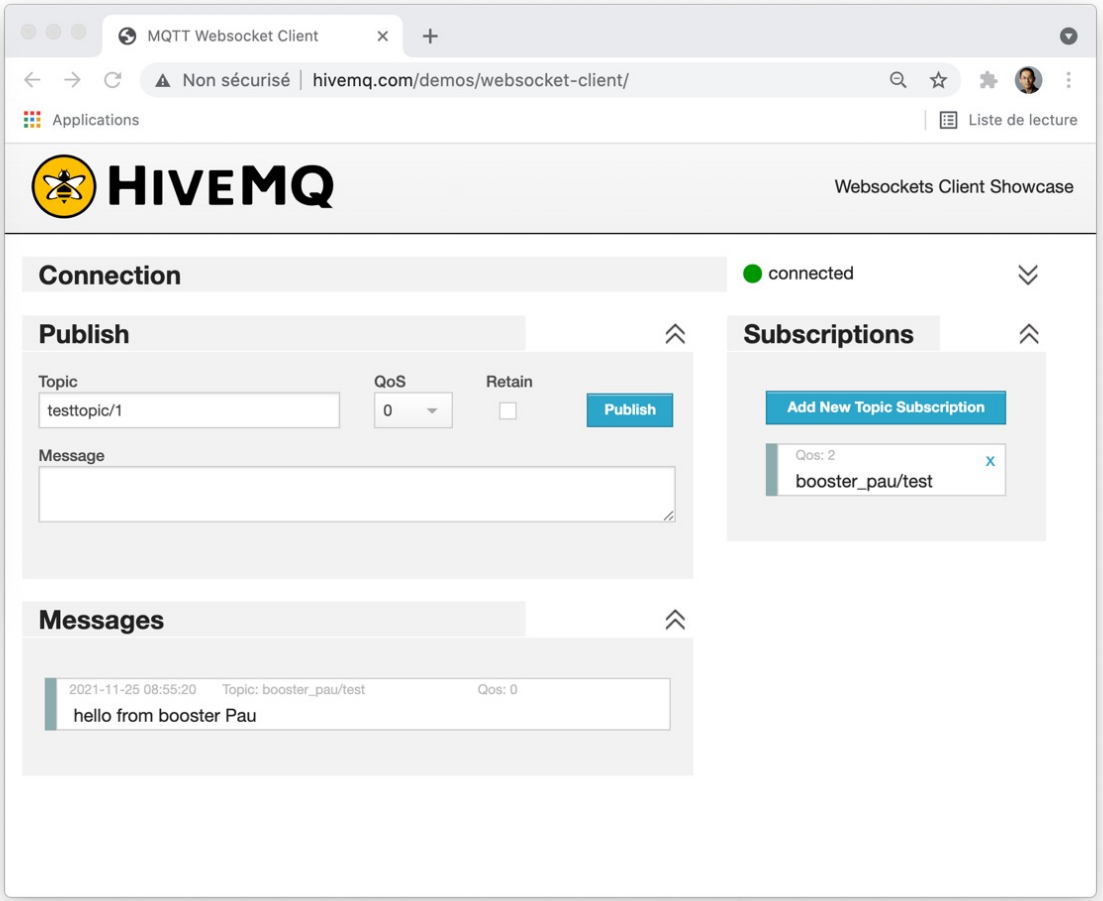
Ex: HiveMQ broker on websocket

- http://www.hivemq.com/demos/websocket-client/





MQTT in real IoT deployment

Sensor part

- Simple IoT devices have no WiFi
- Use Low-Power, Long Range radios, e.g. LoRa
- Send to IoT gateway

LoRa

Control part – IoT gateway

MQTT

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
  - To receive/send message
    - Alice publishes to myWhatsApp/0611223344
    - Bob publishes to myWhatsApp/0655667788
    - Both subscribe to their own topic
  - To create a group
    - Alice creates a group waziup-iot
    - myWhatsApp/0655667788/waziup-iot
  - To join(publish) on(to) the group
    - Subscribe(publish) to myWhatsApp/0655667788/waziup-iot

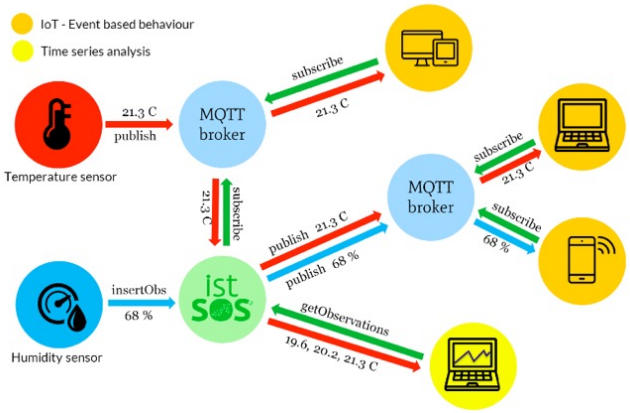
0655667788

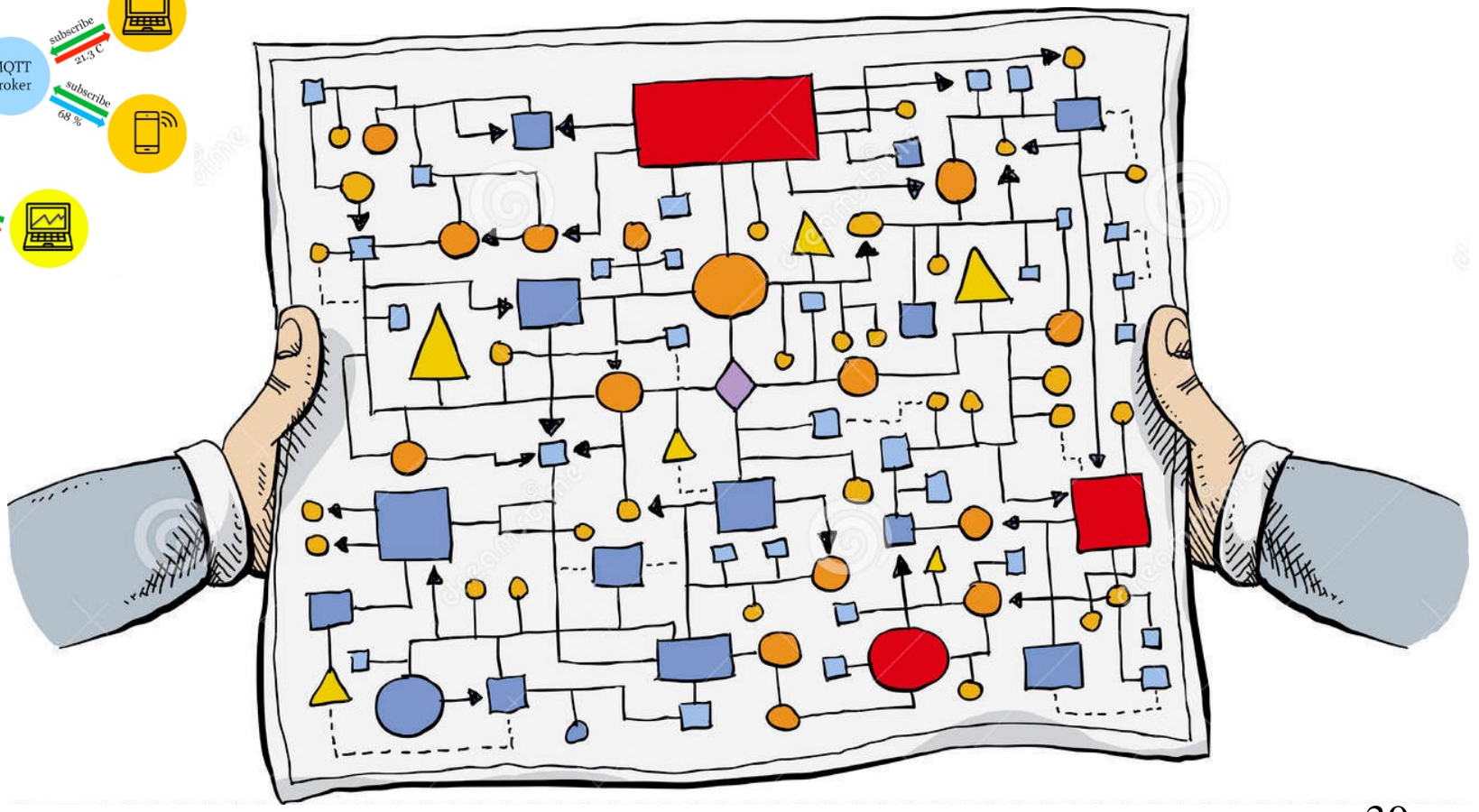
Alice

0611223344

Bob

Creating complex data flows?



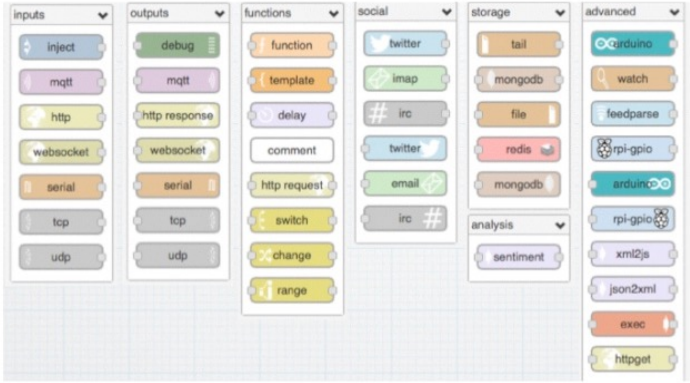


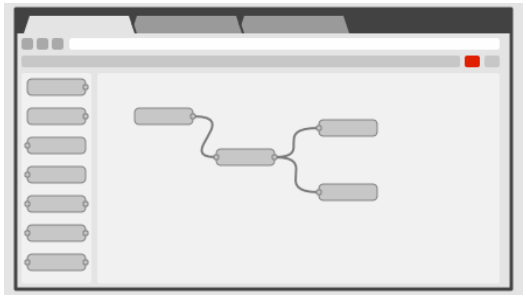
…without programming?

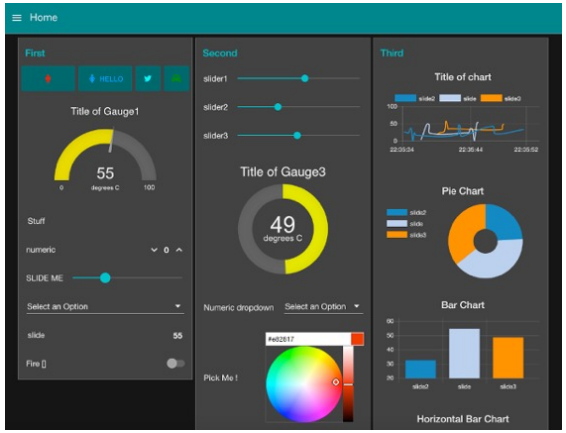
- End-users are not necessarily computer science experts nor high-skilled programmers

Node-RED

- Use graphical tools to build data processing flows, allowing intuivive connection from IoT data producers to IoT data consumers
- 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

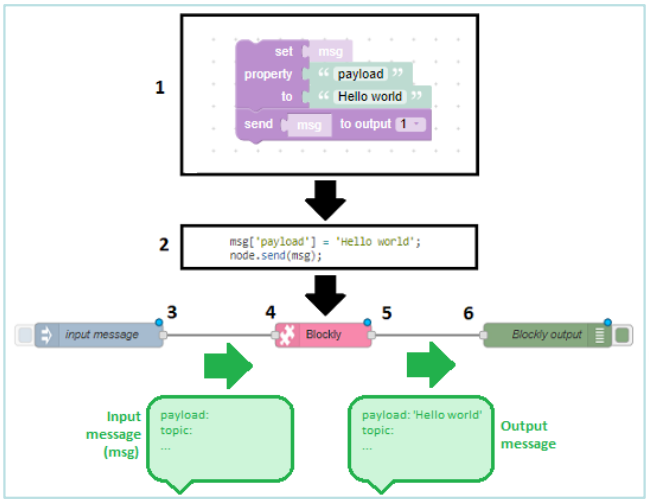




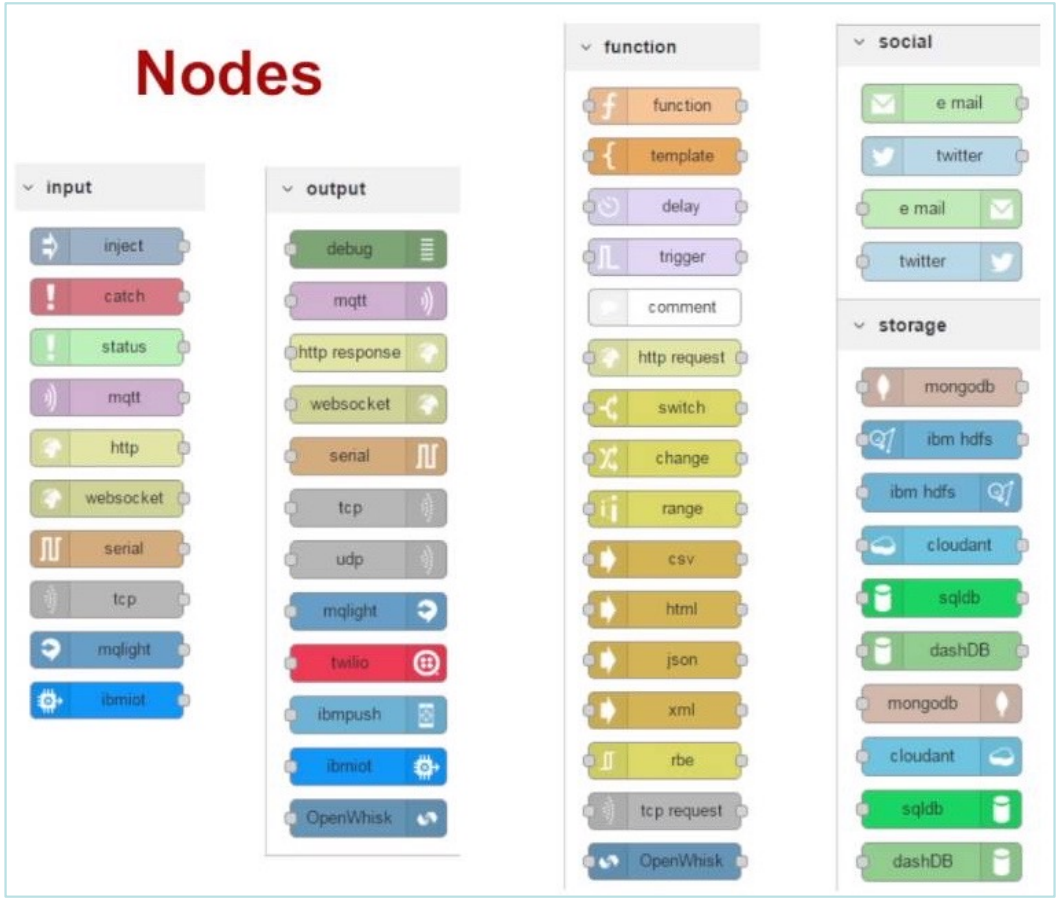


Node-RED blocks

- Increasing number of Node-RED blocks

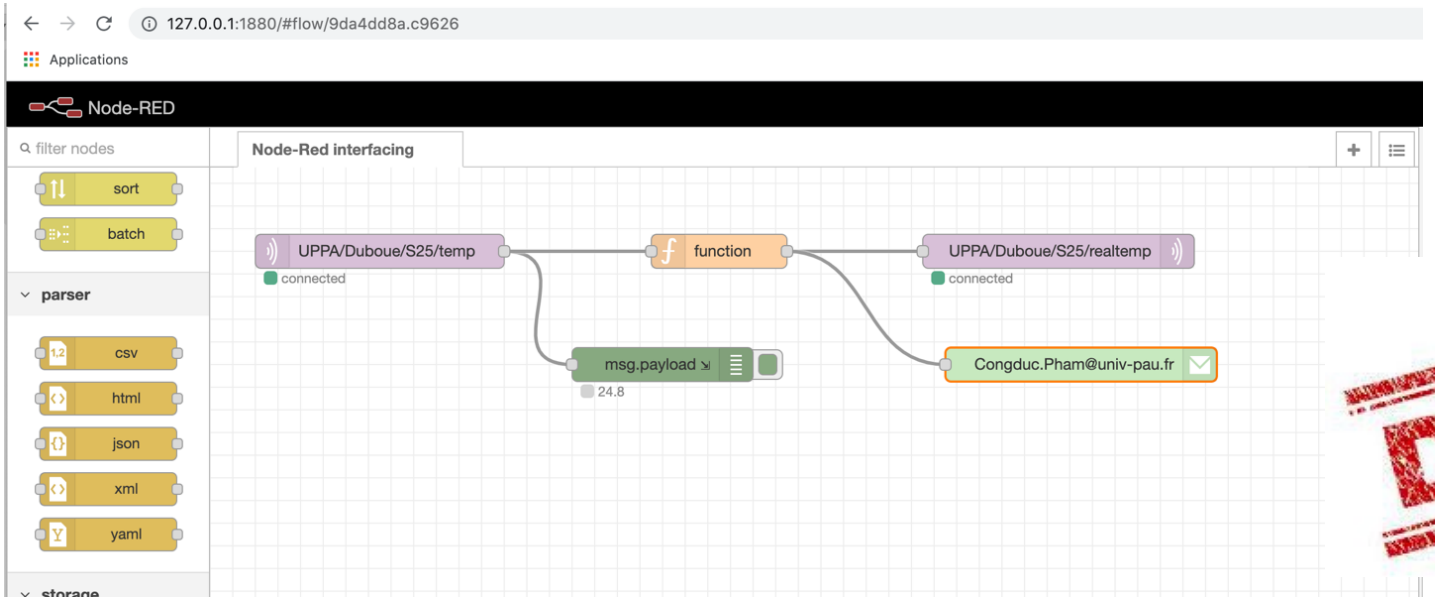


Nodes represent reusable pieces of code and logic. Node-RED comes with a core set of useful nodes, but there are a growing number of additional nodes available to install from both the Node-RED project as well as the wider community or you



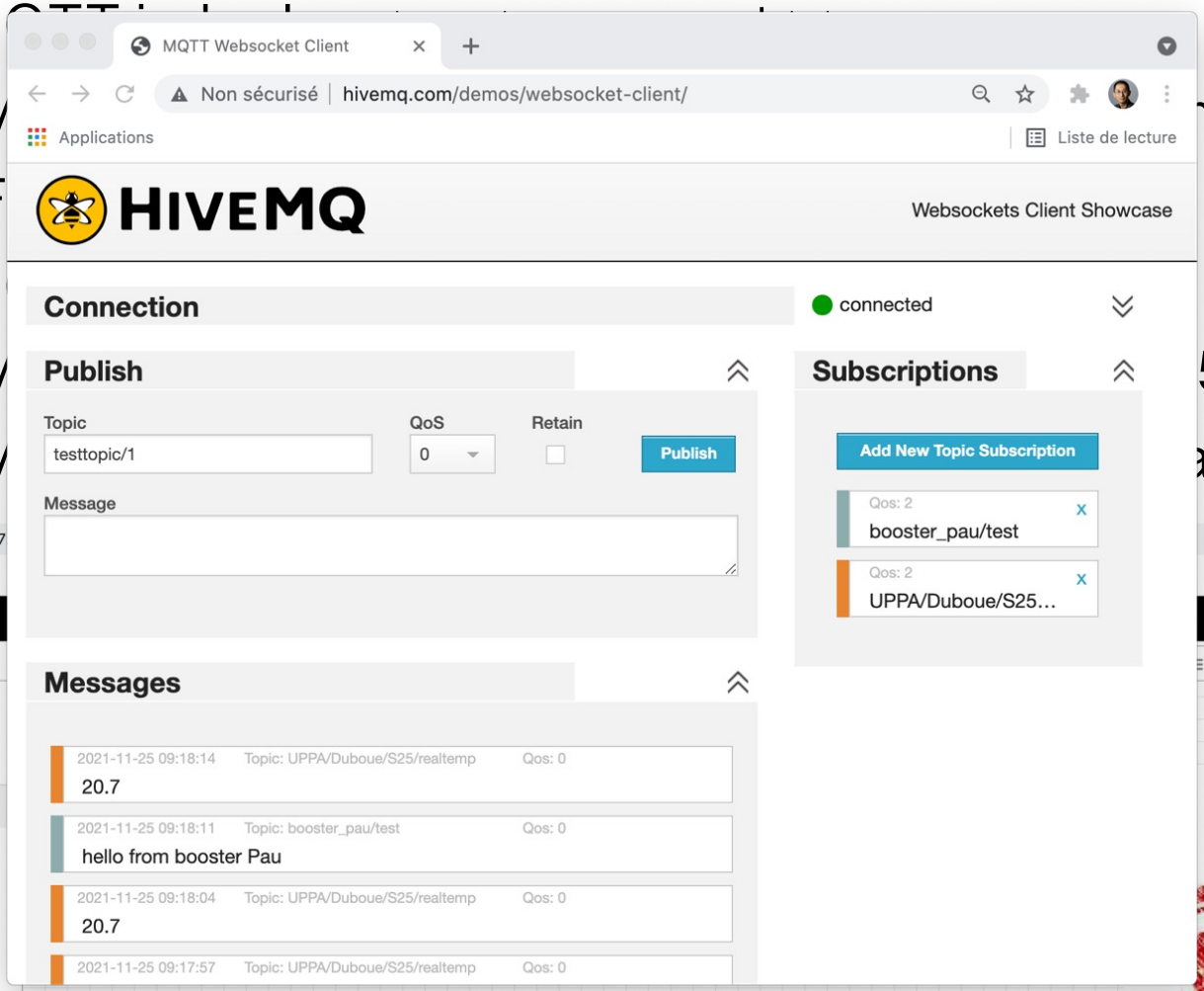
Simple MQTT Node-RED flow

- MQTT in-broker: `test.mosquitto.org`
- "**MQTT in**" node listens on UPPA/Duboue/S25/temp
- "Function" node to correct temperature by -1.8°C
- MQTT out-broker: `broker.hivemq.com`
- "**MQTT out**" node publishes on UPPA/Duboue/S25/realtemp
- "Mail" node sends corrected temp to Congduc.Pham@univ-pau.fr



Simple MQTT Node-RED flow

- M
- "M
- "F
- M
- "M
- "M



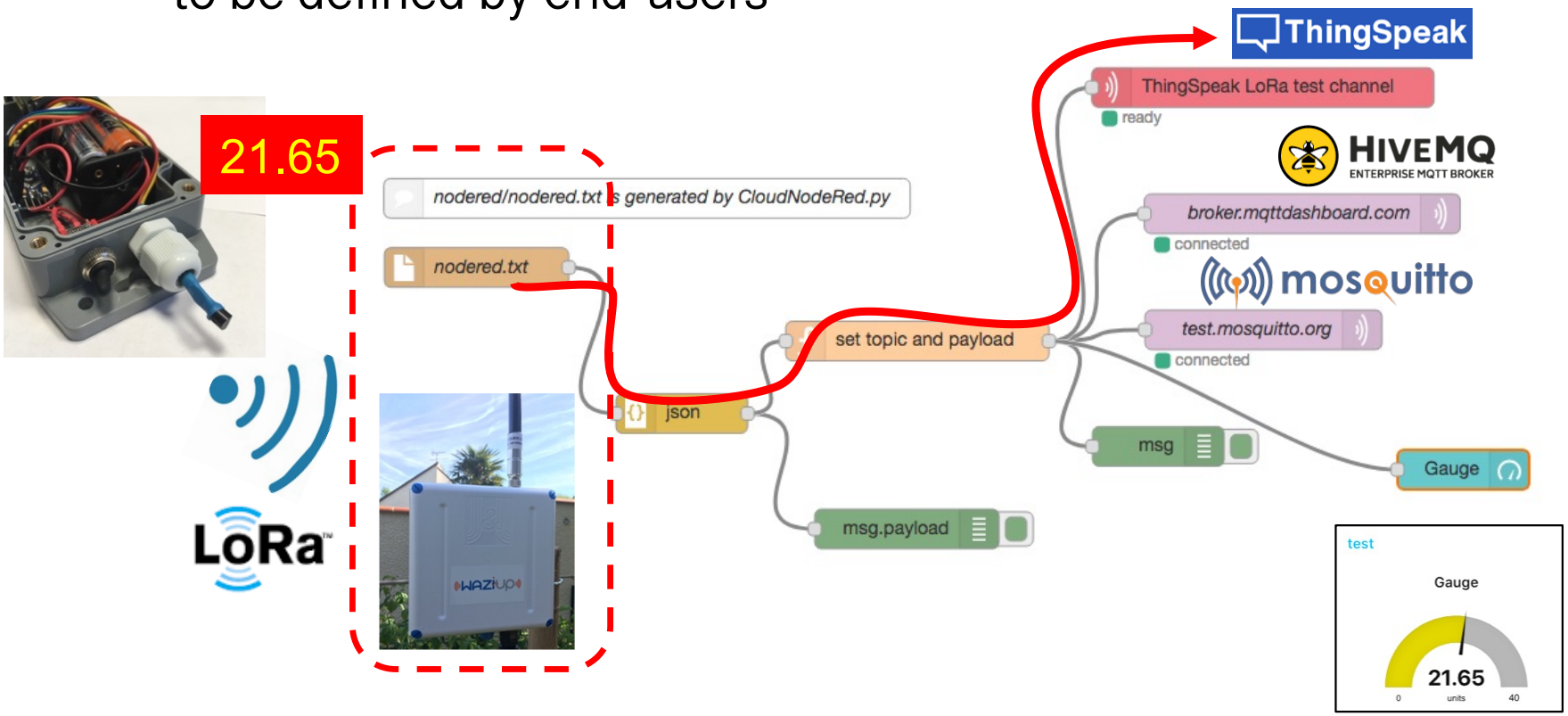
mp

5/realtemp

am@univ-pau.fr

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



Generalizing interactions?

Adding interactions?

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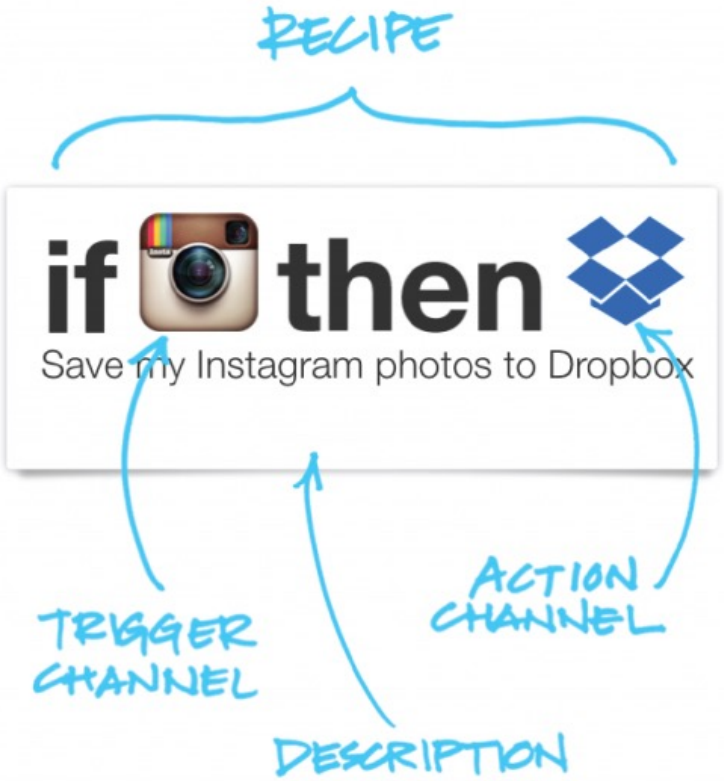
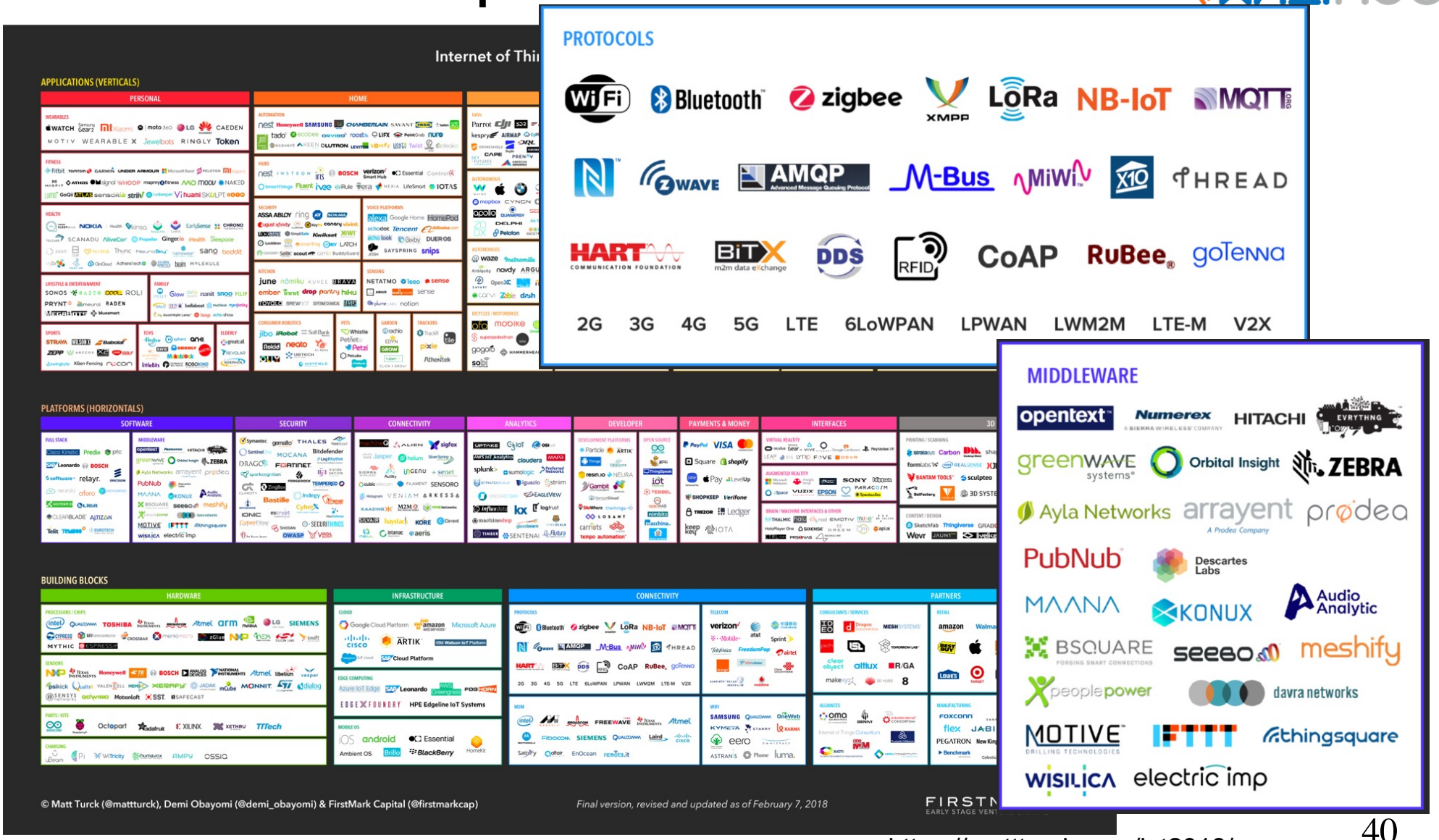
http://www.univ-pau.fr/~cpham

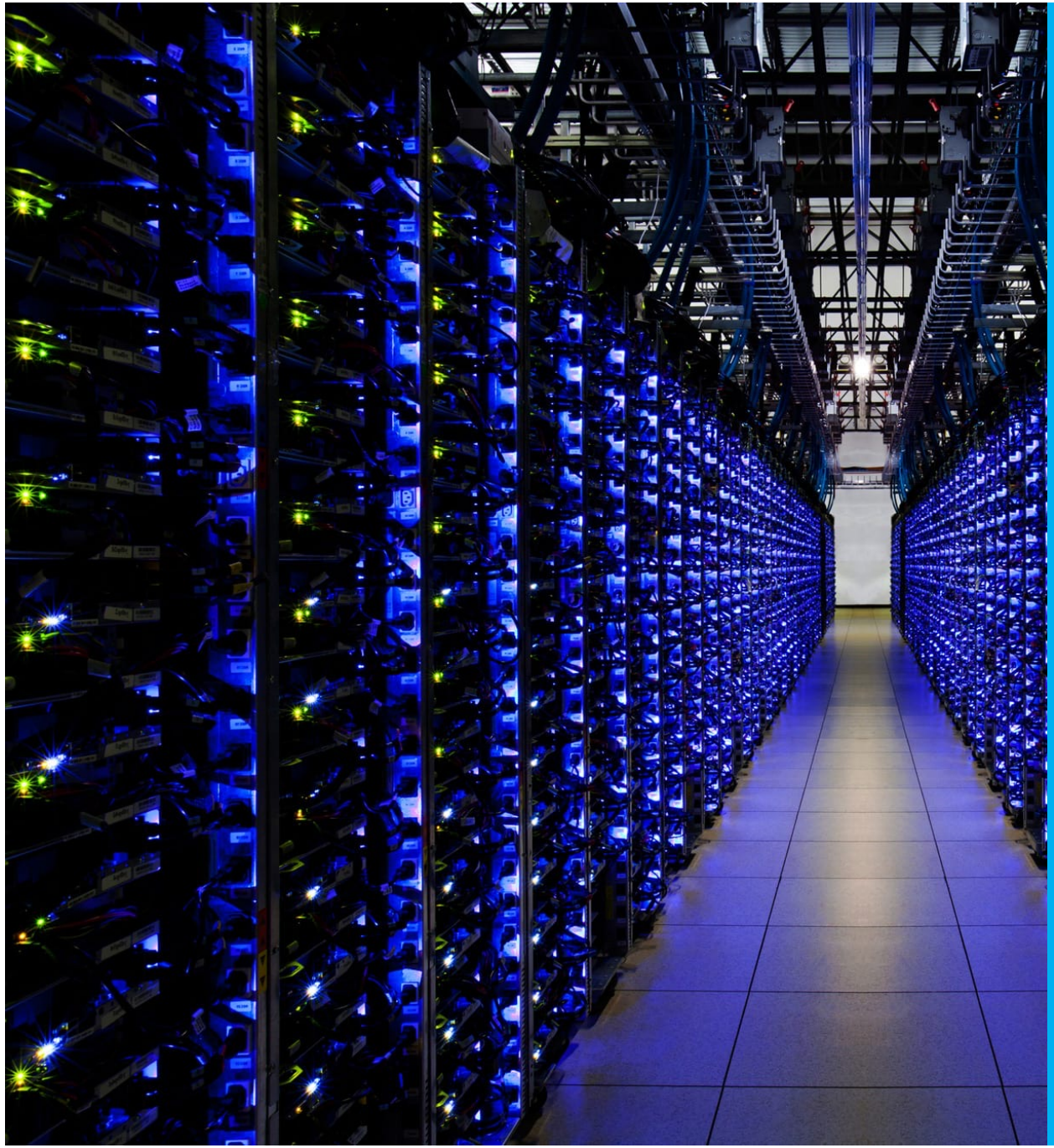
IF THIS THEN THAT applets



IoT landscape

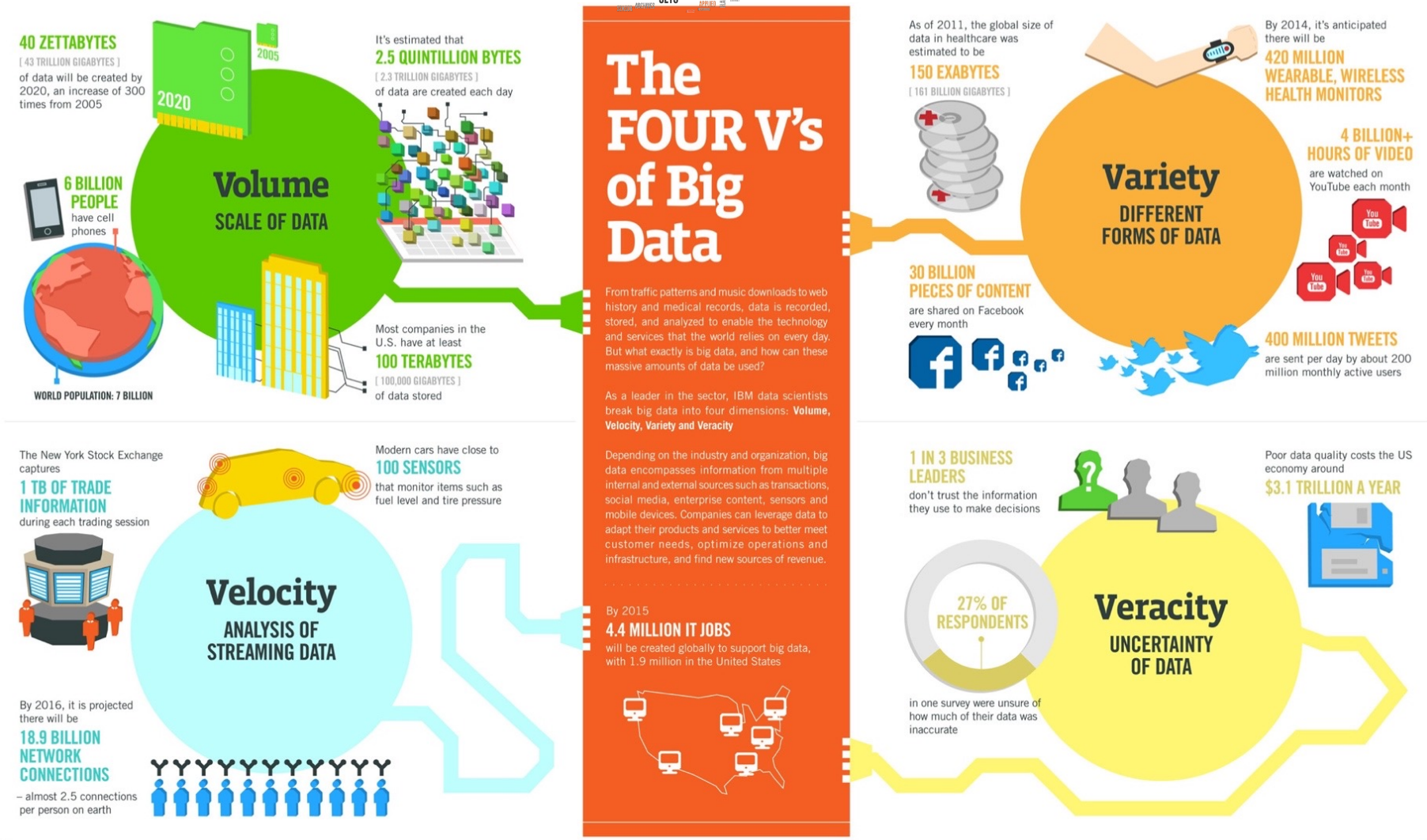


https://mattturck.com/iot2018/



IOT
BACKOFFICE

IoT usually means …



…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!

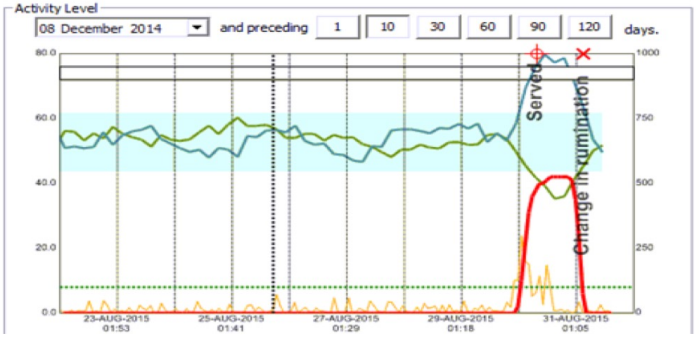
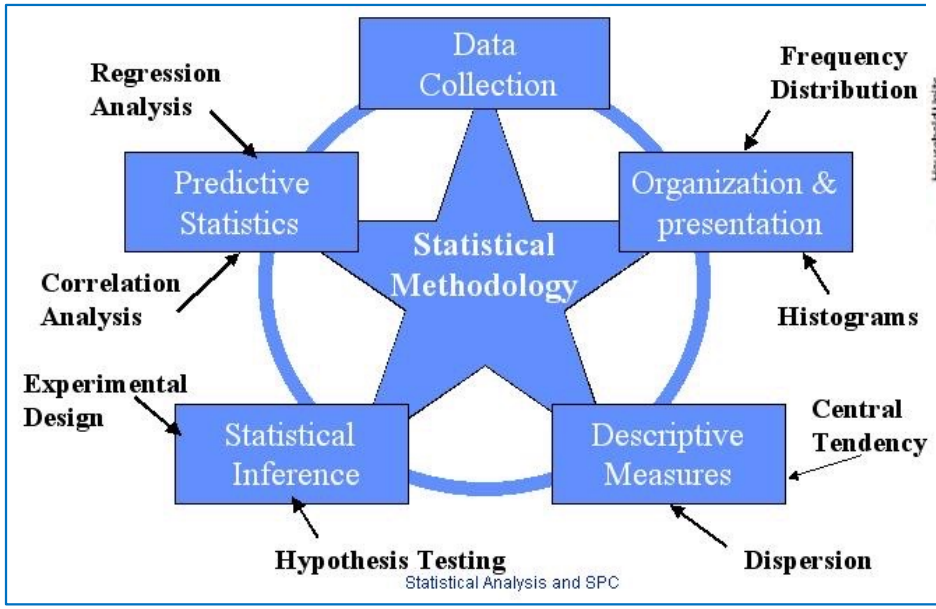
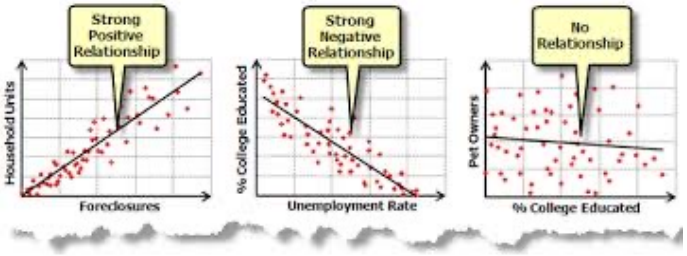


Fig. 3. Illustration of a rise in activity accompanied by a fall in rumination at the point of oestrus

Analysis techniques

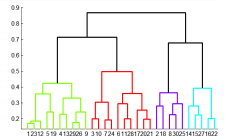
- Traditional statistic methods still valid, and useful!

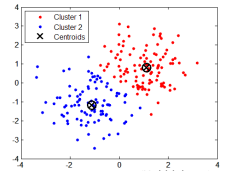




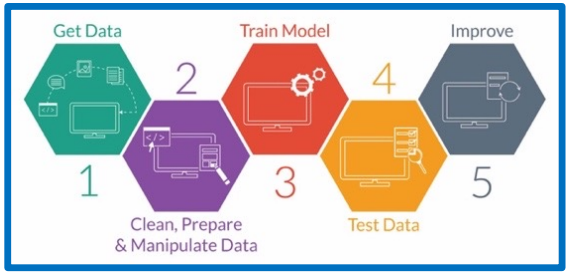
Clustering Analysis

- 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, ...



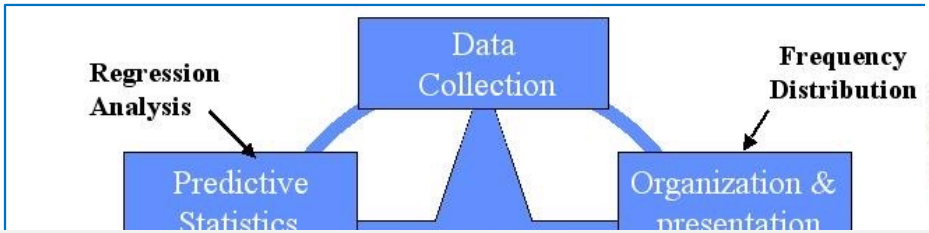


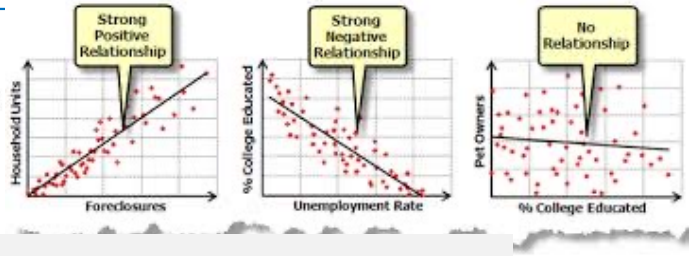
From Jong Youl Choi

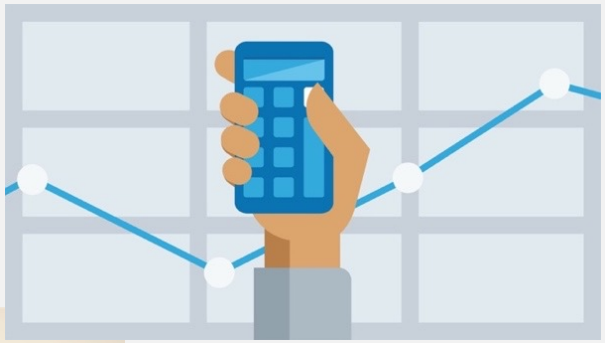


Analysis techniques

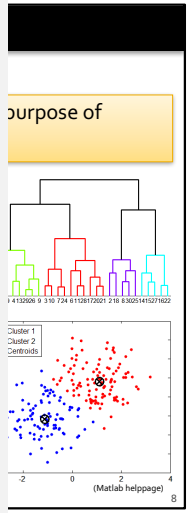
- Traditional statistic methods still valid, and useful!



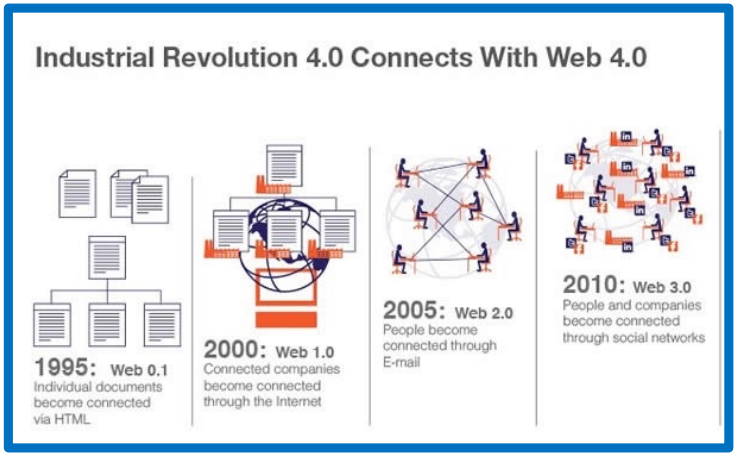


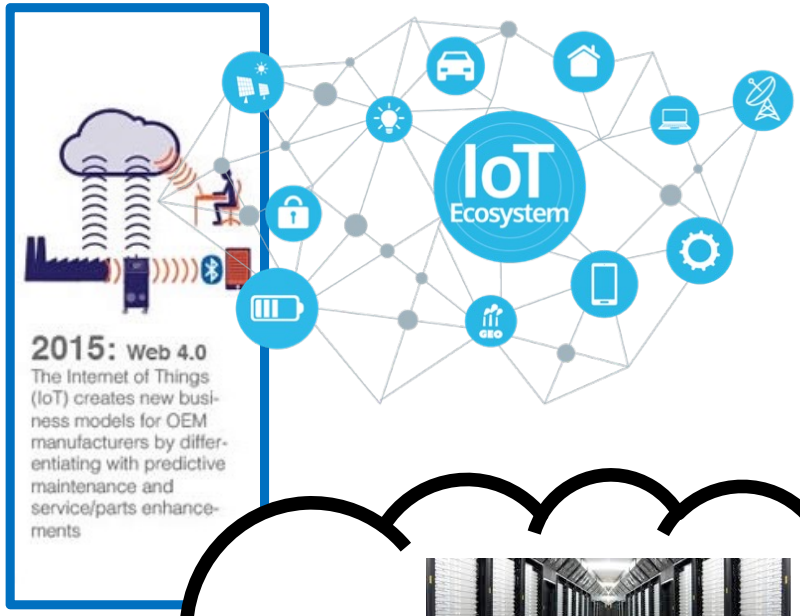


Going old school ?



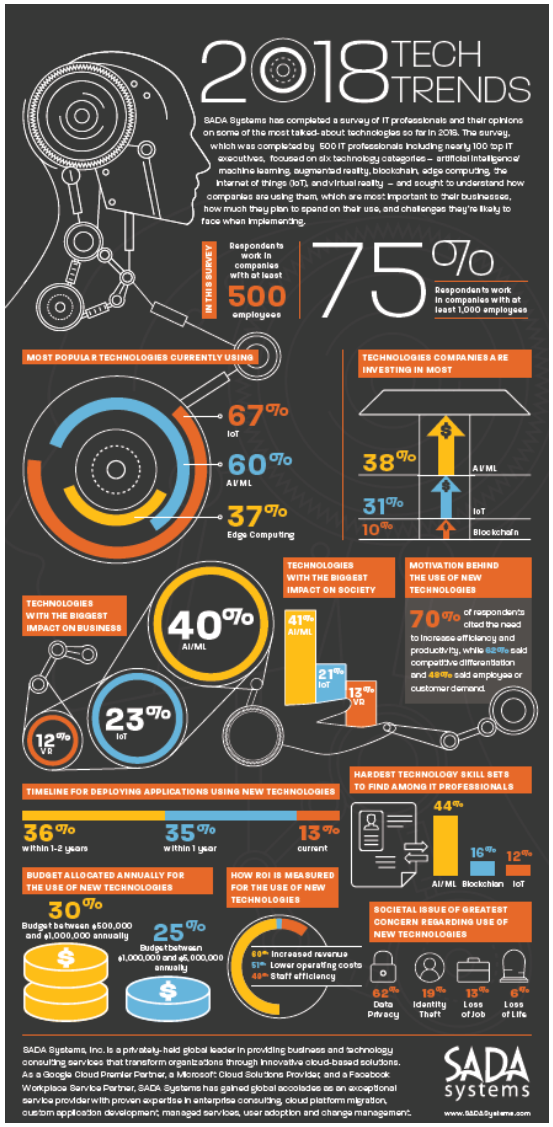
Use the full power of the Internet!

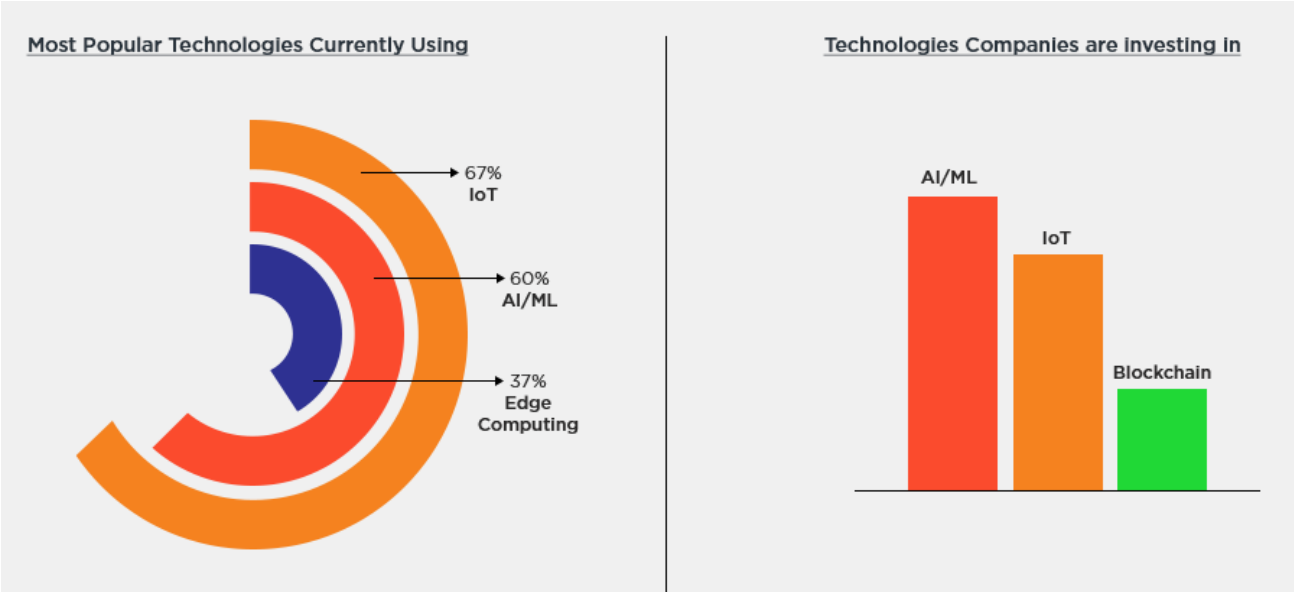




- IoT data are already on Internet data clouds
- Computing resources using Virtual Machines can easily be obtained from Internet Computing clouds
- Parallel processing
- Optimized libraries
- Web tools to orchestrate

Analysing IoT data: what's the trend?

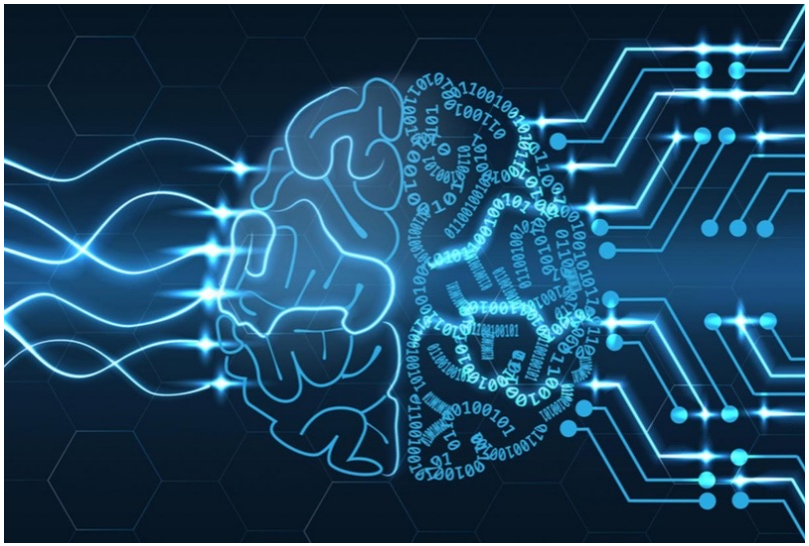


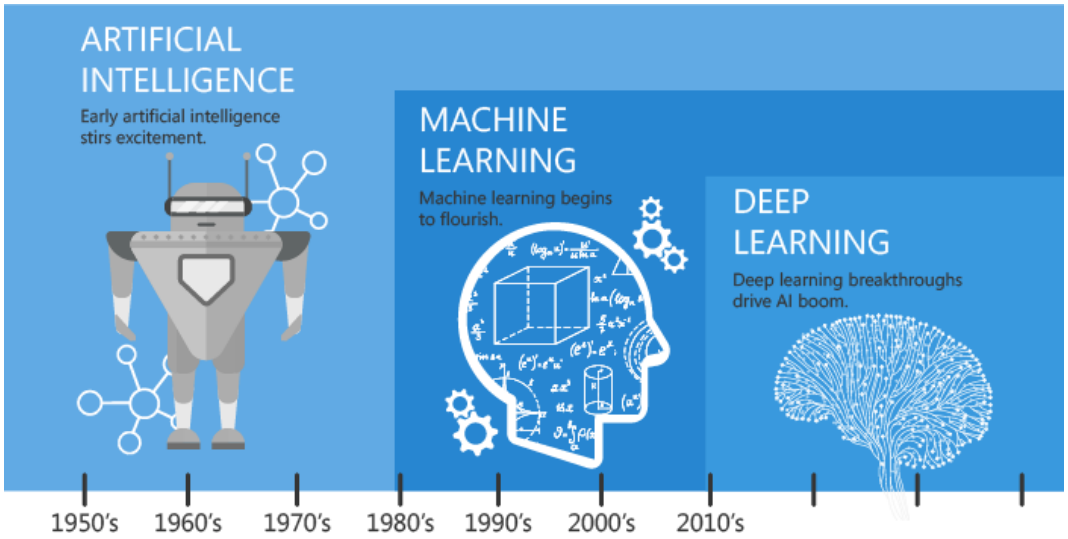


There must be a reason IoT+AI are number 1!

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!

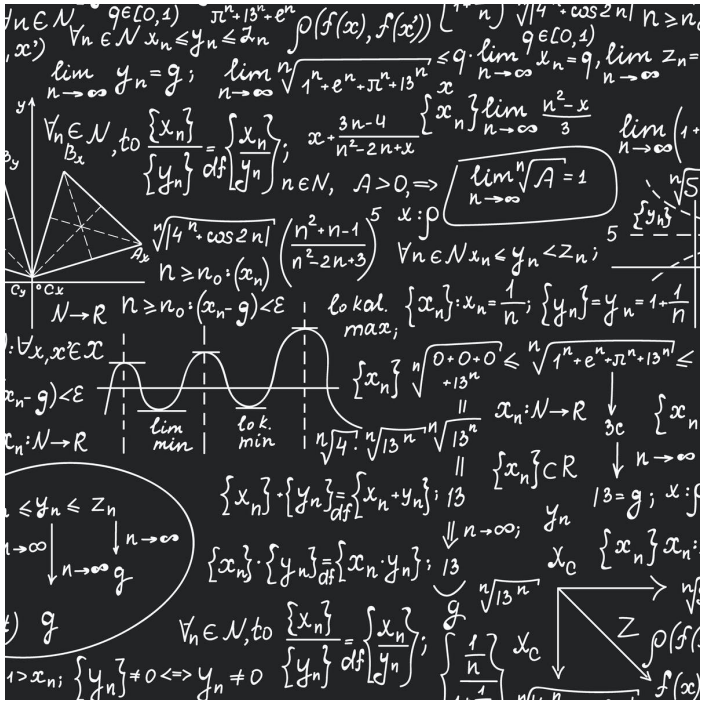




Since an early flush of optimism in the 1950's, smaller subsets of artificial intelligence - first machine learning, then deep learning, a subset of machine learning - have created ever larger disruptions.

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.

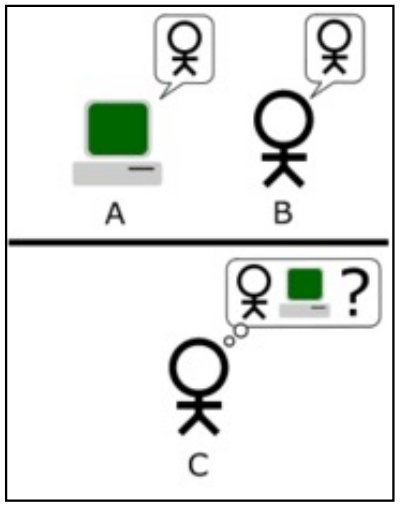


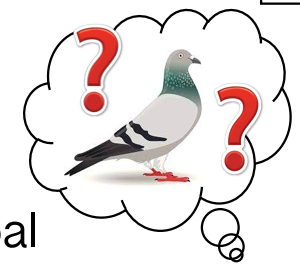
Prof. Congduc Pham
http://www.univ-pau.fr/~cpham

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]





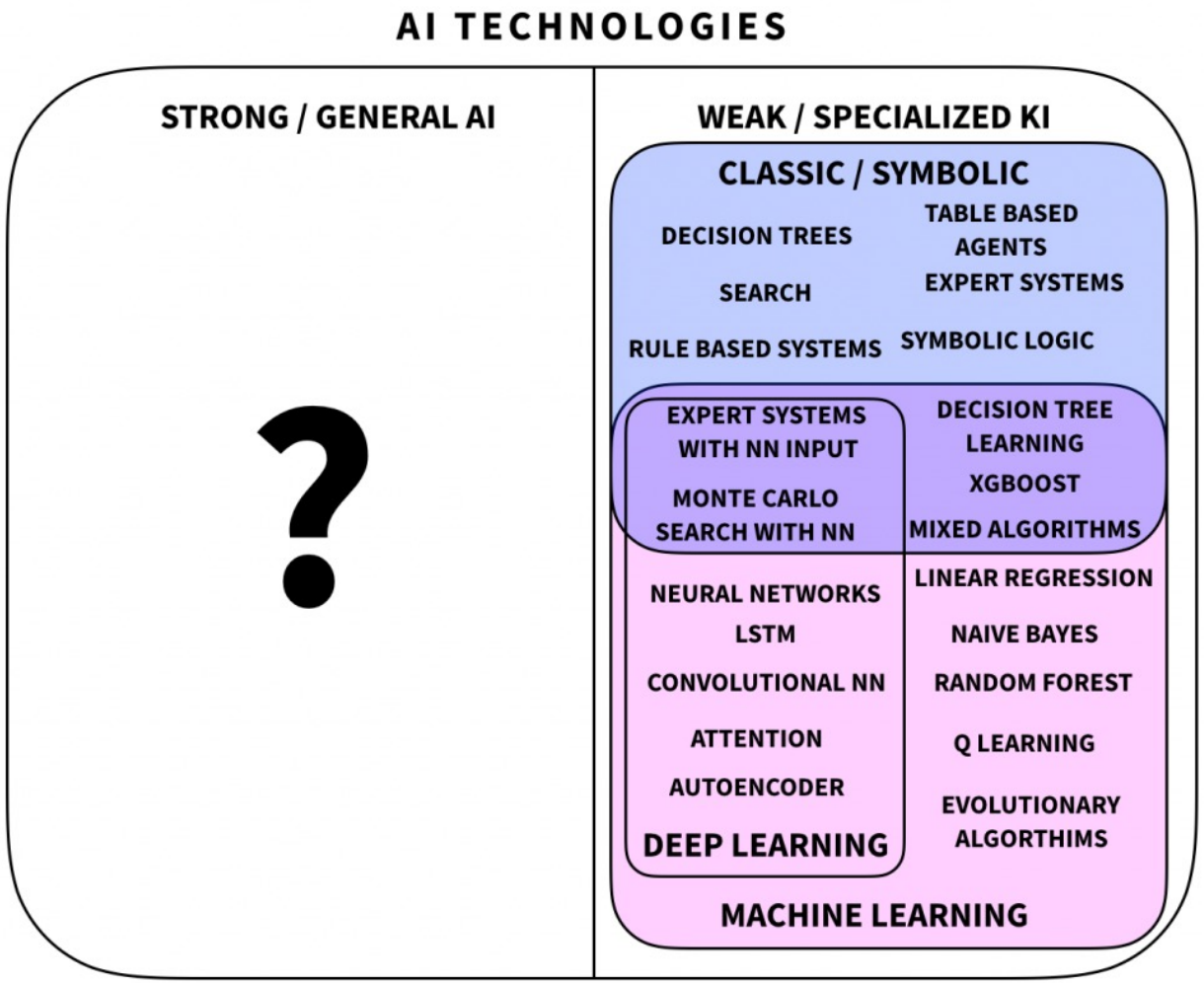
Reflection

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

Systems that think like humans	Systems that think rationally
Systems that act like humans	Systems that **act rationally**

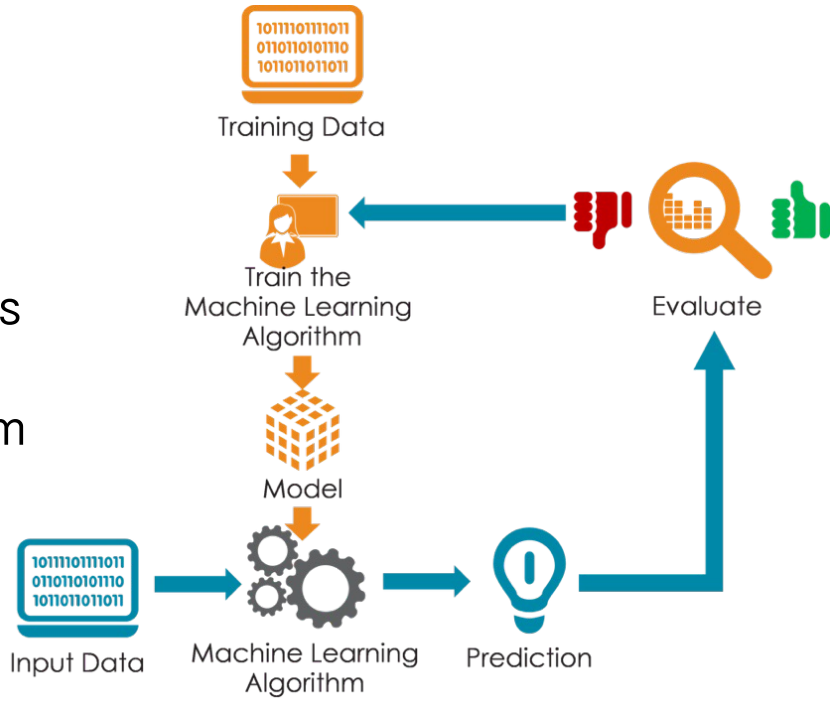
AI focus on **action.** Avoids philosophical issues such as "is the system conscious" etc.

AI Technologies



Machine Learning

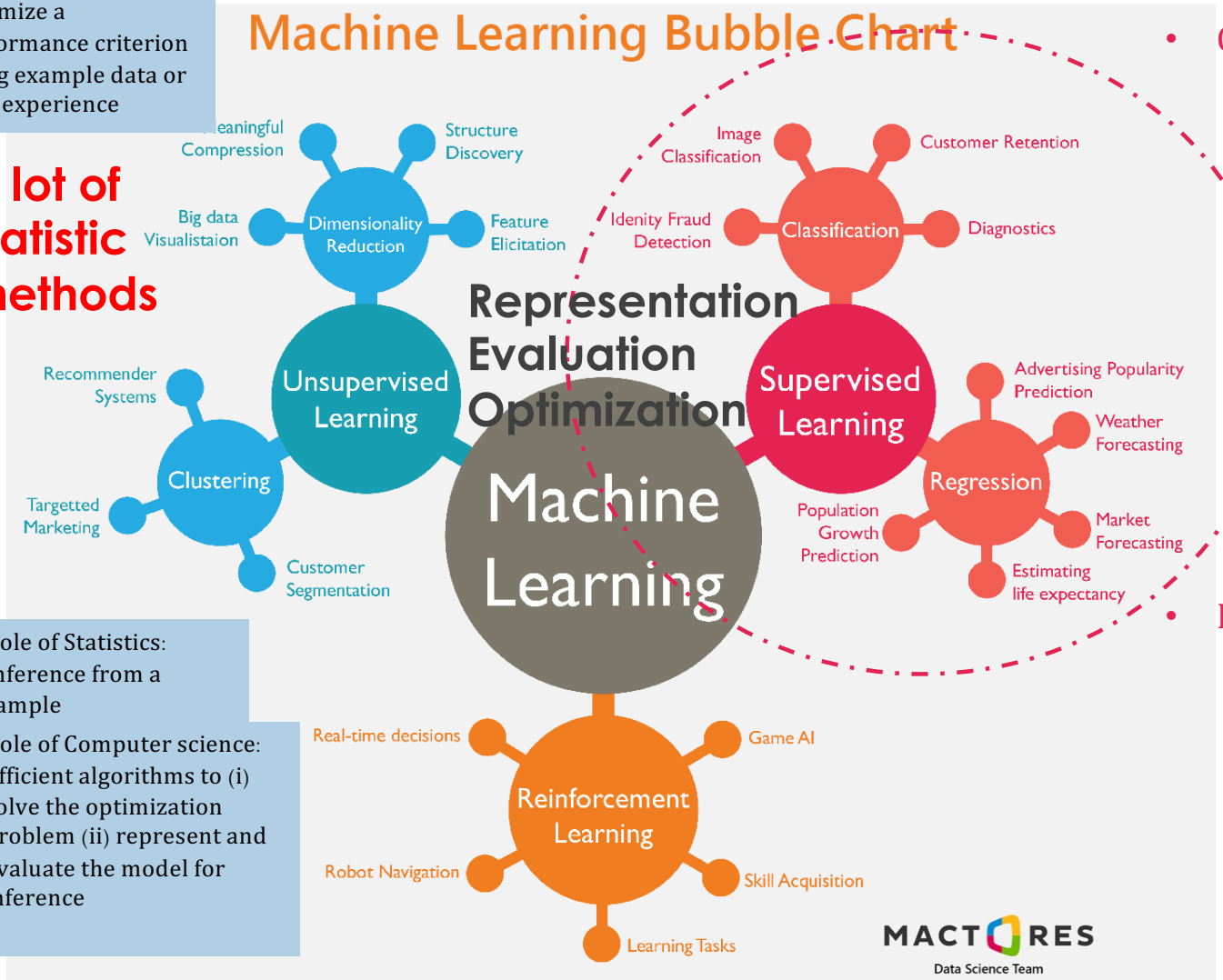
- Develops Narrow Artificial Intelligence systems through examples
  - A developer creates a model and then “trains” it by providing it with many examples
  - The machine learning algorithm processes the examples and creates a mathematical representation of the data that can perform prediction and classification 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

Optimize a performance criterion using example data or past experience

A lot of statistic methods



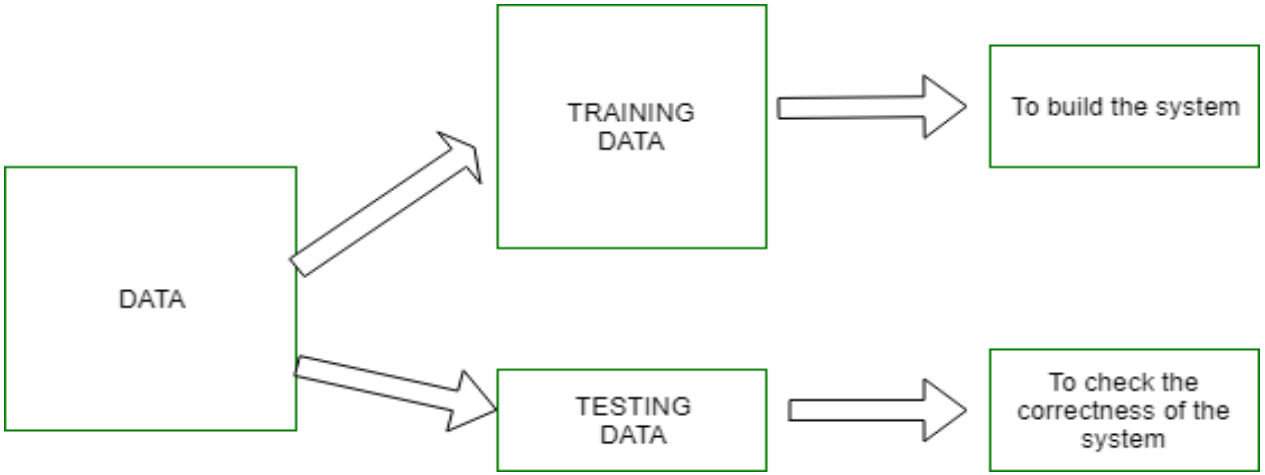
Role of Statistics: Inference from a sample

Role of Computer science: Efficient algorithms to (i) solve the optimization problem (ii) represent and evaluate the model for inference

- Classification
  - Logic
  - SVM
  - Random Forest
  - Hidden Markov
  - ...
- Regression
  - Lasso
  - Ridge
  - Loes
  - KNN
  - Spline
  - XGBoost
  - ...

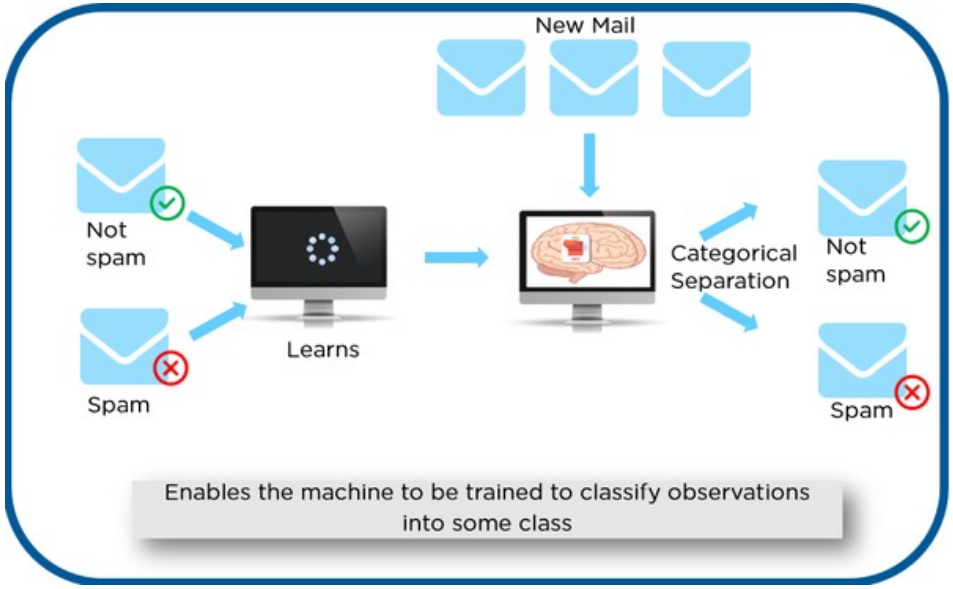
Supervised Learning

- 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*.



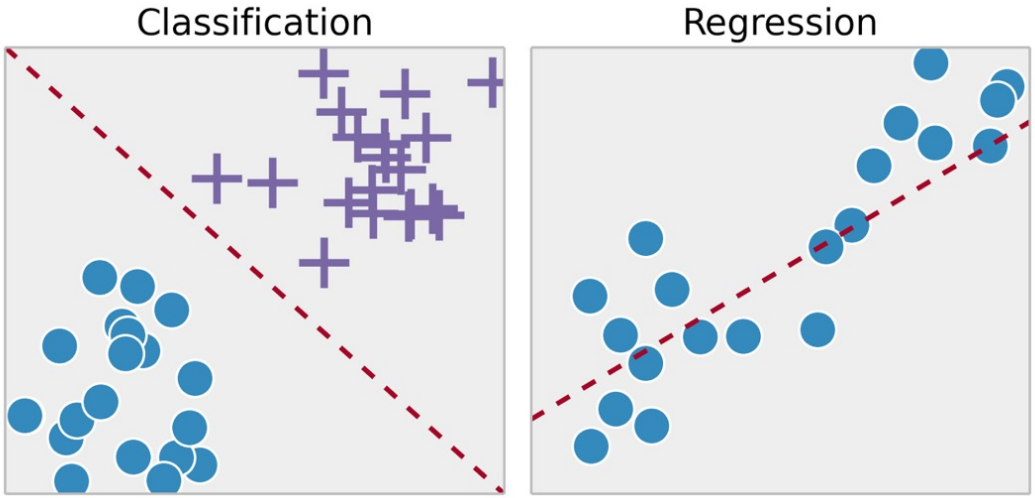
Spam Mail Example

- 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).



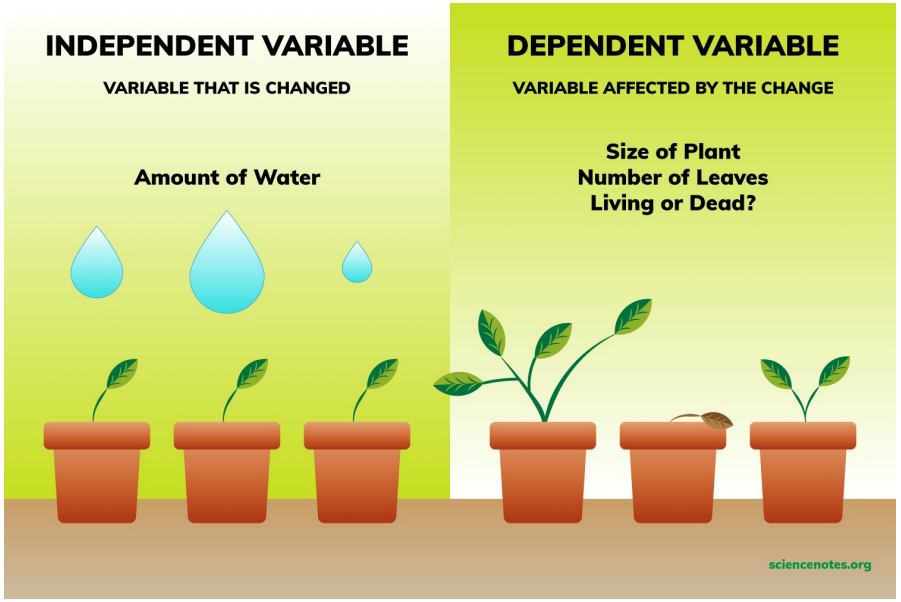
Types of Supervised Learning

- **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”.



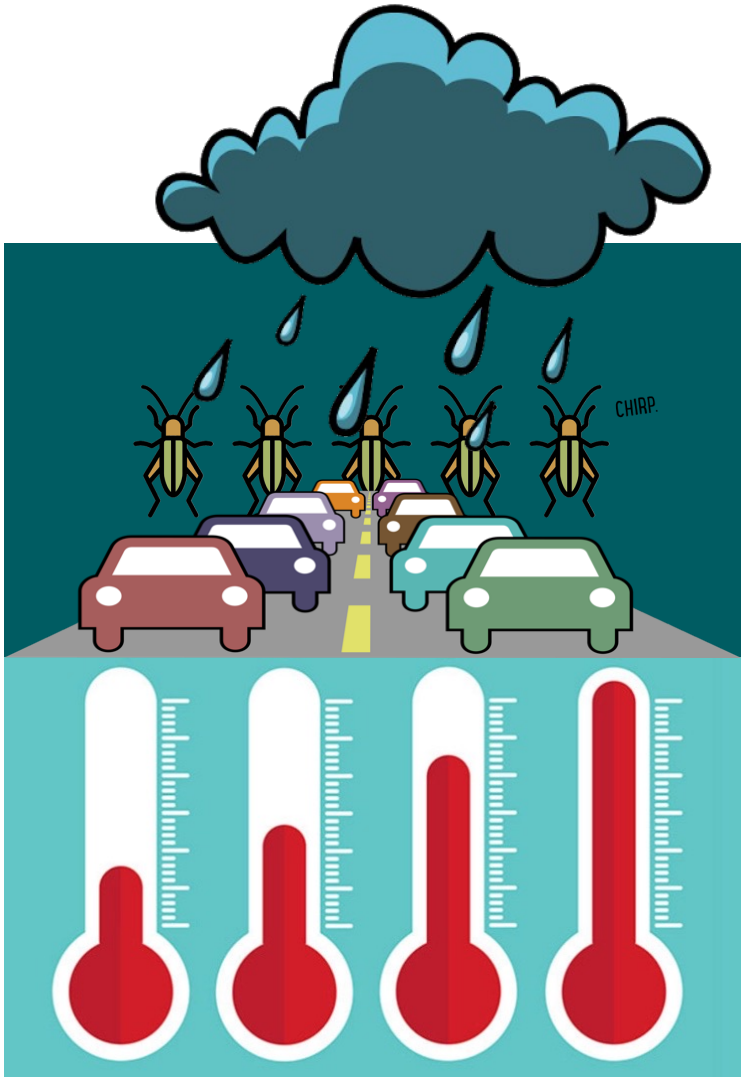
Regression

- **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.*



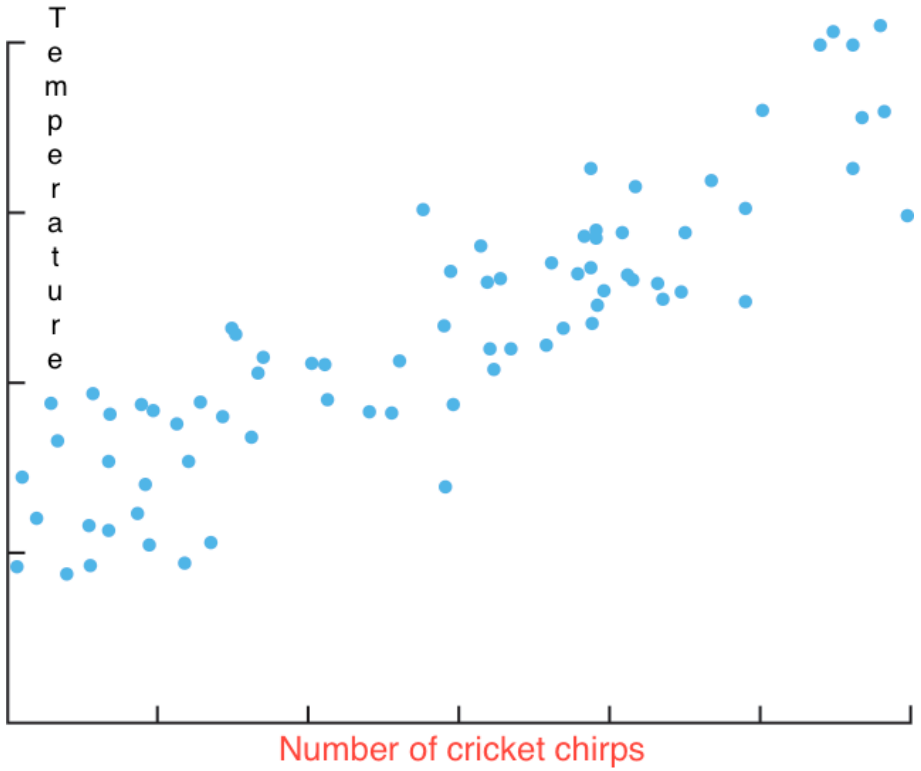
Types of Regression

- **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



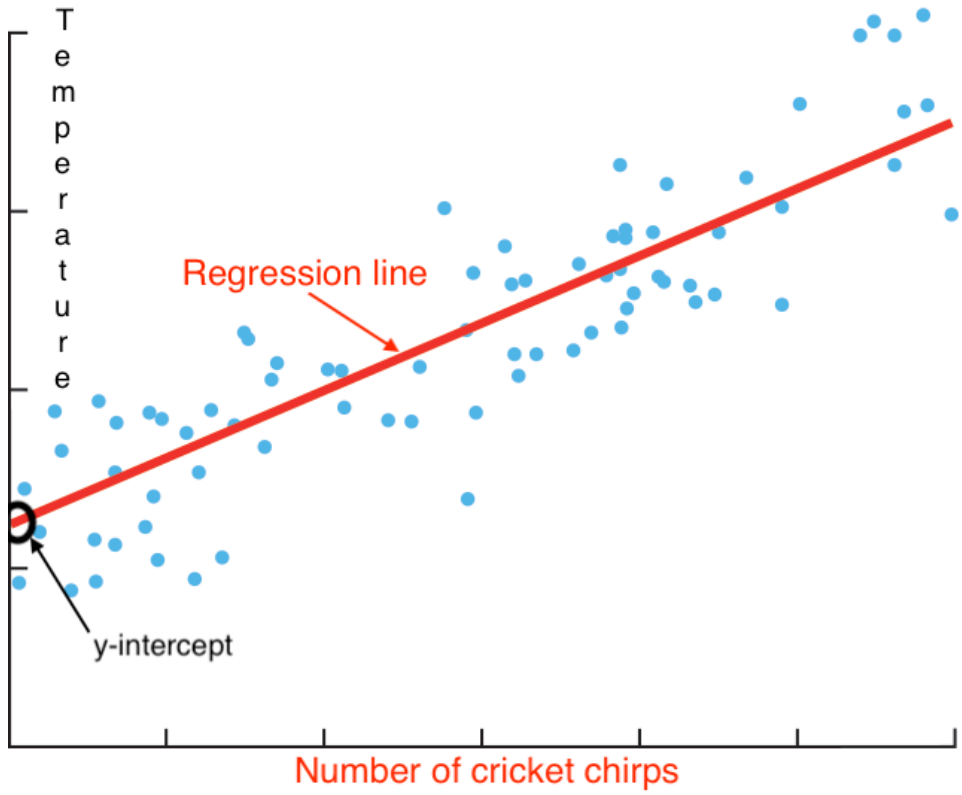
Scatter Plot

- Data gathering on the variables in question
- The vertical scale represents one set of measurements and the horizontal scale the other



Linear Regression

- A linear relationship to predict the (average) numerical value of **Y** for a given value of x using a straight line, called the ***regression line***.
- Knowing the *slope* and the **y**-intercept of that regression line, it is possible to plug in a value for x and *predict* the average value for **Y**. In other words, predict the average **Y** from x.



Simple and multivariate

- Simple linear regression: $\mathbf{Y} = a\boldsymbol{x} + b + u$
- Multiple linear regression: $\mathbf{Y} = a_1\boldsymbol{x}_1 + a_2\boldsymbol{x}_2 + a_3\boldsymbol{x}_3 + \ldots + a_i\boldsymbol{x}_i + b + u$

Y: the variable to predict

$\boldsymbol{x}$: the variable used to predict **Y**

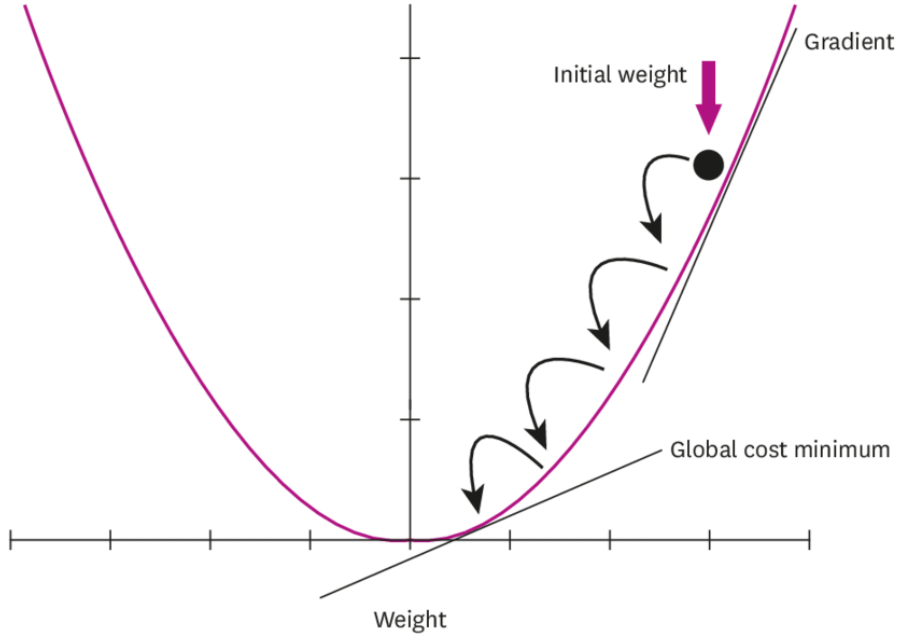
a: the slope

b: the **y**-intercept

u: the regression residual.

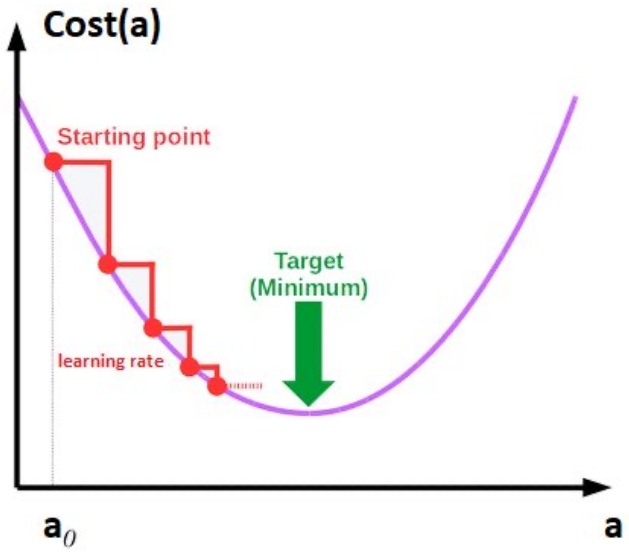
Searching for best a and b

- A **cost function** will usually help to figure out the best possible values for a and b which would provide the best *regression line* for data points
- Then, to find best values for a and b, this search problem is converted into a minimization problem whereby to *minimize* the **error** (cost function) between the **predicted** value and the **actual** value

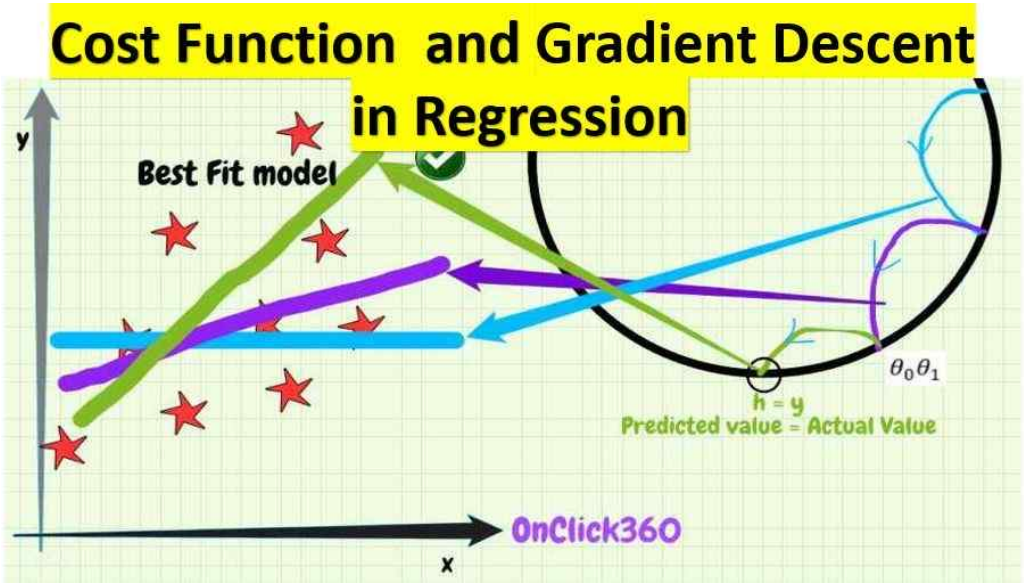


Gradient Descent method

- Gradient Descent is a method of updating a and b to reduce the error (Cost Function).
- The idea is to start with some values for a and b then change these values iteratively to reduce the cost.
- Gradient Descent helps on how to change the values.

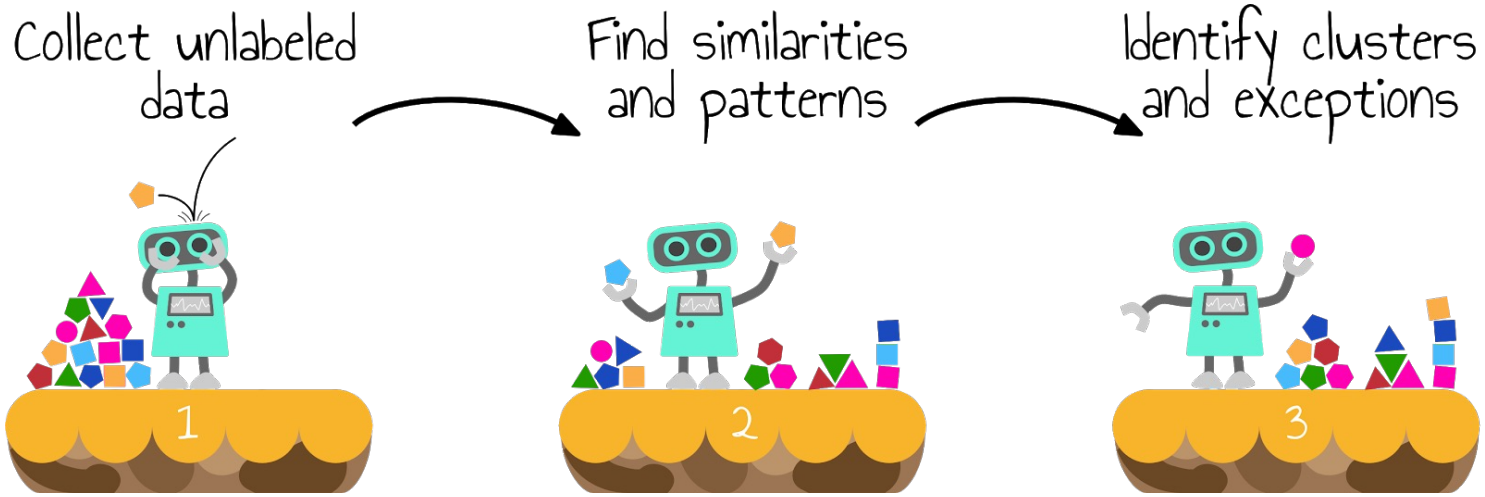


http://aishelf.org/gradient-descent/



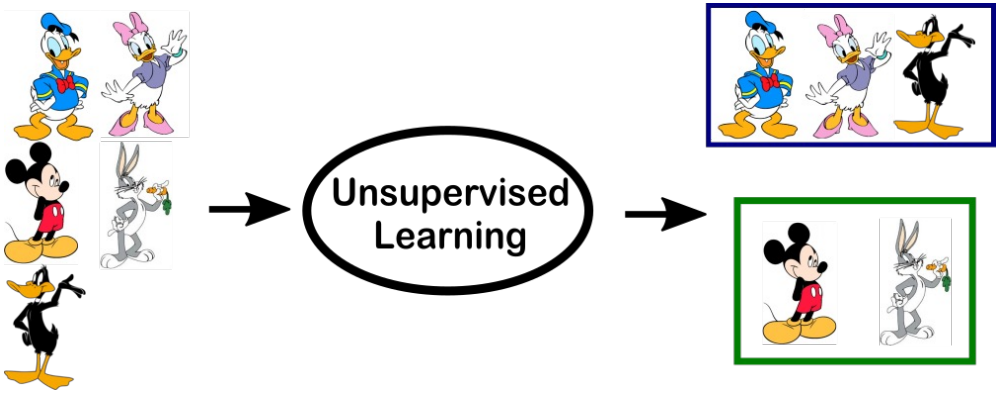
Unsupervised Learning

- 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.



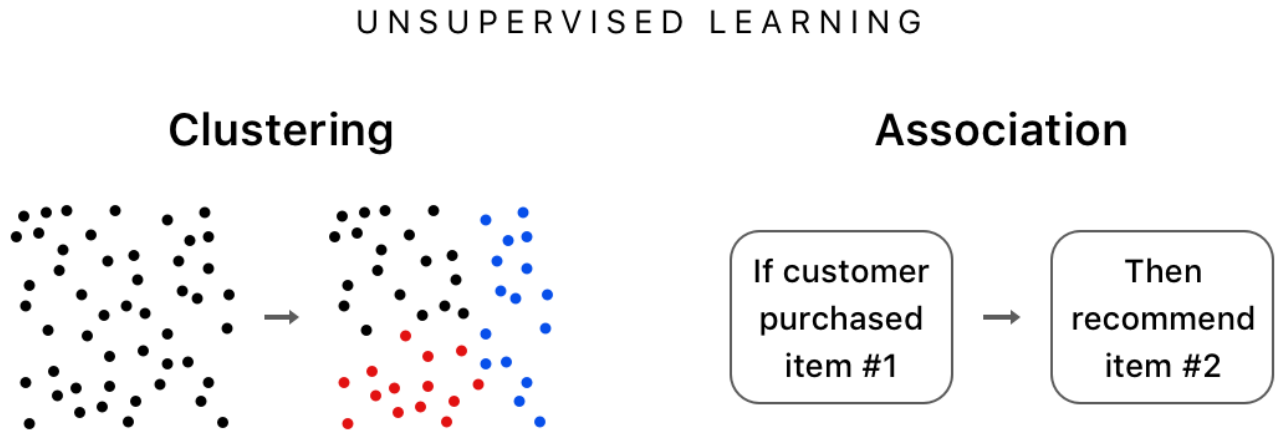
Ducks Example

- 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.



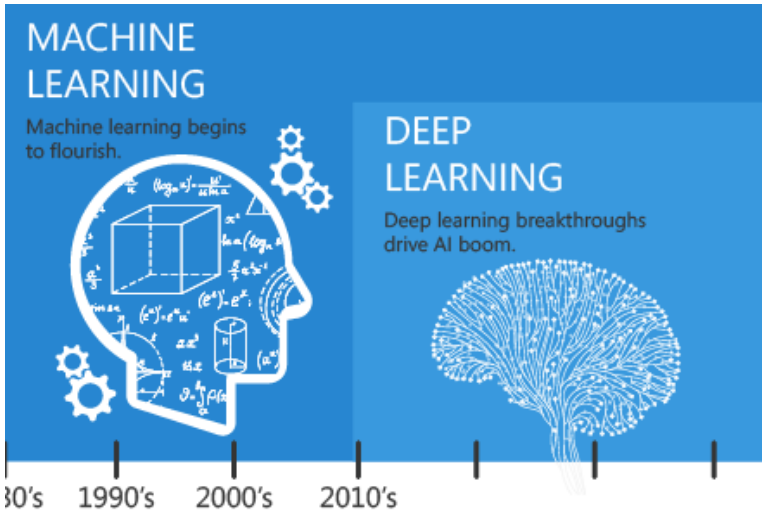
Types of Unsupervised Learning

- **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.



Beyonds Machine Learning?

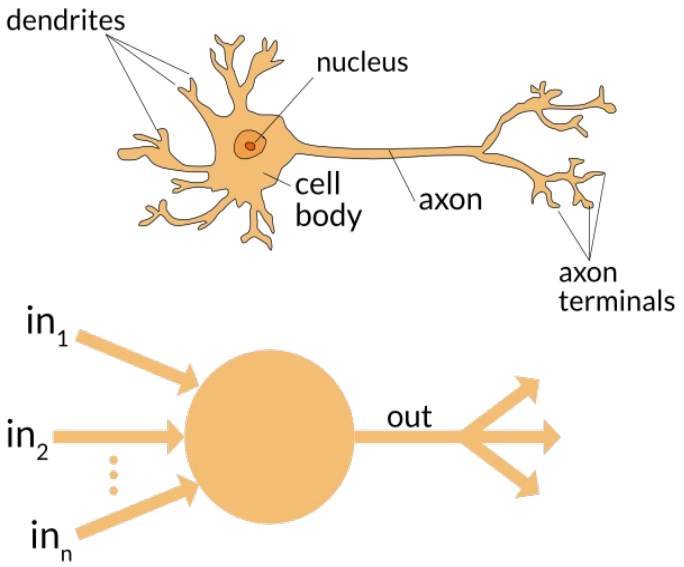
- Combines advances in computing power and special types of **Neural Networks** to learn complicated patterns in large amounts of data
- State of the art for identifying objects in images and words in sounds
- Applied successes in pattern recognition to more complex tasks such as automatic language translation,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



s, smaller subsets of artificial intelligence - first machine learning, then - have created ever larger disruptions.

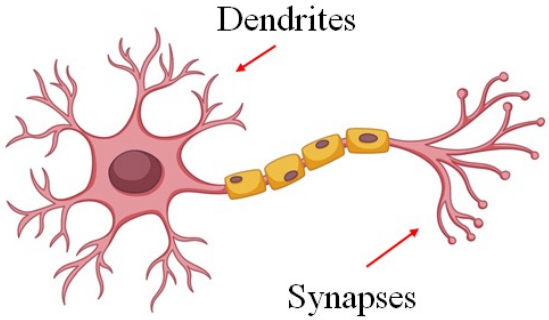
Neural Networks: the Perceptron

- 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)

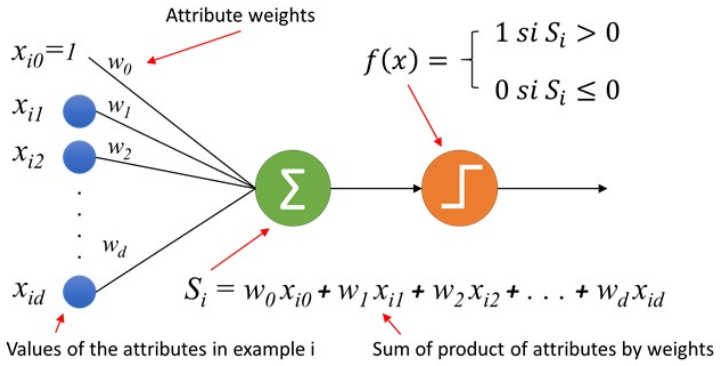


How does a Perceptron Work?

- 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.



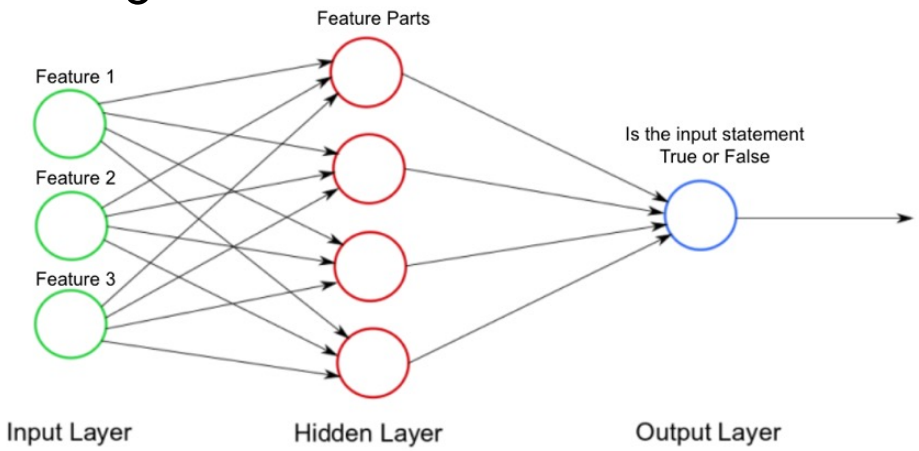
NEURON



PERCEPTRON

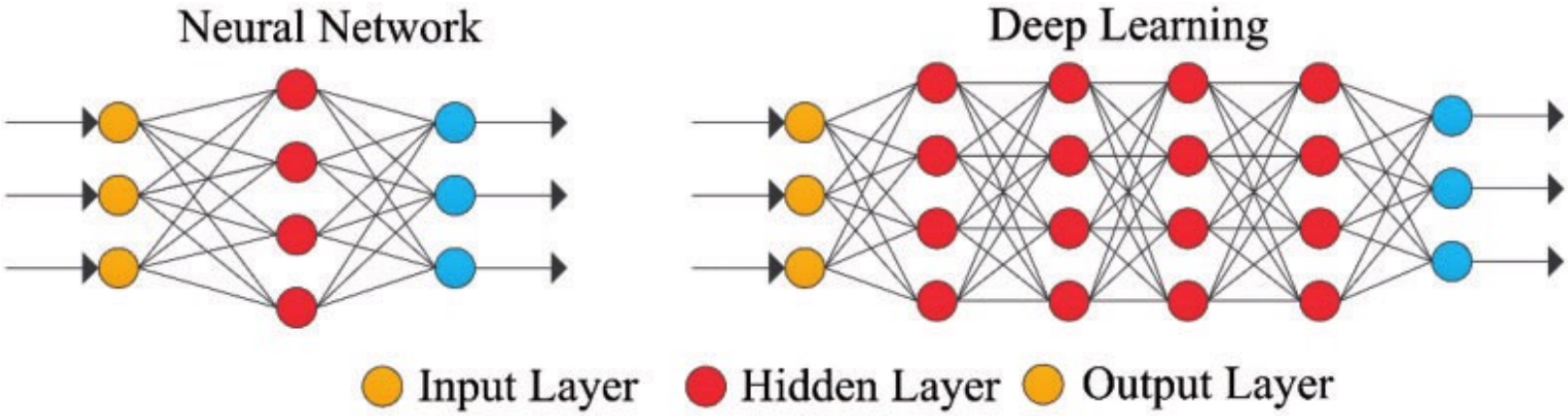
Neural Networks

- 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.



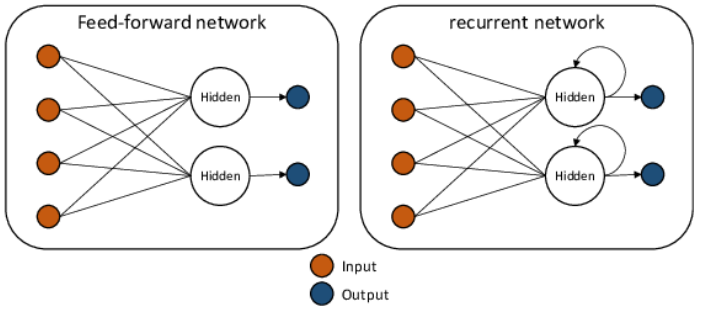
Deep Neural Networks

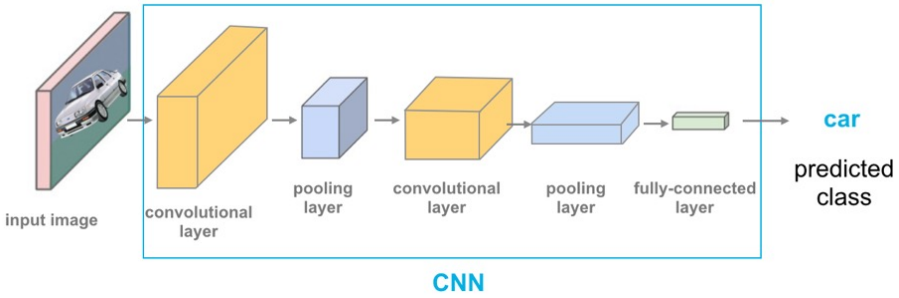
- In the 1980s, most Artificial Neural Networks (**ANN**) were single-layered due to the cost of computation and availability of data.
- Nowadays is possible to afford more hidden layers in ANN, hence the moniker “Deep Neural Networks” (**DNN**).
- Regained popularity since ~2006.
- Rebranded field as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

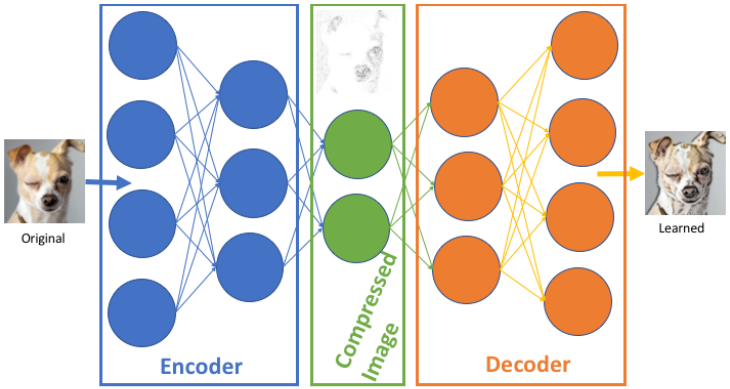


Types of Deep Neural Networks

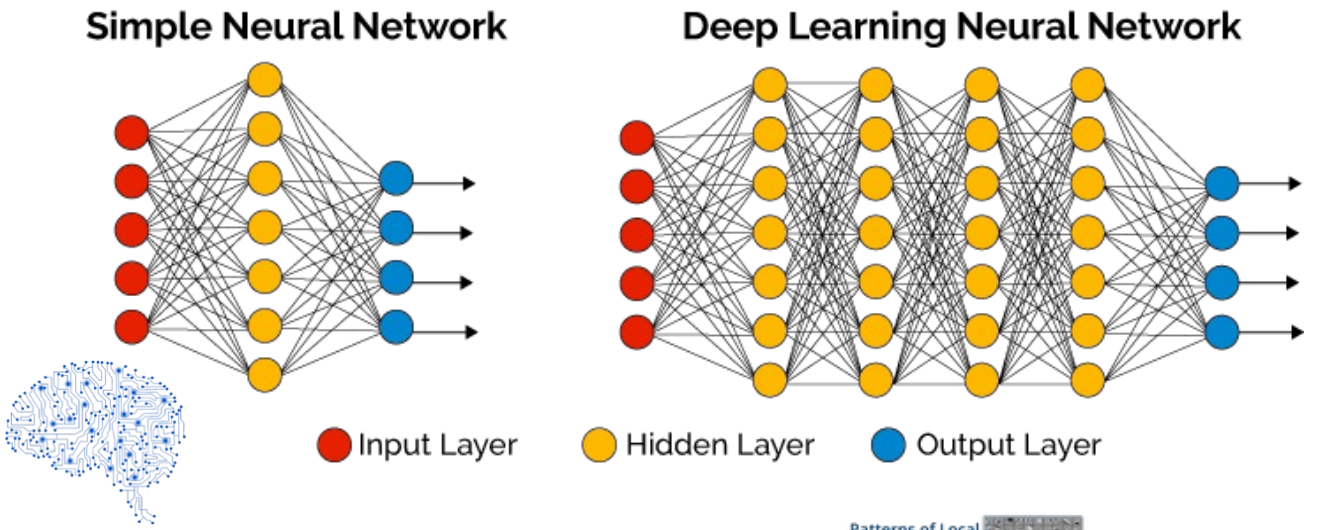
- Feedforward Neural Networks (**FFNs, ANNs** or **NNs**)
- Recurrent Neural Networks (**RNNs**)
- Convolutional Neural Networks (**CNNs**)
- Autoencoder Neural Networks (**AEs**)

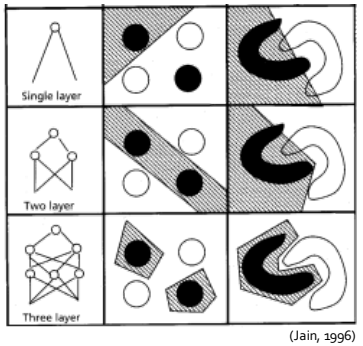






CNN success thanks to GAFA

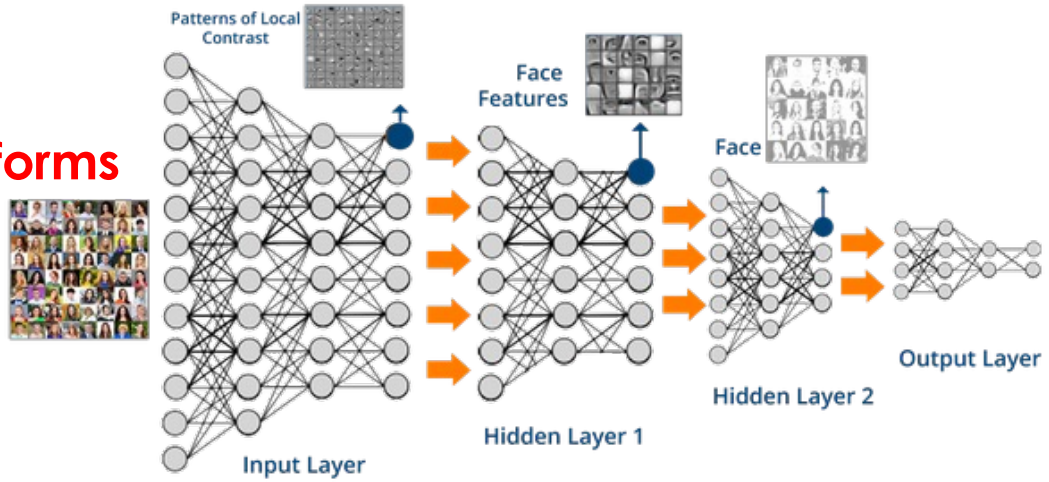




(Jain, 1996)

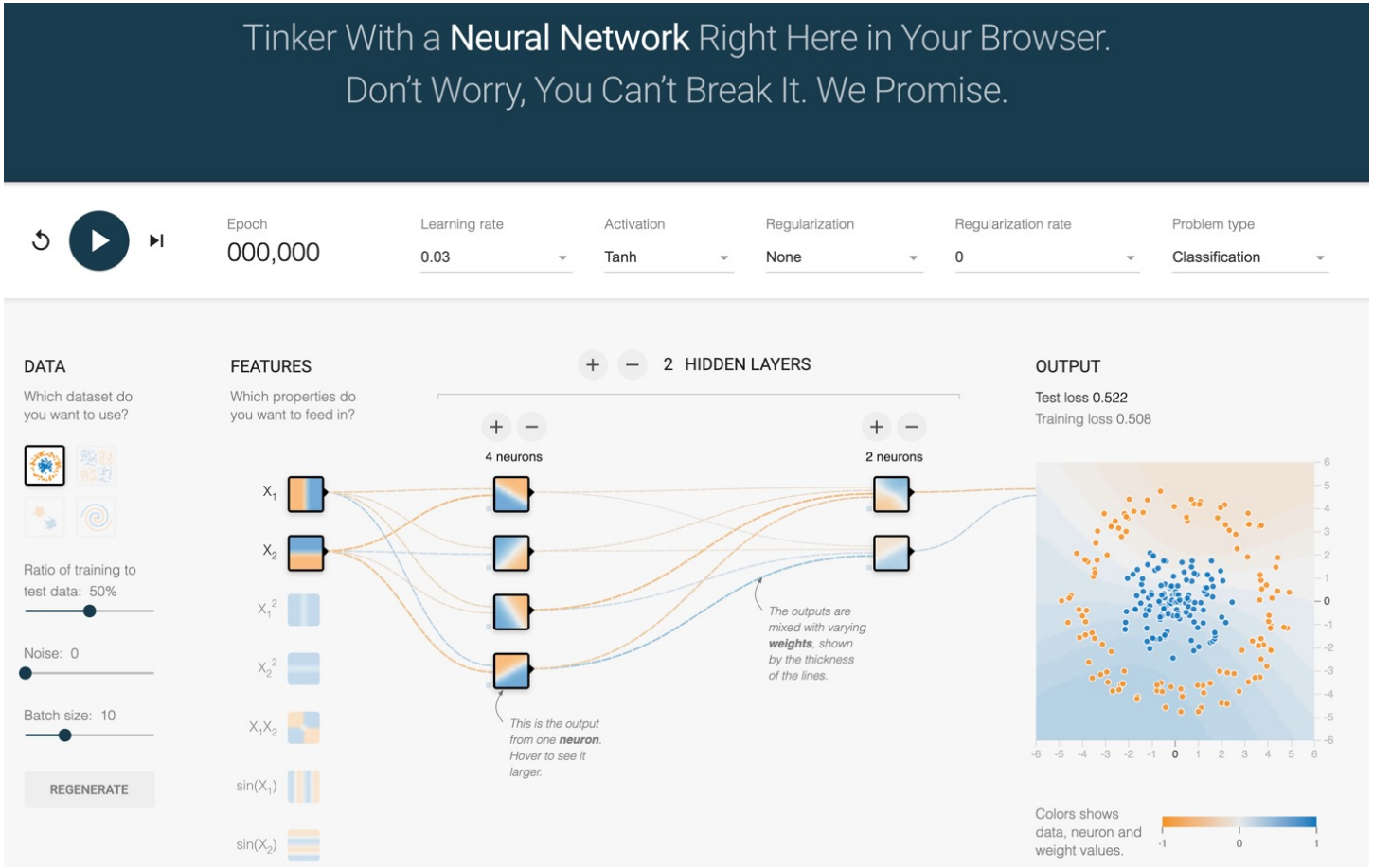
Voice/Face/Patterns recognition on many platforms

- Facebook
- Google Photos
- Twitter
- Siri
- …

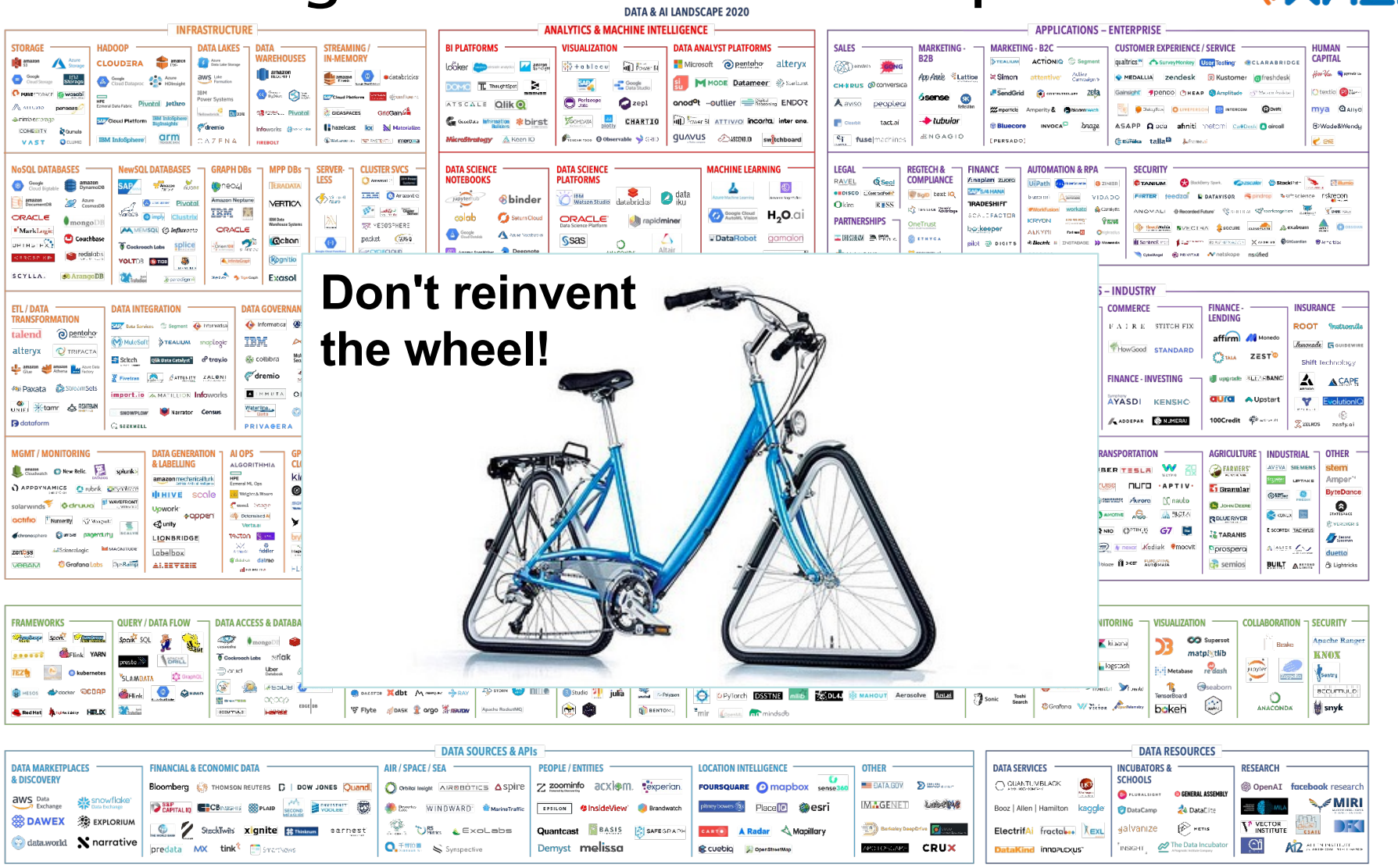


Want to try DeepLearning?

- https://playground.tensorflow.org/



The BigData & AI Landscape



IOT+AI ILLUSTRATION

PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

Intel-IrriS

Smallholders & Smart Agriculture?

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

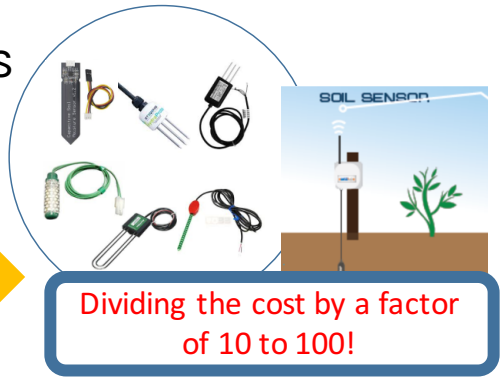
Illustration with Intel-IrriS

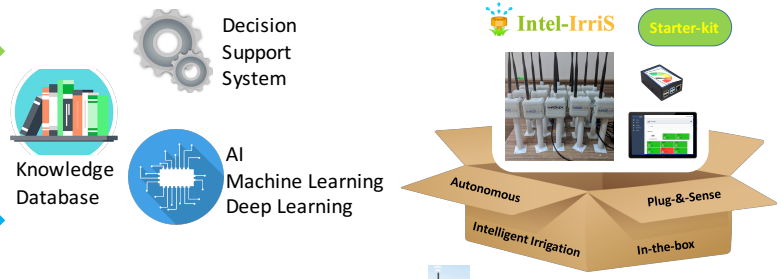
PRIMA PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

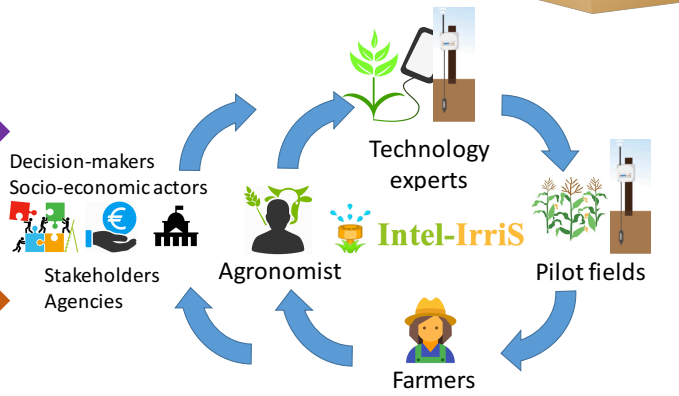
Intel-IrriS June 2021 – May 2024

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



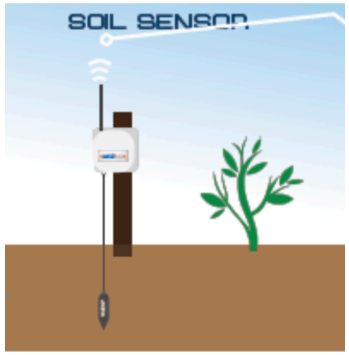




Low-cost sensors: accuracy?

Sensor part

Intel-IrriS



- Build on low-cost, low-power IoT expertise WAZIUP
- 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

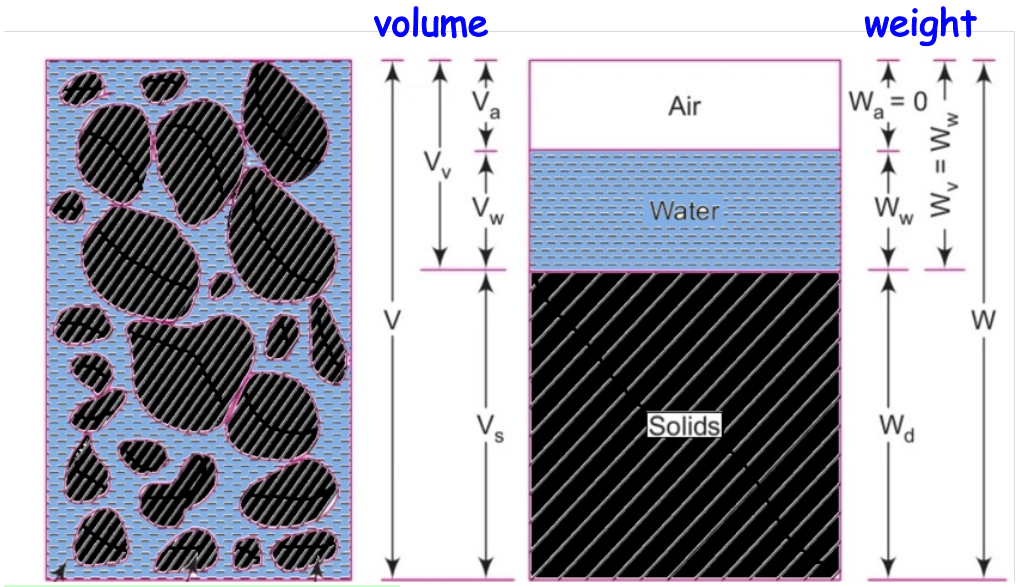
Understanding soil water

Source: Christian Hartmann, IRD

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

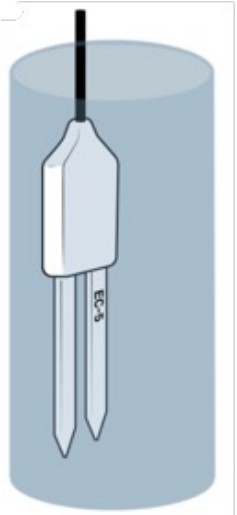
Geometry of the aggregates & pores

Schematical view of the 3 phases



Saturated soil

water volume capacitive sensors



Decagon EC5
120 euros

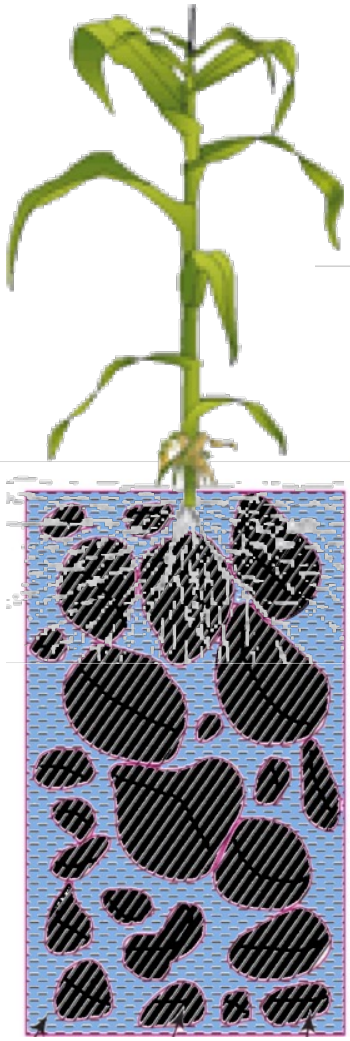
accurate

Gravity SEN193
6 euros

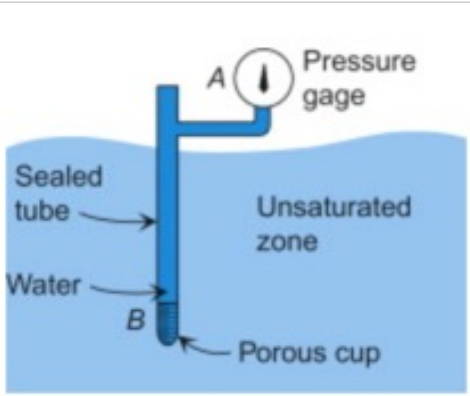
under test

Soil water? Not enough!

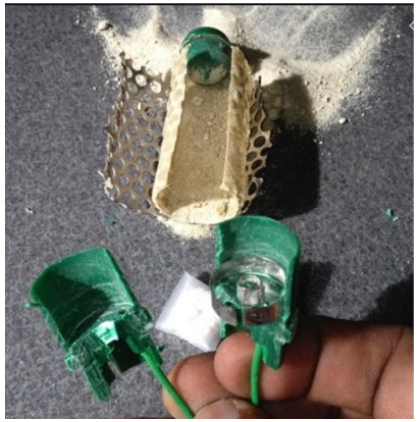
Source: Christian Hartmann, IRD



- 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?

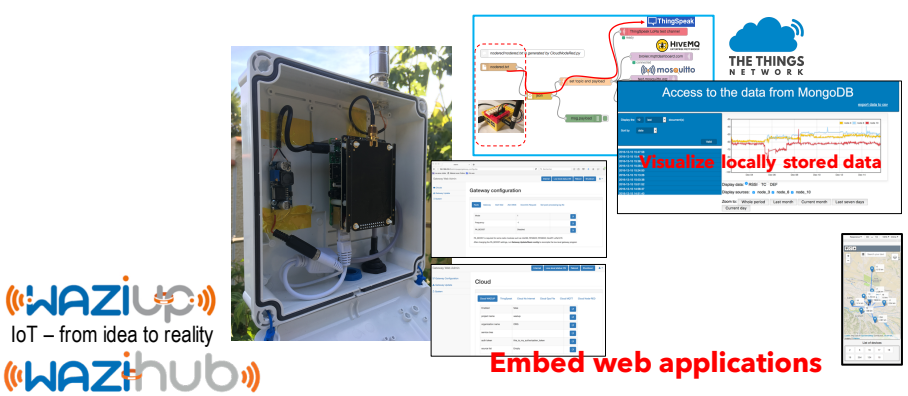
Smart embedded control

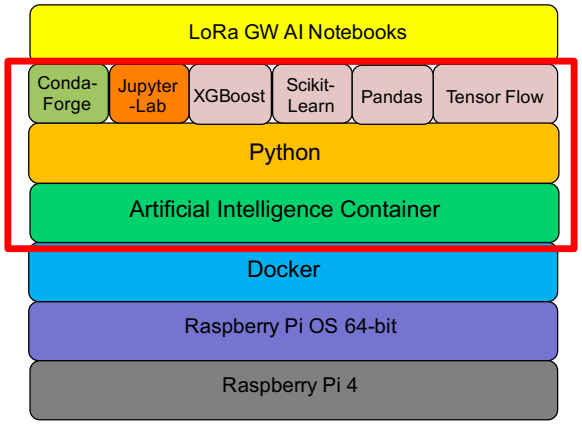
- Build on low-cost embedded & open IoT gateway expertise
- Implement the “Intelligent Irrigation in-the-box” vision
- Model complex interactions: water-soil-plant interaction, evapotranspiration,…
- Embed Decision Support System (DSS) and disruptive Artificial Intelligence (AI)
- Integration of multiple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

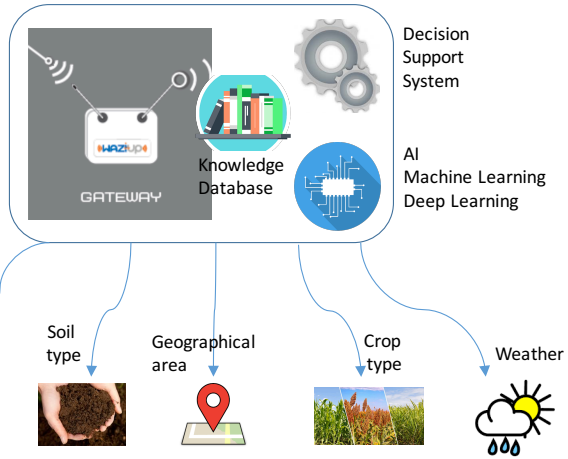
Prof. Congduc Pham
http://www.univ-pau.fr/~cpham

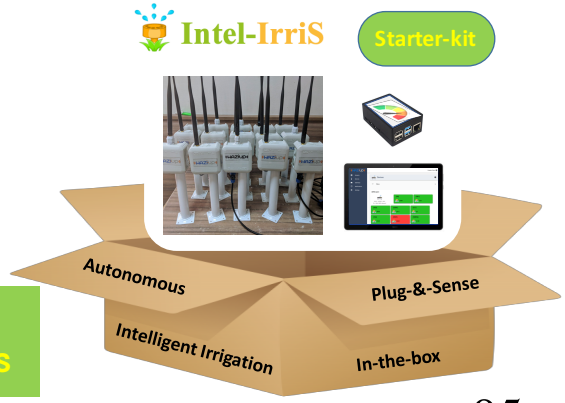
Edge-AI for fully autonomous system

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





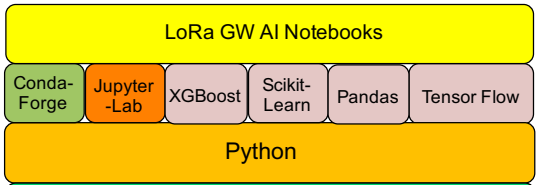




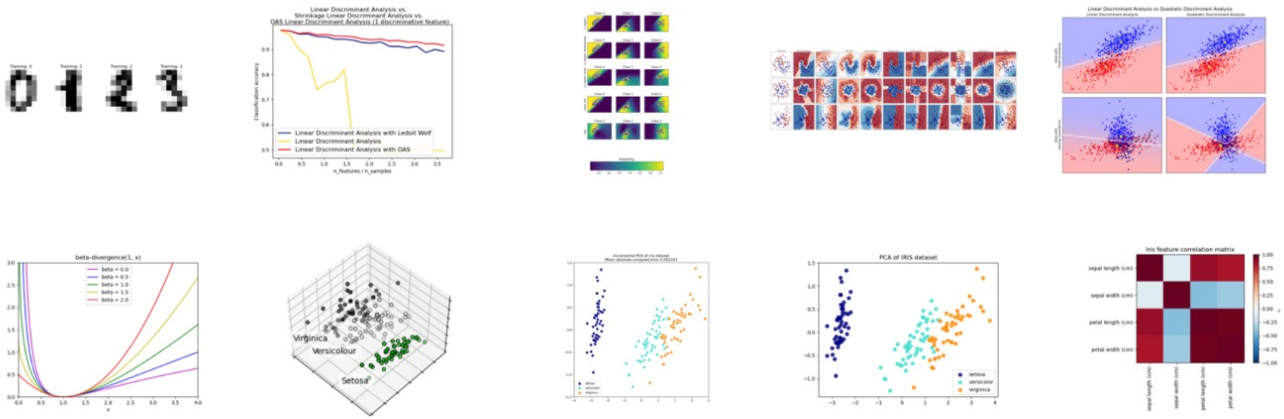
Integration of multiple knowledge streams

Fully autonomous

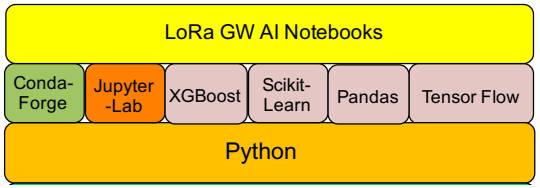
Package: Scikit-Learn



- Scikit-learn is an open source machine learning library that supports supervised and unsupervised learning
- It also provides various tools for model fitting, data preprocessing, model selection and evaluation, and many other utilities
- https://scikit-learn.org/stable/auto_examples/index.html



Package: XGBoost

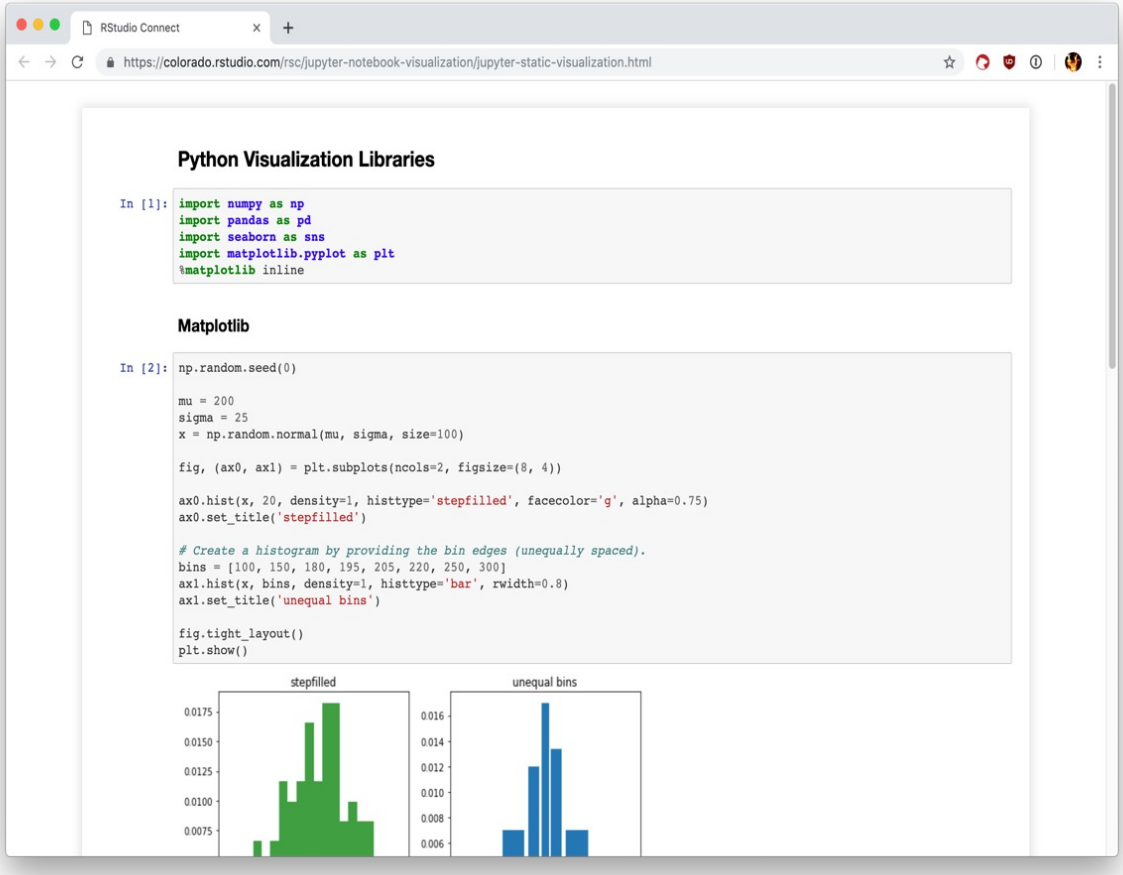


- eXtreme Gradient Boosting is an optimized open source implementation of the gradient boosting trees algorithm
- Gradient Boosting is a **supervised learning algorithm** whose principle is to combine the results of a set of data and weaker models in order to provide a **better prediction** (regression)
- XGBoost includes a large number of hyperparameters which can be modified and tuned for improvement
- XGBoost is not part of Scikit-Learn but works perfectly with it
- XGBoost behaves remarkably in machine learning competitions!
- Source: "XGBoost: The super star of algorithms in ML competition". See examples from http://aishelf.org/xgboost/

Jupyter Notebook

Web application that allows to create and share documents that contain live code, equations, visualizations and narrative text.

- Data cleaning and transformation
- Numerical simulation
- Statistical modeling
- Data visualization
- Machine learning, and more.



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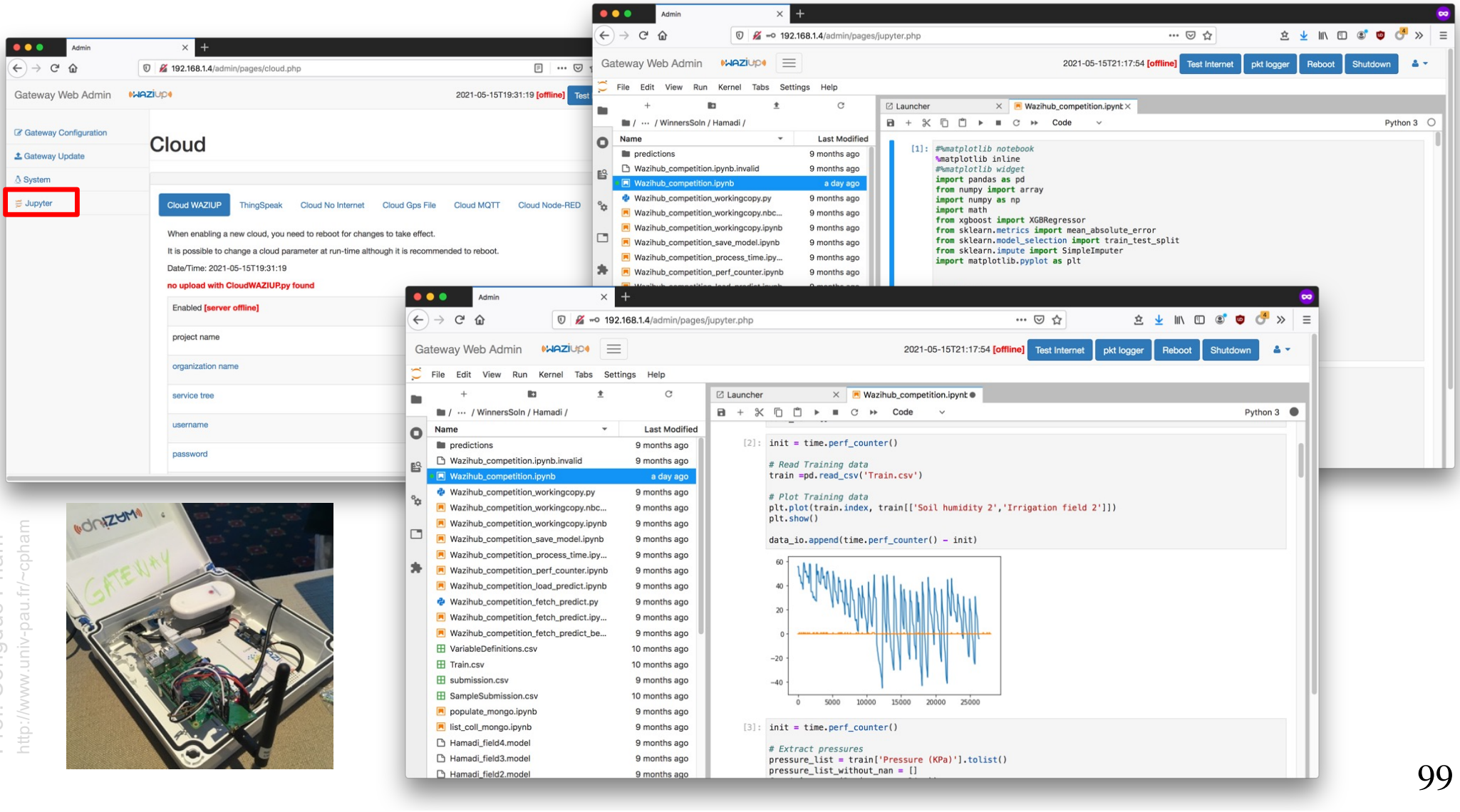
Edge-AI integration: JupyterLab



Conclusions

- Internet-of-Things provides the unique feature to make things "talk" to us: localisation, surrounding environmental conditions, particular events, …
- After many years of maturing IoT technologies…
- … current trends is to optimize IoT for verticals
- IoT is a concept made possible by technologies
- IoT concept allows for collection of massive amount to data
- Optimizing for verticals means take out the most of these data…
- … to find correlations, predict trends to…
- … give meaningful information to end-users
- It is a huge opportunity to provide low-cost, efficient systems that can be deployed "out-of-the-box"

IOT_2: Unleash the power of IoT data

Booster Pau – Learning Capsule – 2021

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

IoT – from idea to reality

Paving for the next 10 years of innovation in IoT and AI