IOT_2: Unleash the power of IoT data

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

OneTech Booster

Capsule Booster – 2022

Prof. Congduc Pham

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

UNIVERSITÉ DE PAU ET DES PAYS DE L'ADOUR

LIUPPA

European Commission

Horizon 2020
European Union funding
for Research & Innovation

WAZIUP

IoT – from idea to reality

WAZIHUB

HUBiquitous

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

PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

Intel-IrriS

RESILINK

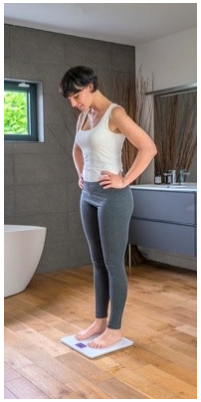
Advanced and disruptive IoT/AI technologies targeting the smallholder community for increased resilience

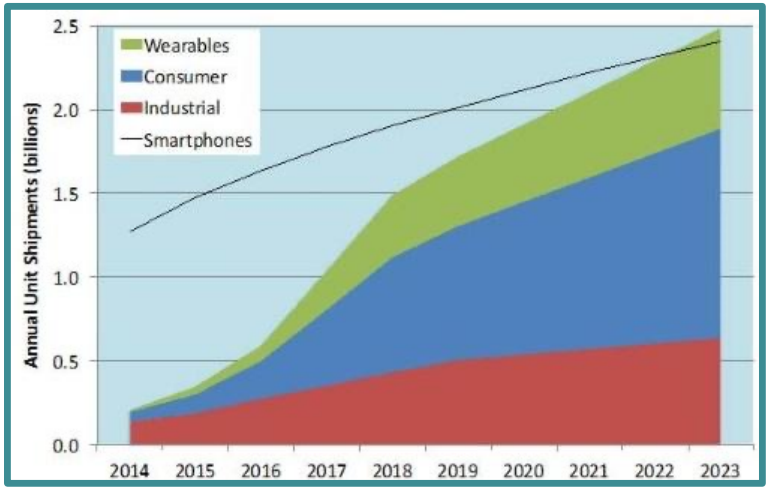
IOT

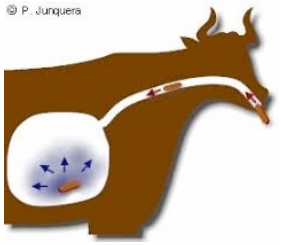
TECHNOLOGY ?

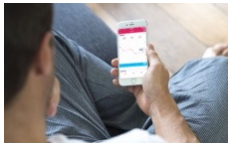
CONCEPT ?

IoT=communicating objects









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IoT=interactions with physical world

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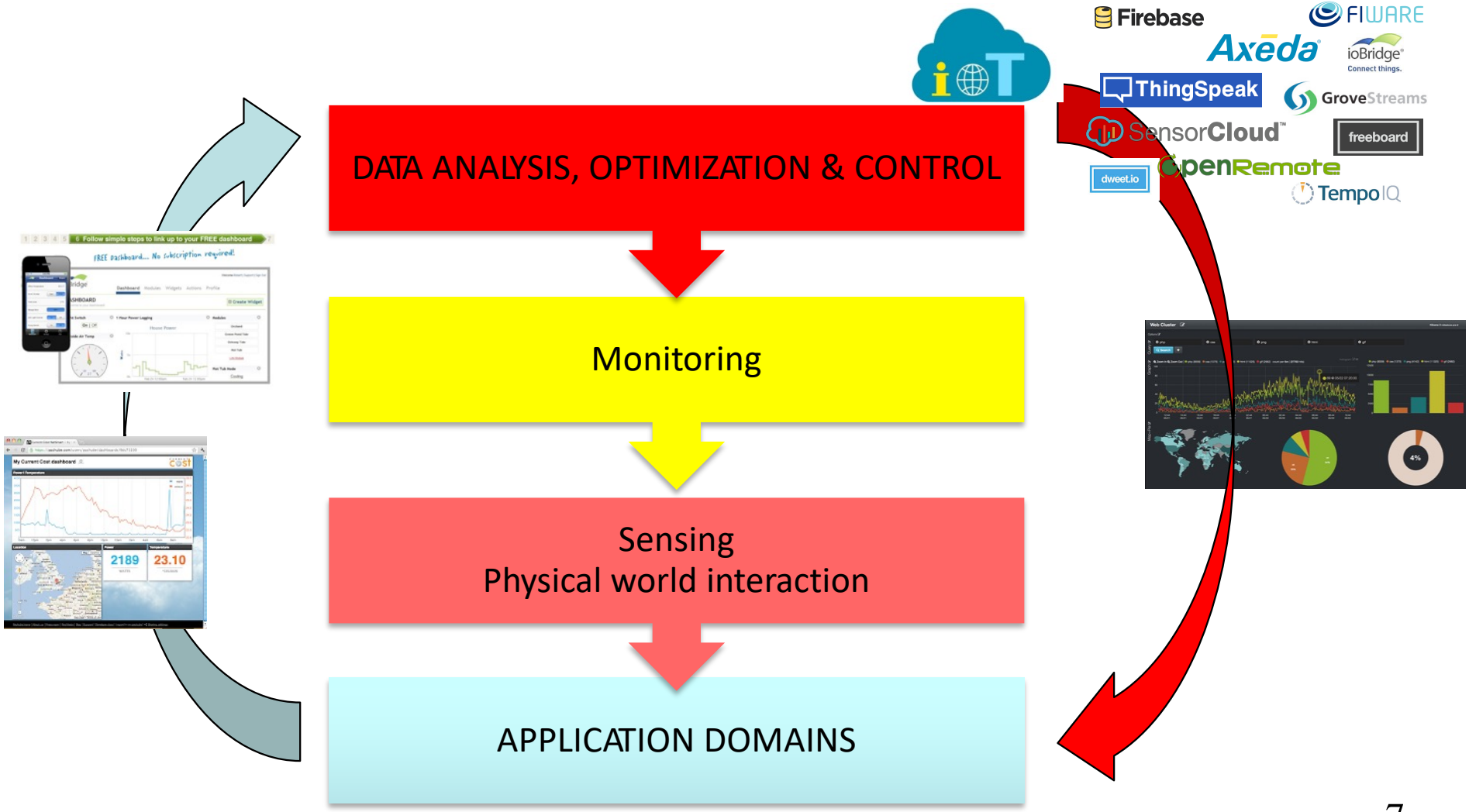
Sense, Monitor, Optimize & Control



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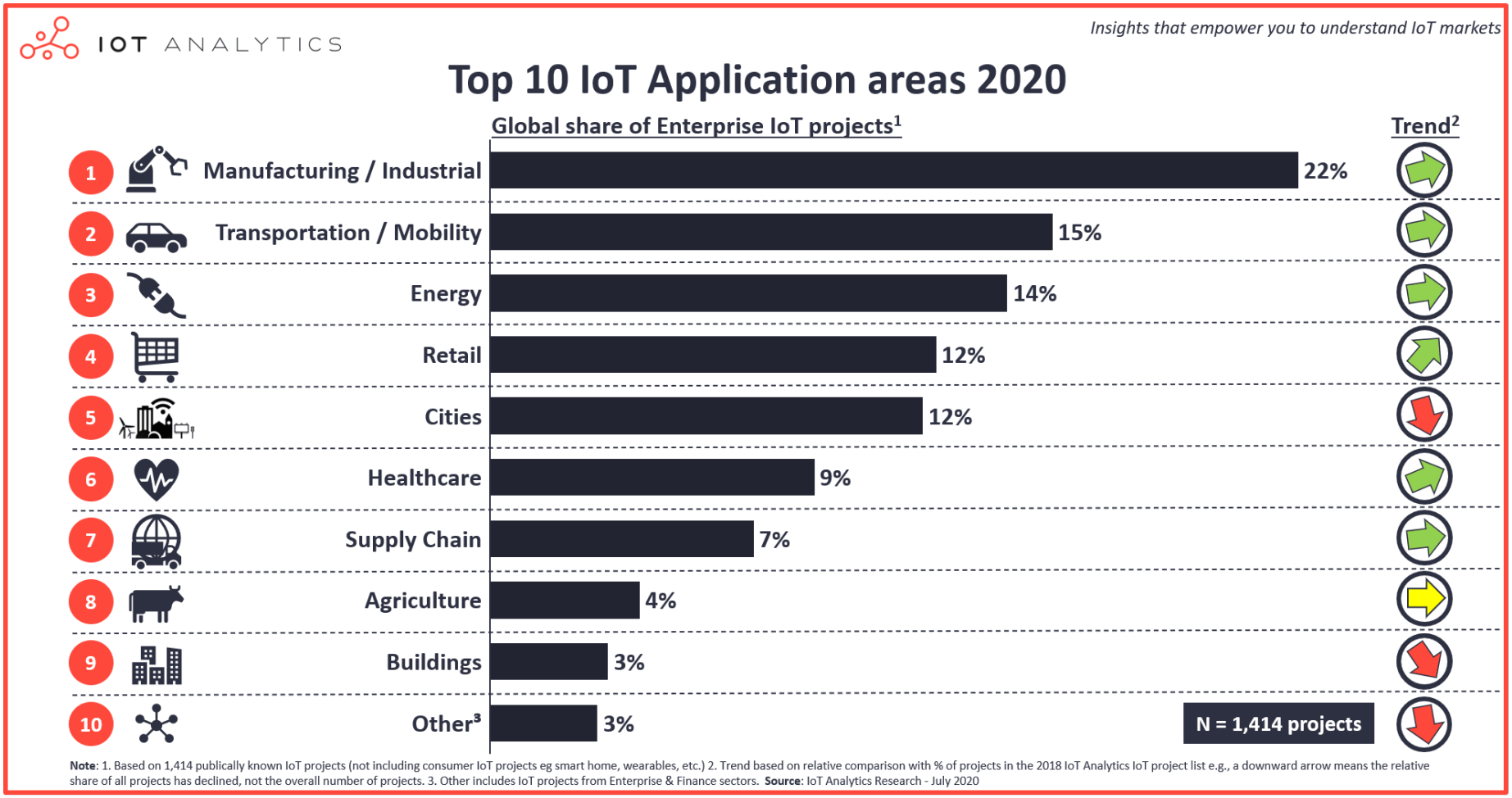
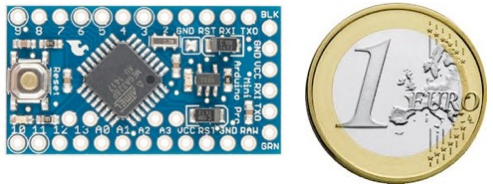
Top IoT applications, 2020



Low-cost microcontroller boards

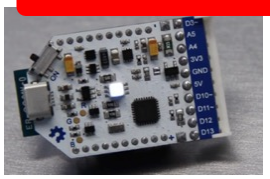
Arduino Pro Mini



LoPy

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

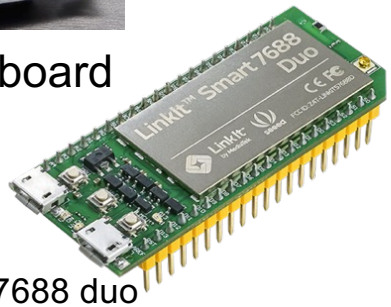
http://blog.atmel.com/2015/04/09/25-dev-boards-to-help-you-get-started-on-your-next-iot-project/



Theairboard

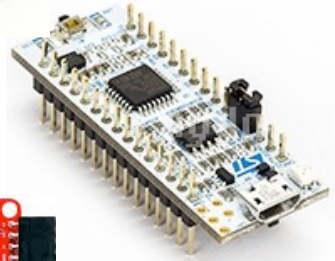
Expressif ESP32

Teensy 3.2



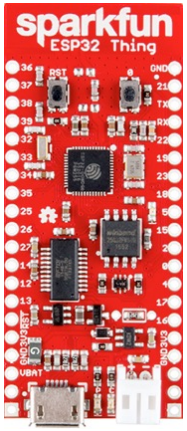
LinkIt Smart7688 duo

STM32 Nucleo-32



Heltec ESP32 + OLED

Adafruit Feather



Sparkfun ESP32 Thing

Tessel

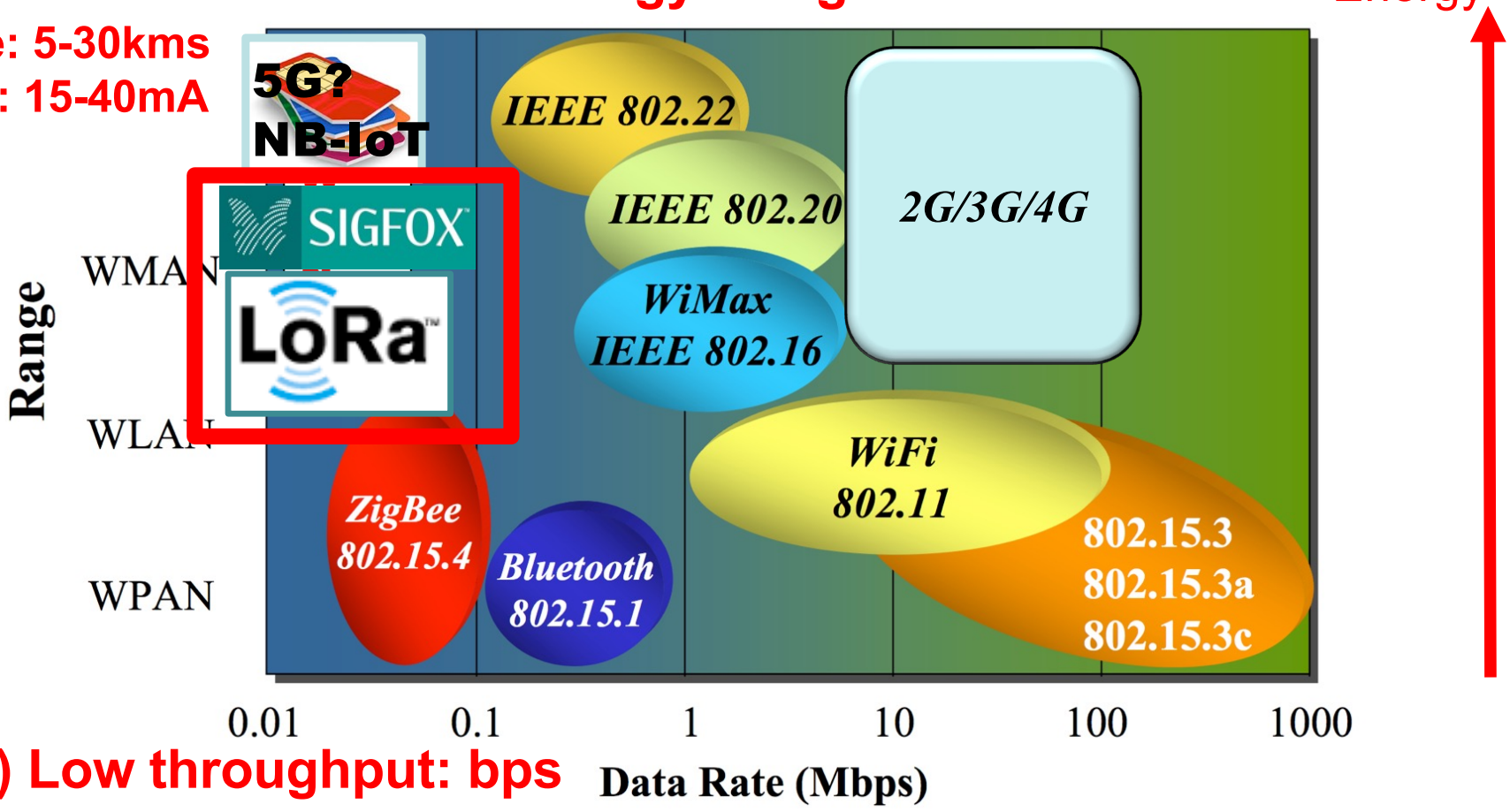
SodaqOnev2

Tinyduino

Low-power & long-range radios

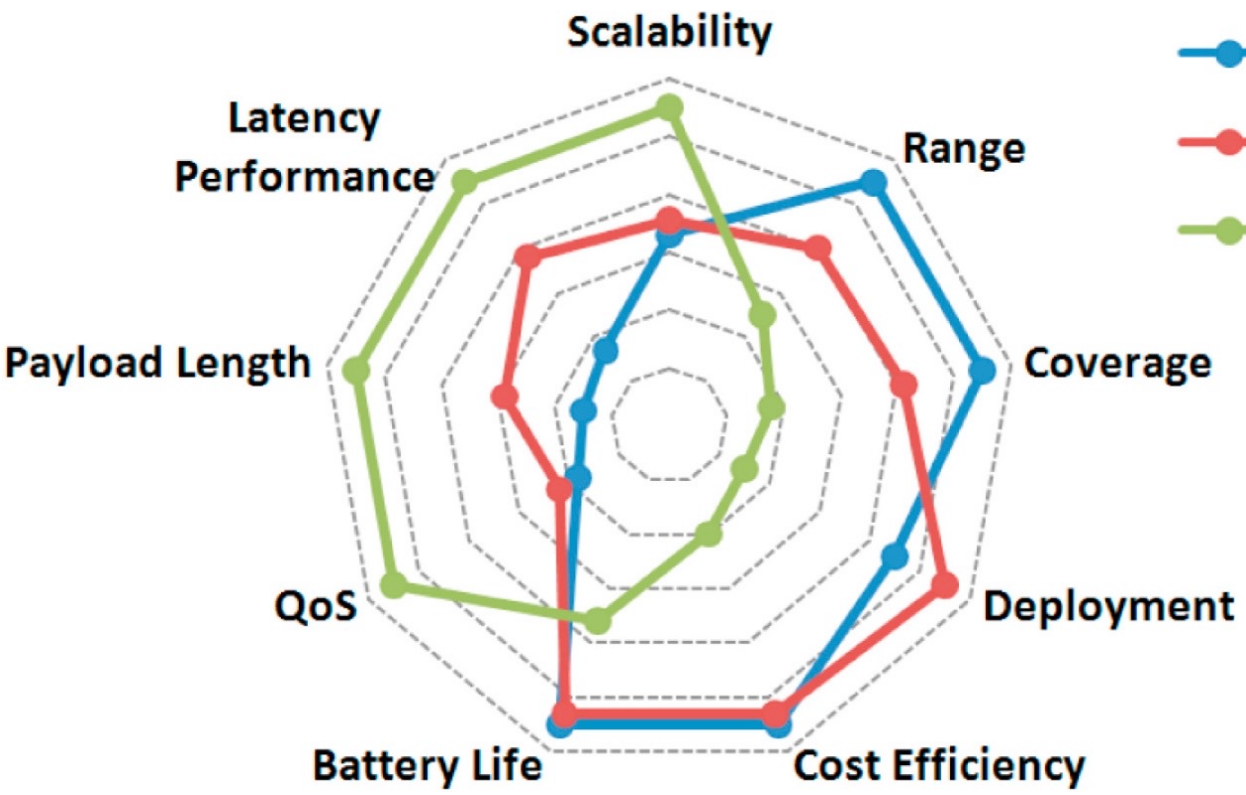
Energy-Range dilemma

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



(Very) Low throughput: bps

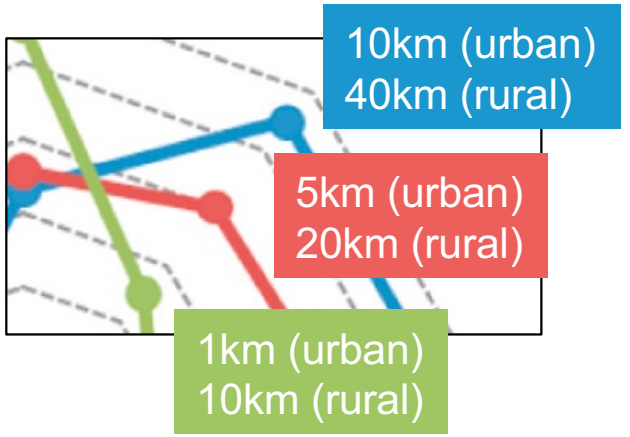
LPWAN expected range?



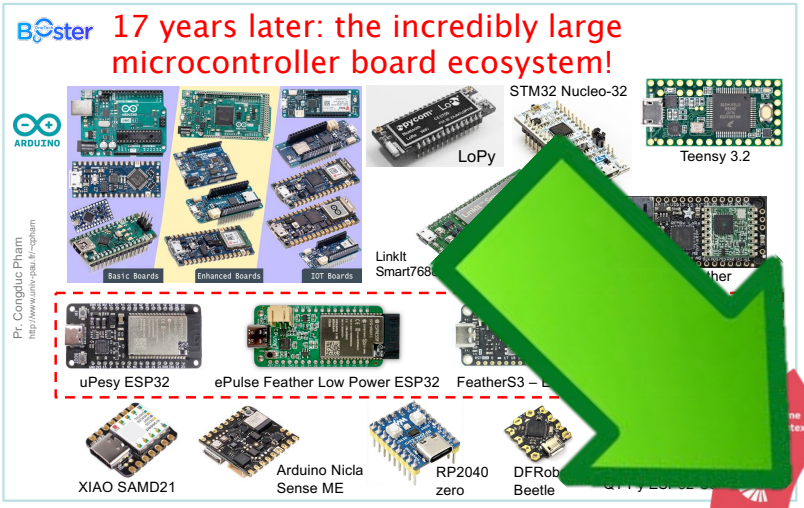
Bluetooth: about 20m

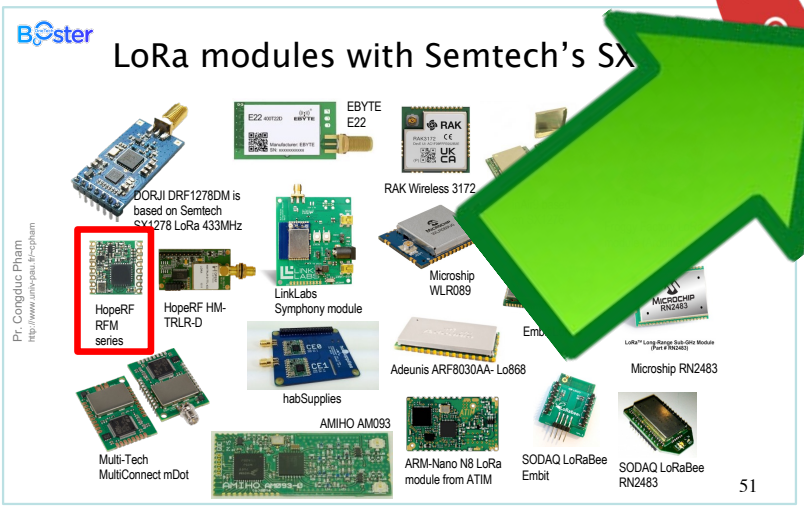
WiFi: about 300m-500m

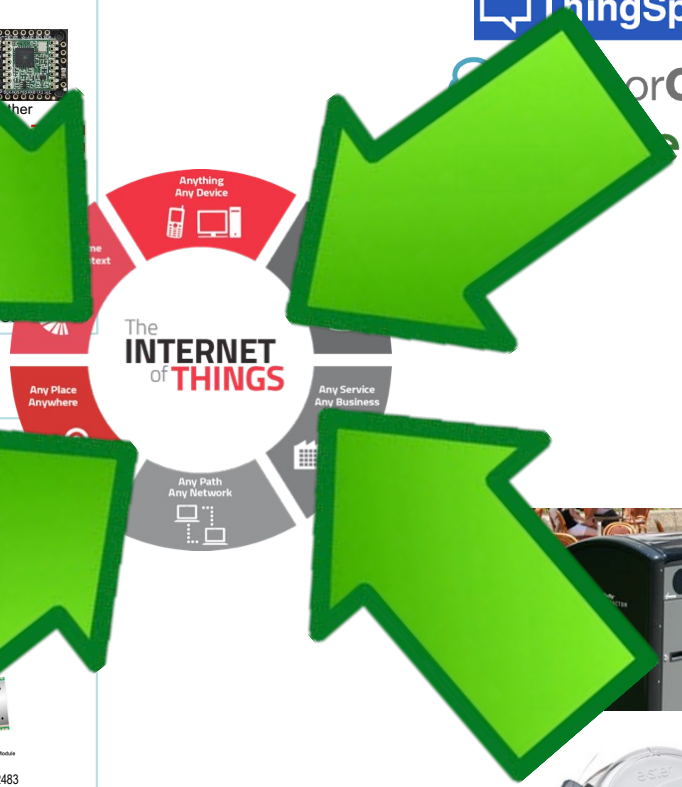
3G/4G: about 2km-4km



IoT becomes reality!

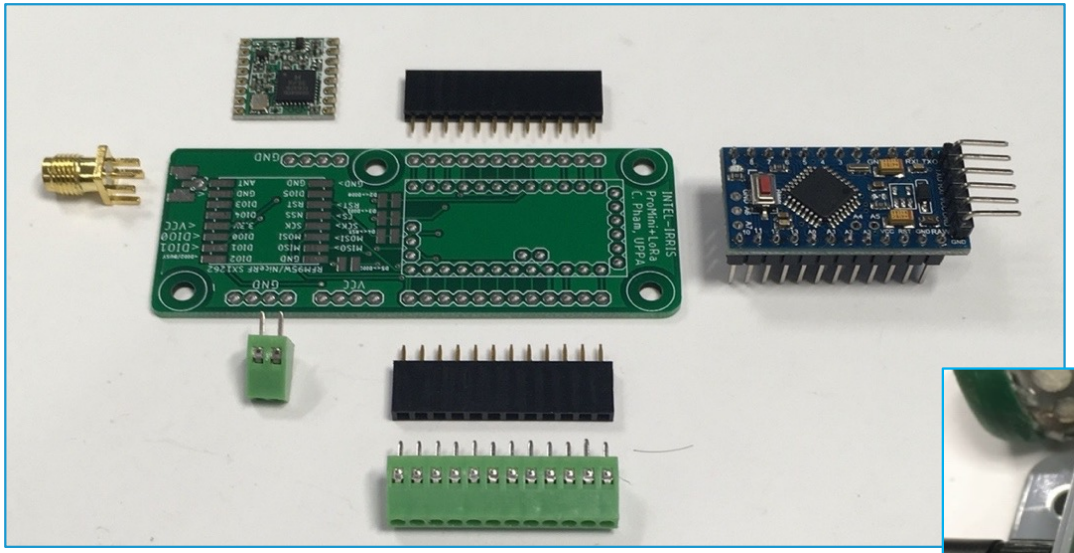


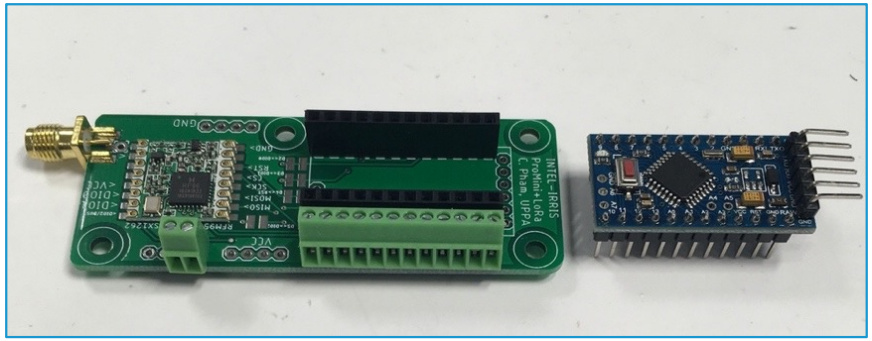


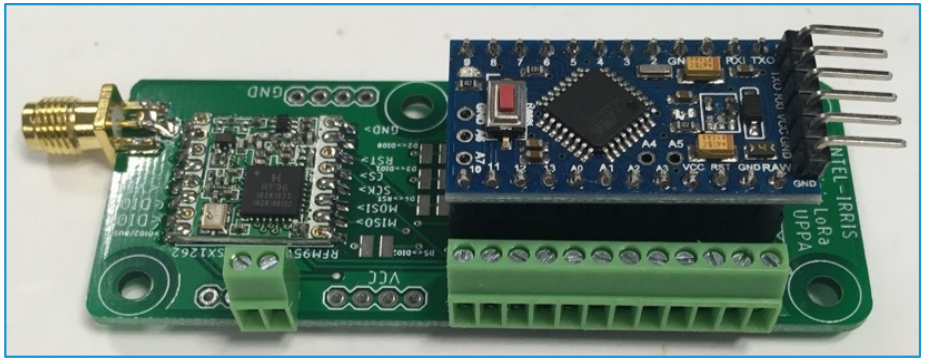


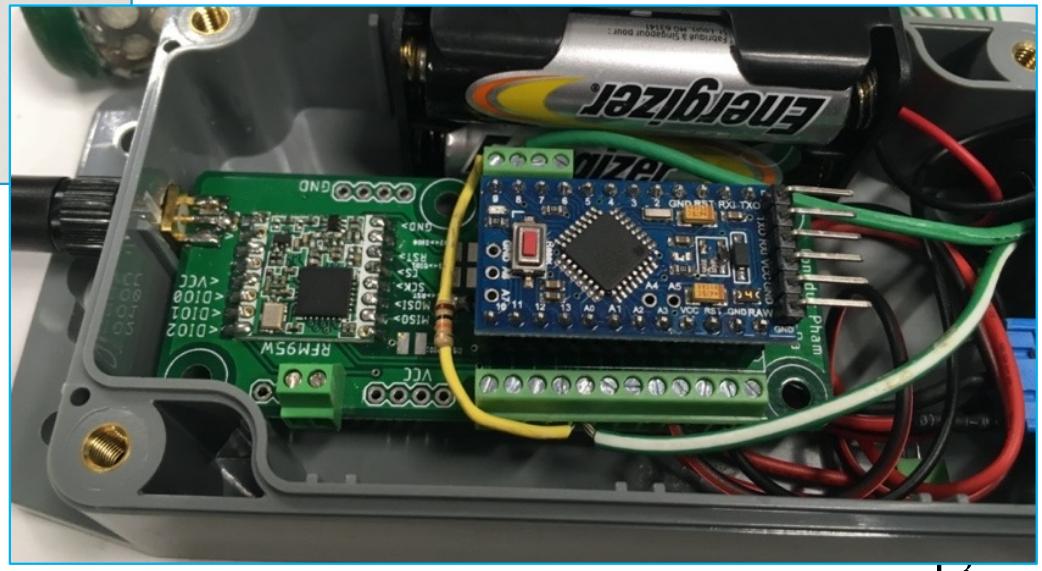
Simple & Modular design

- Simple integration on PCB of off-the-shelves components









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INTEL-IRRIS starter-kit

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

< 90€

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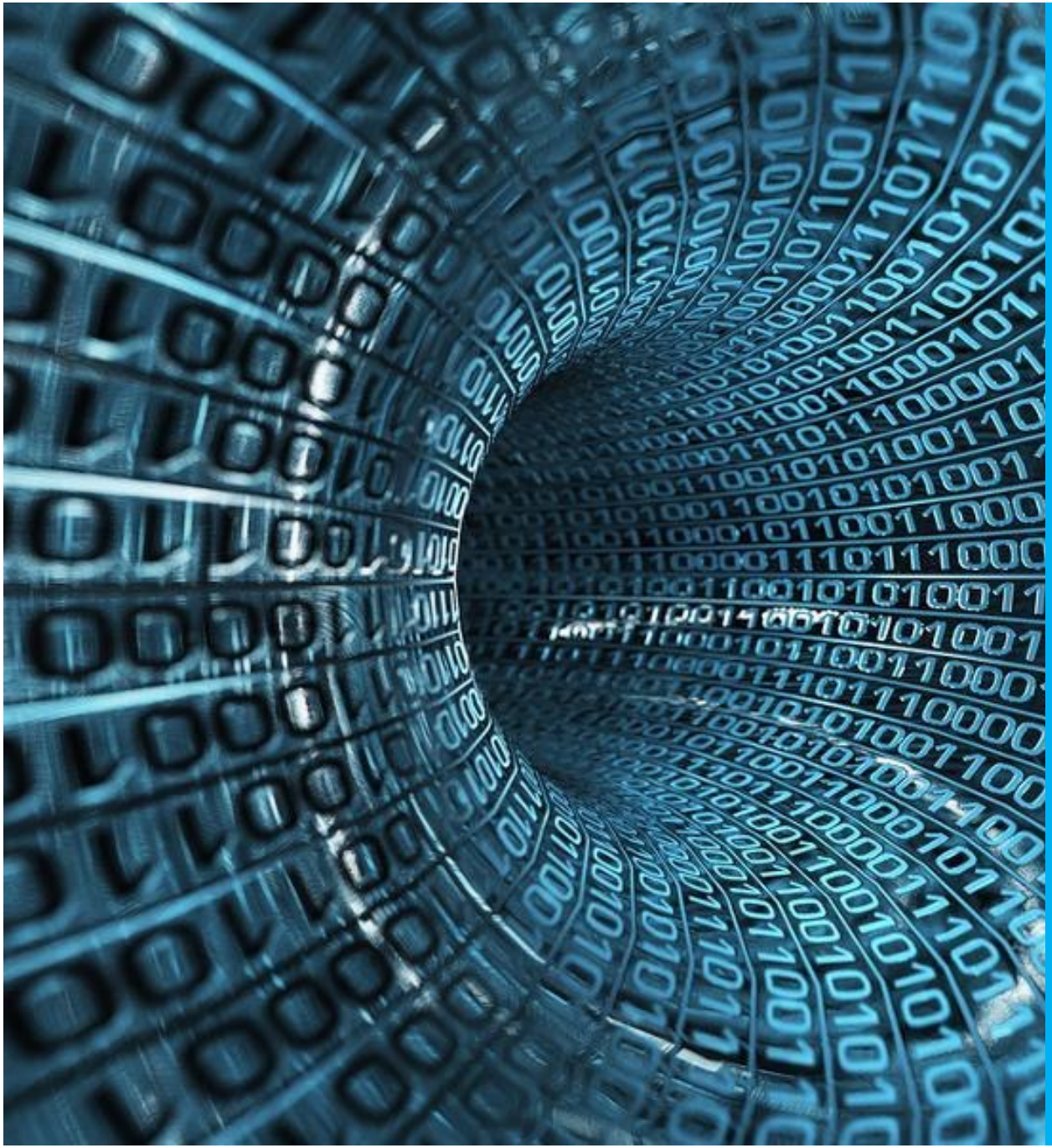
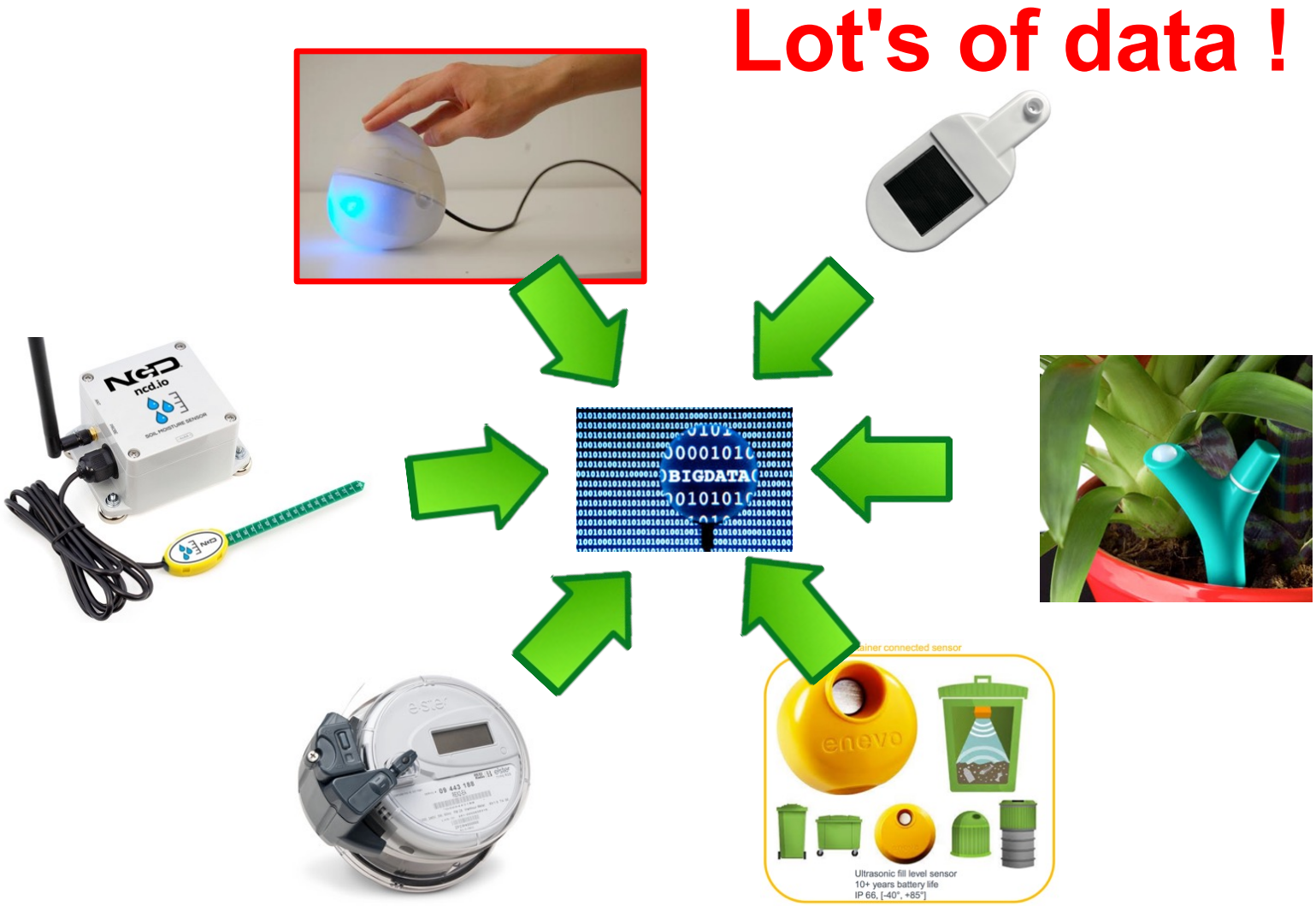


IOT

Unleash the power of IoT data !


2022, billions of IoT devices
are deployed worldwide !

These things talk a lot!



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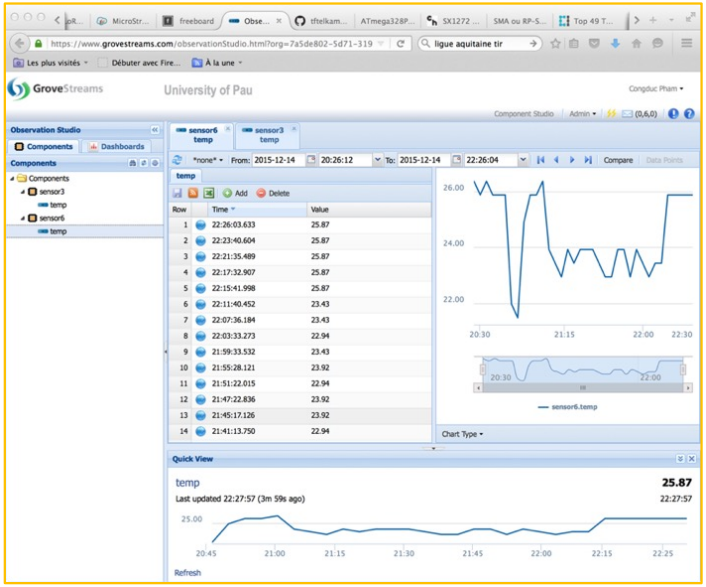
Things talks to IoT clouds

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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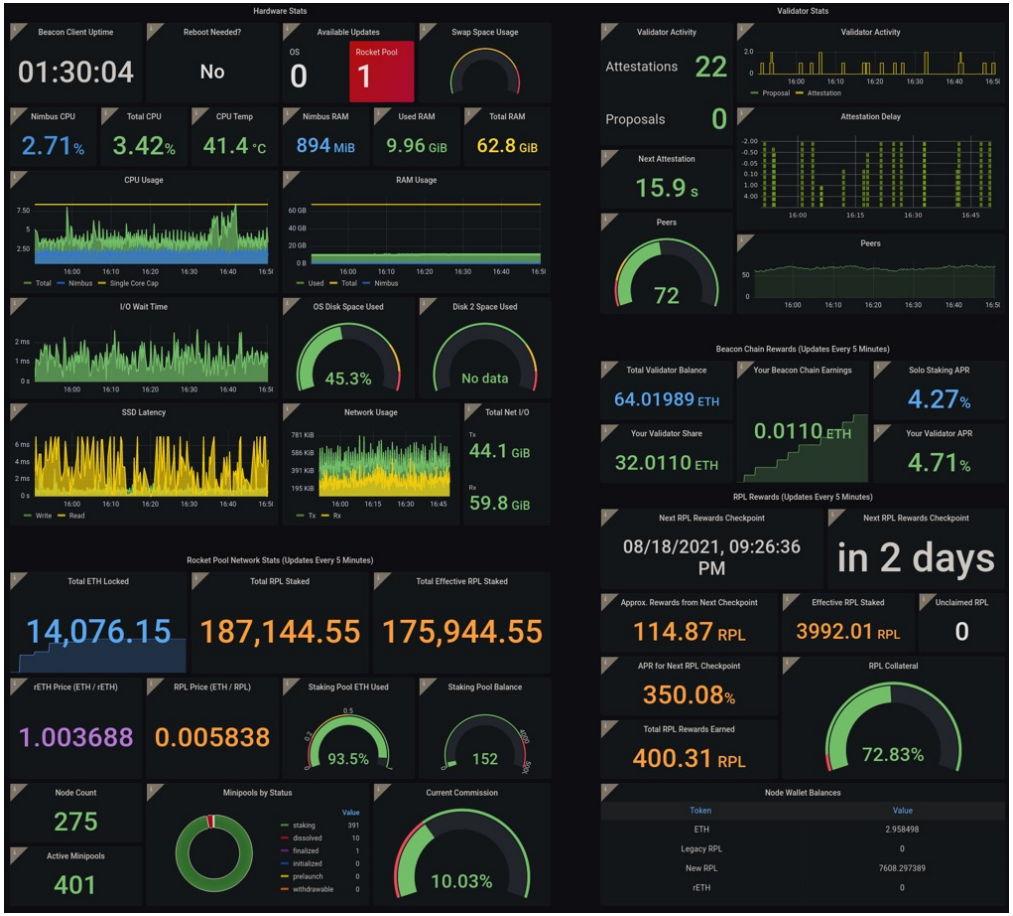
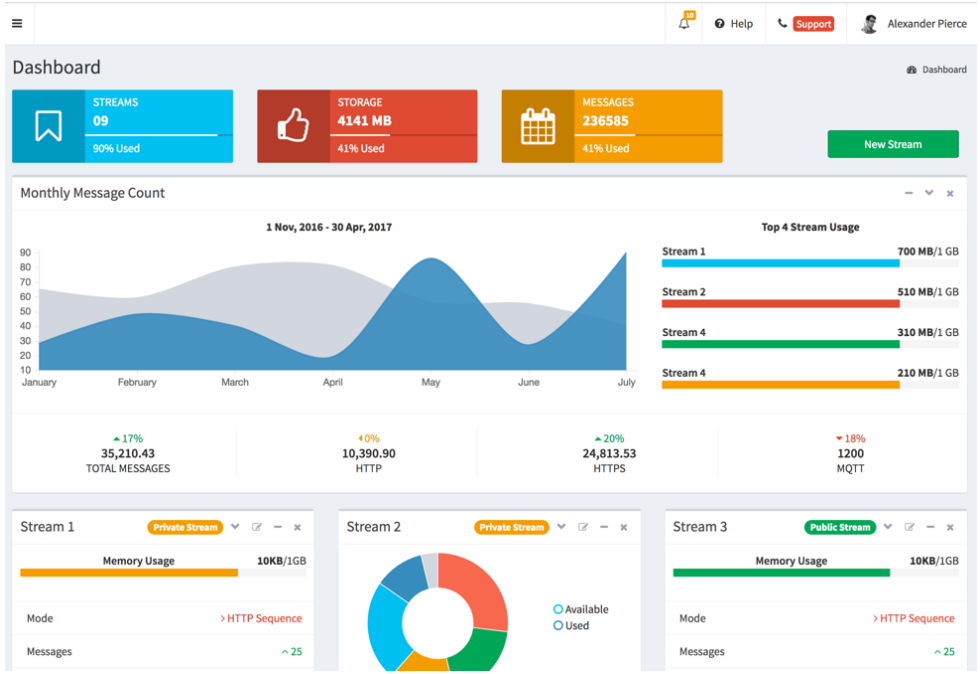
Integrating multiple data sources





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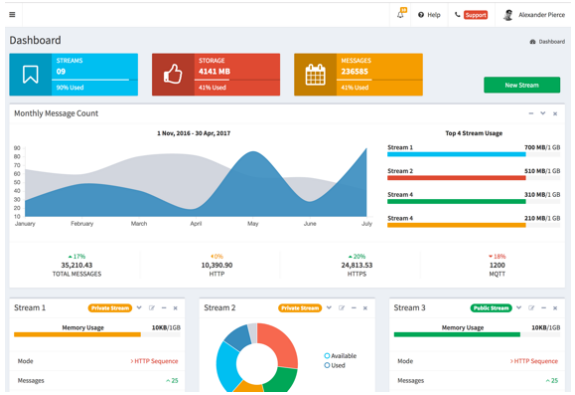
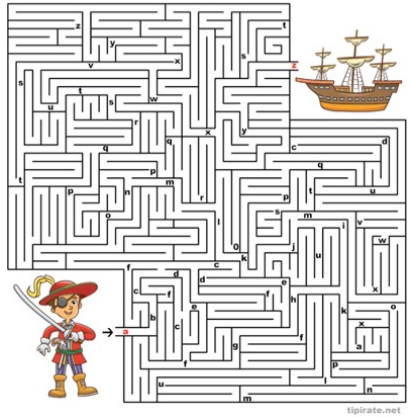
Searching for IoT data

- 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





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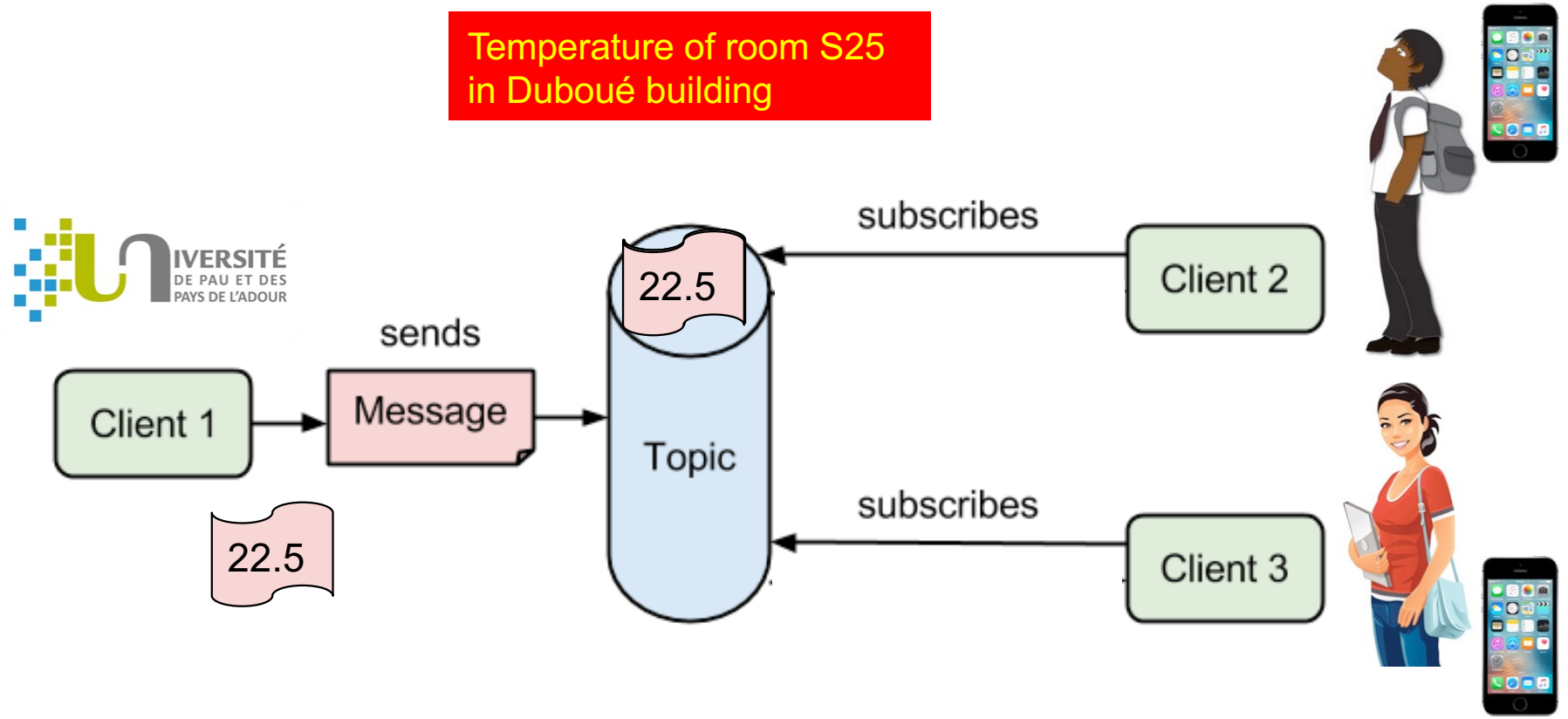
From "search for info" to "get the info"

- Use the PUBLISH/SUBSCRIBE model



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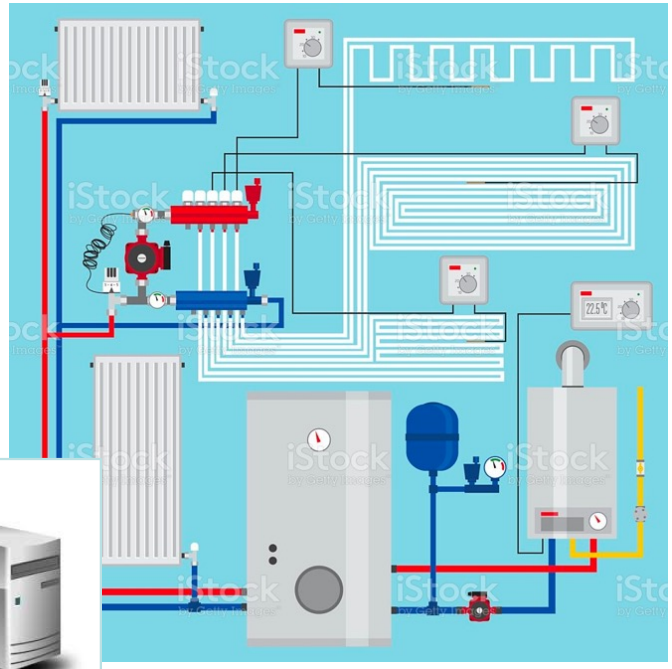
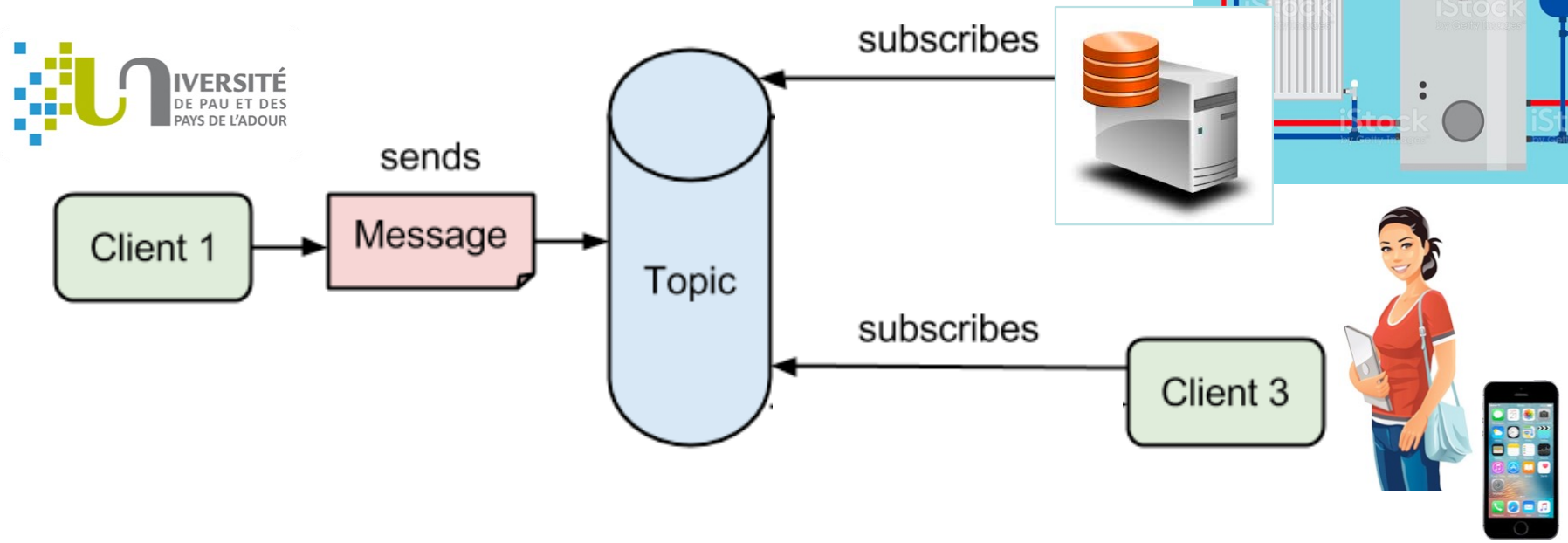
Automatization made simpler

- Use the PUBLISH/SUBSCRIBE model



Temperature of room S25
in Duboué building



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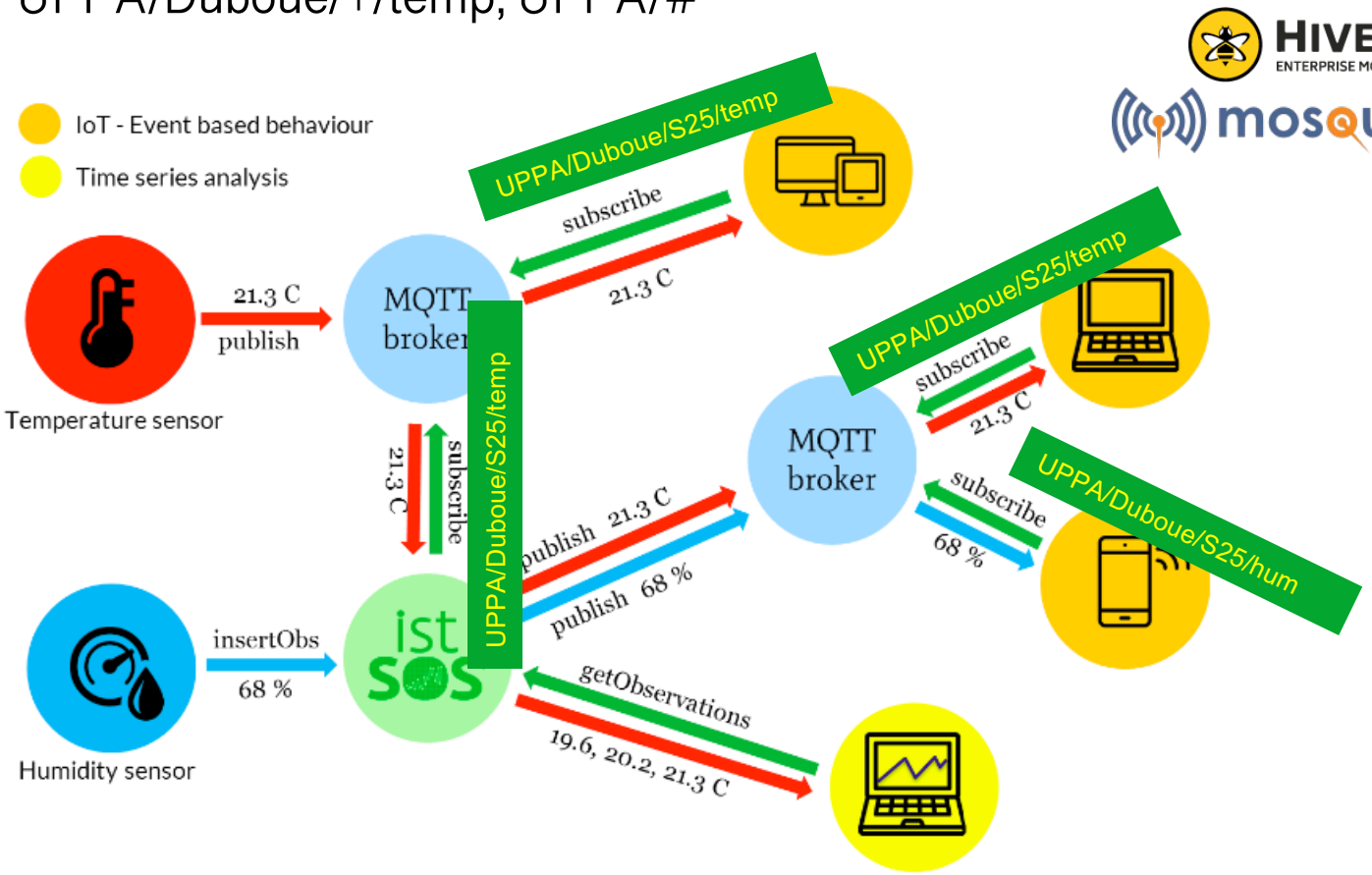
MQTT

Message Queue Telemetry Transport

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



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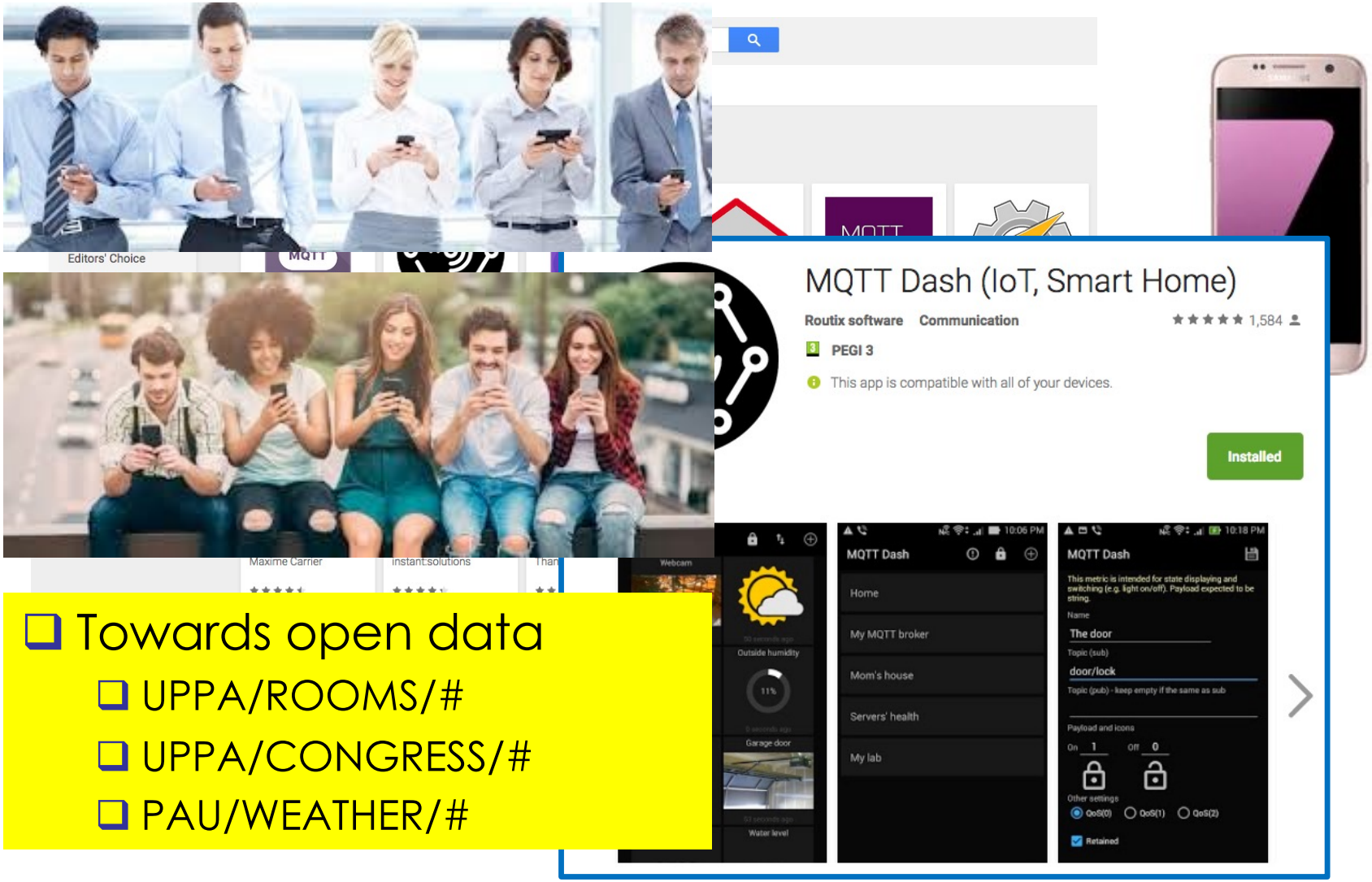
MQTT+smartphone=



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

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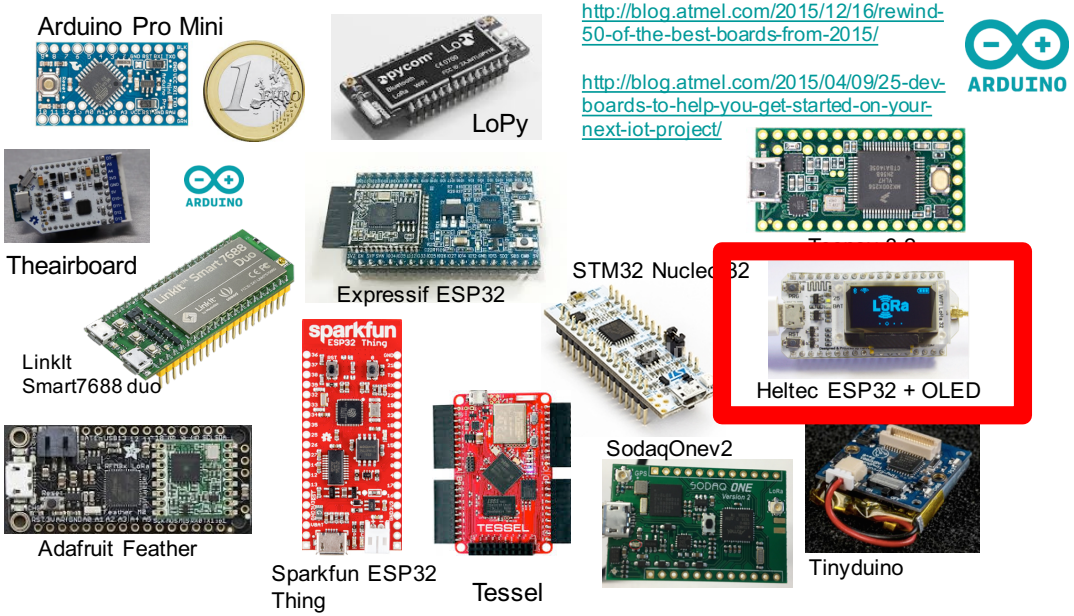
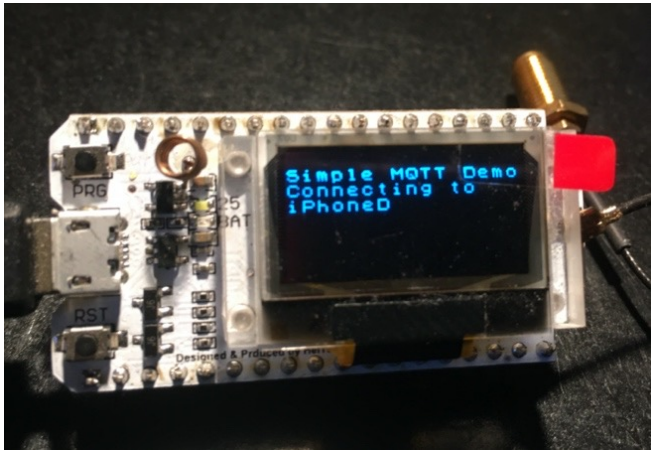
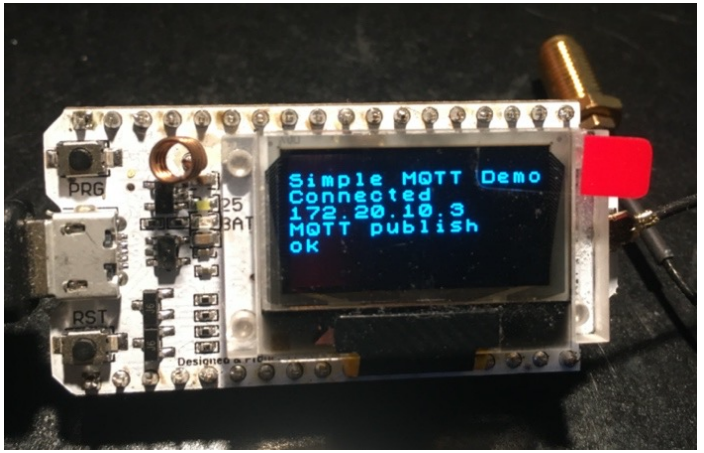
MQTT is very lightweight

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







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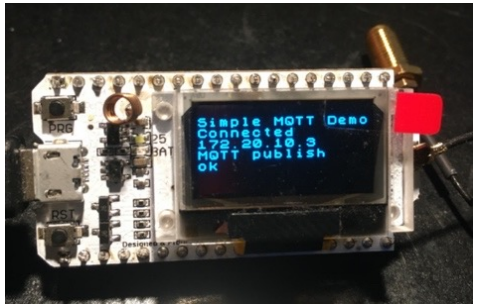
Ex: Mosquitto MQTT broker



- 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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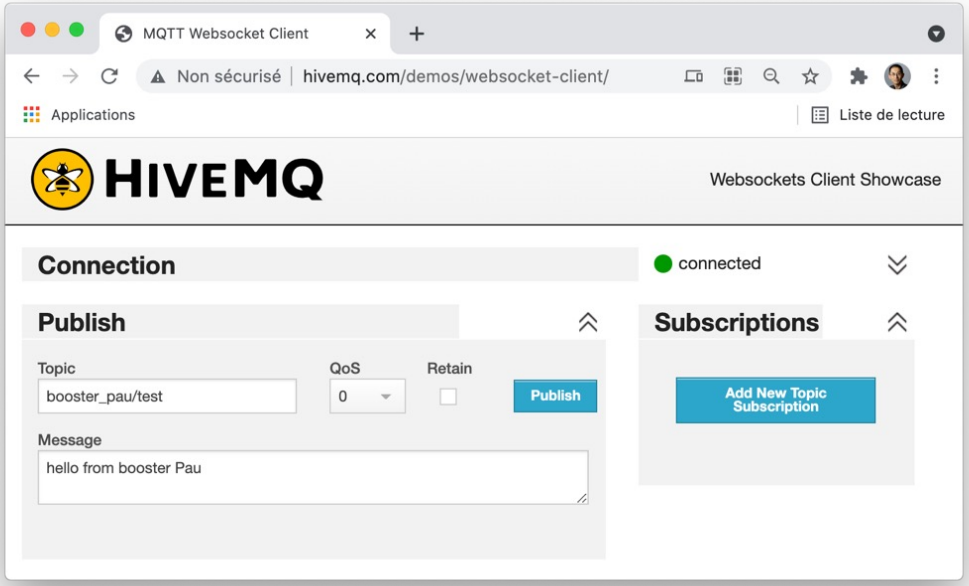
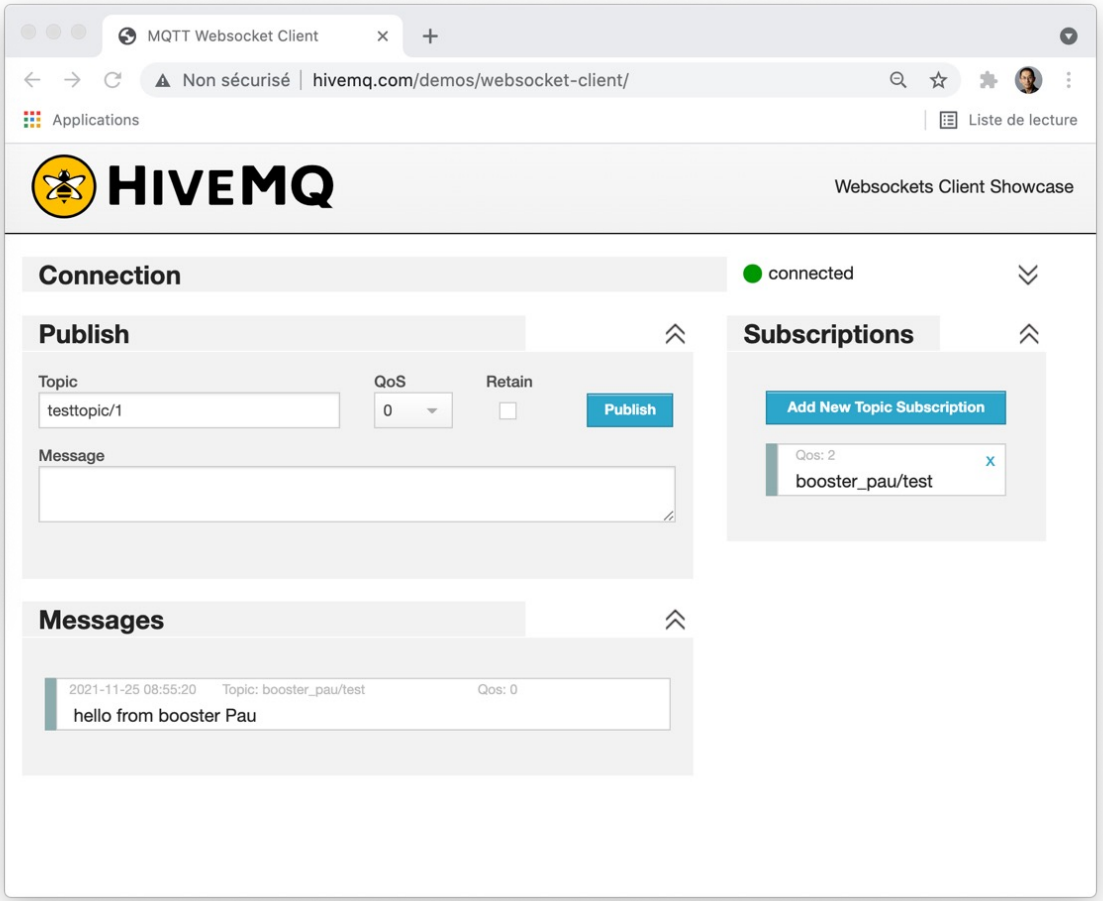
Ex: HiveMQ broker on websocket

- 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

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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 showcase-iot
    - myWhatsApp/0655667788/showcase-iot
  - To join(publish) on(to) the group
    - Subscribe(publish) to myWhatsApp/0655667788/showcase-iot

0655667788

Alice

0611223344

Bob

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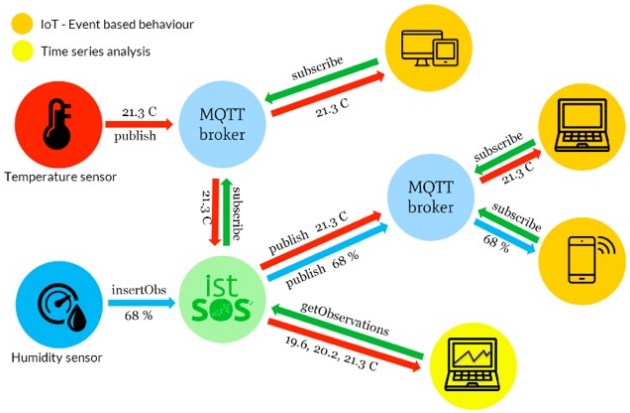
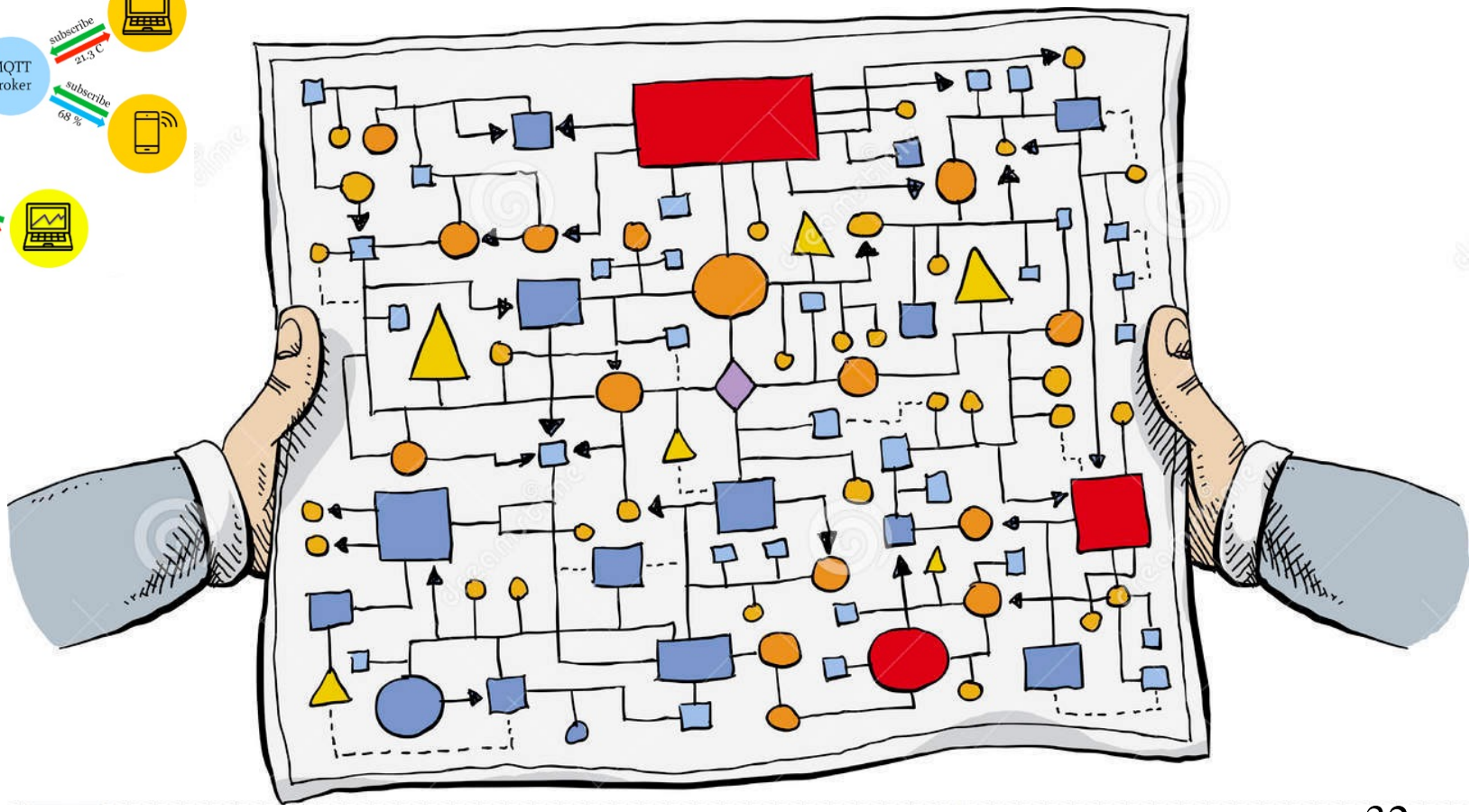
Creating complex data flows?



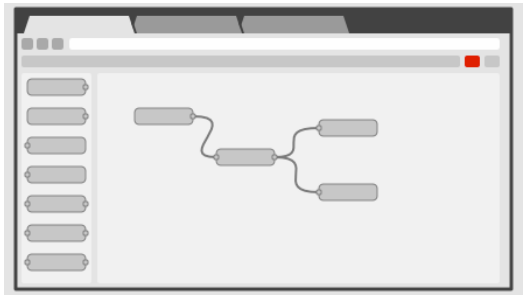


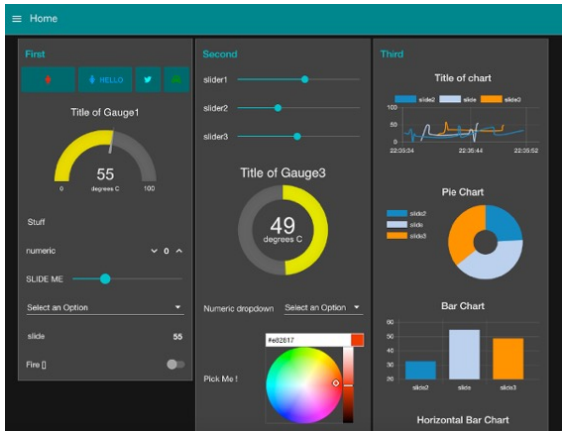
…without programming?

- 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





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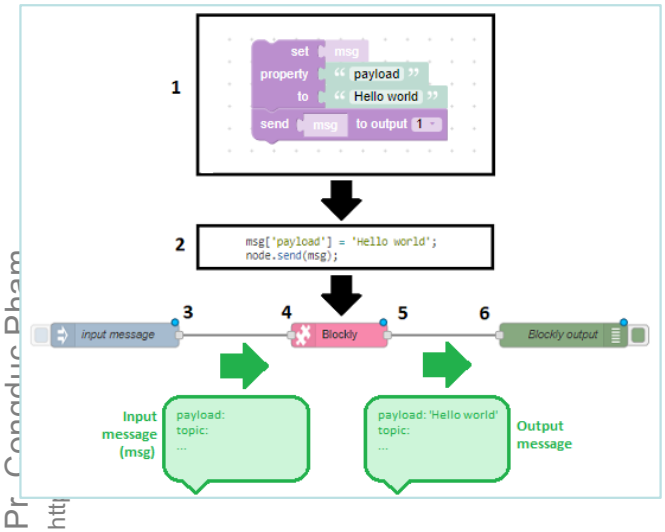
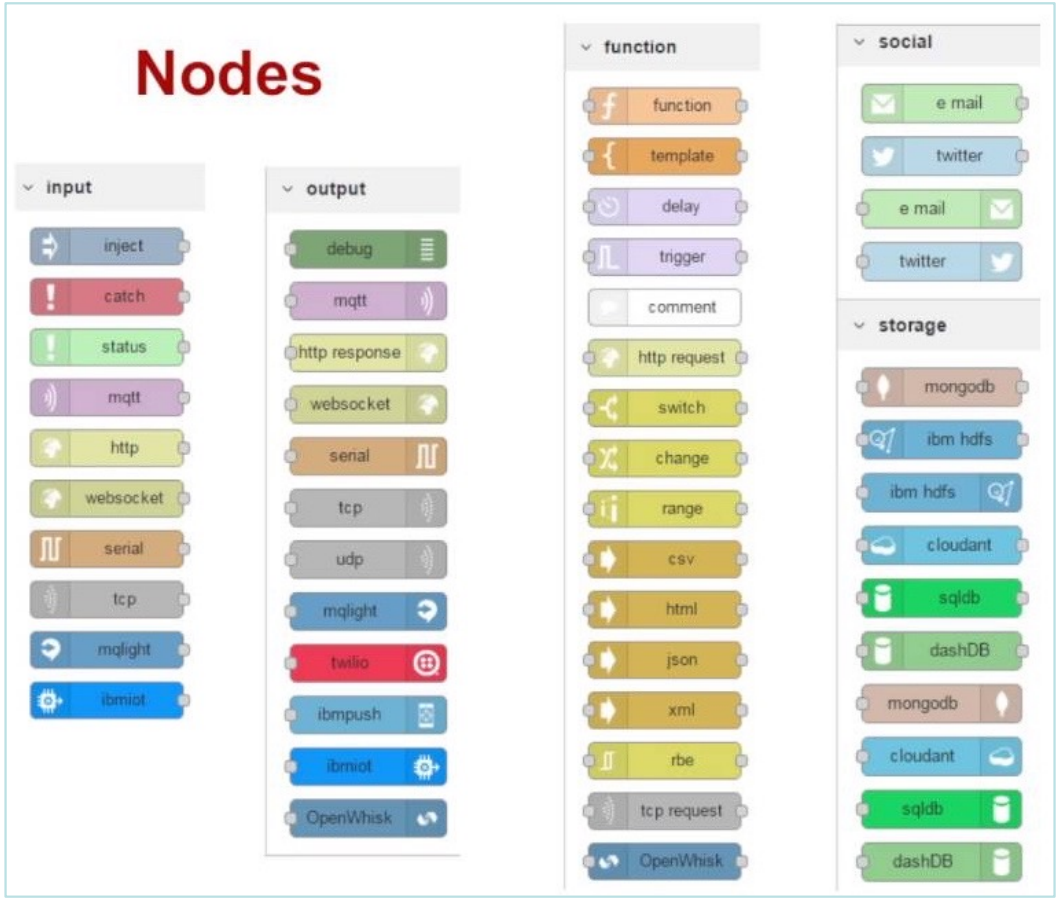
Node-RED blocks

- Increasing number of Node-RED blocks

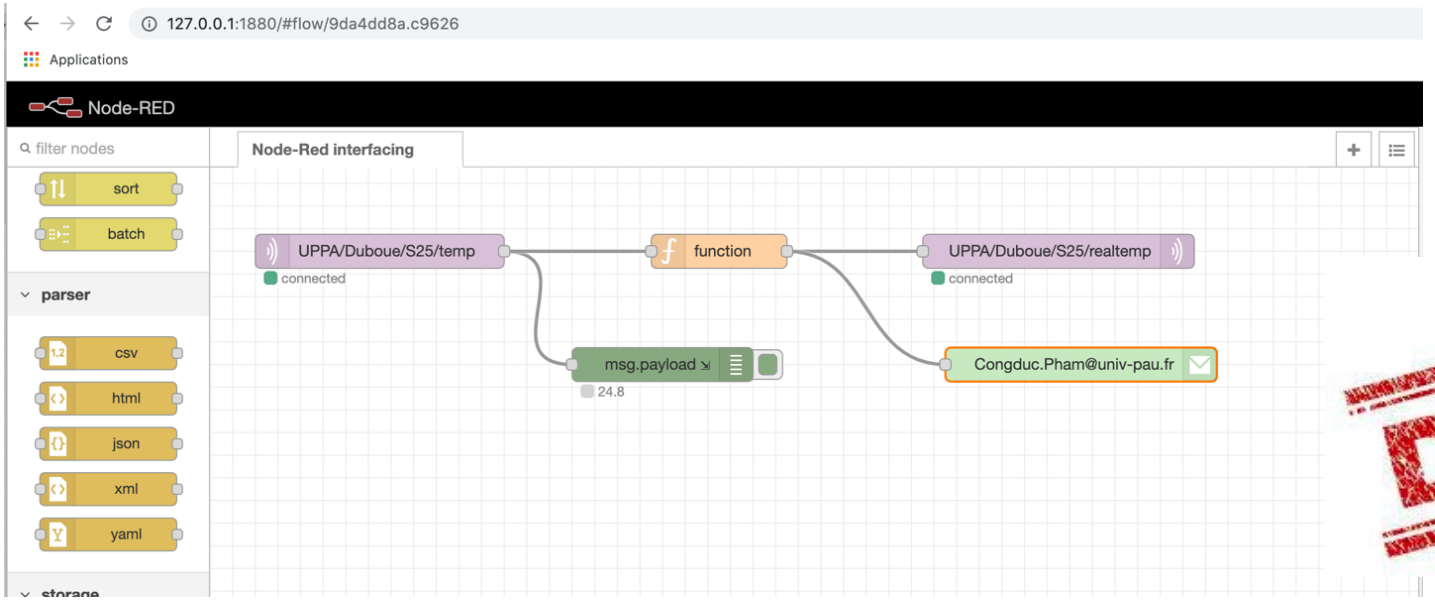


Nodes represent reusable pieces of code and logic. Node-RED comes with a core set of useful nodes, but there are a growing number of additional nodes available to install from both the Node-RED project as well as the wider community or you



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



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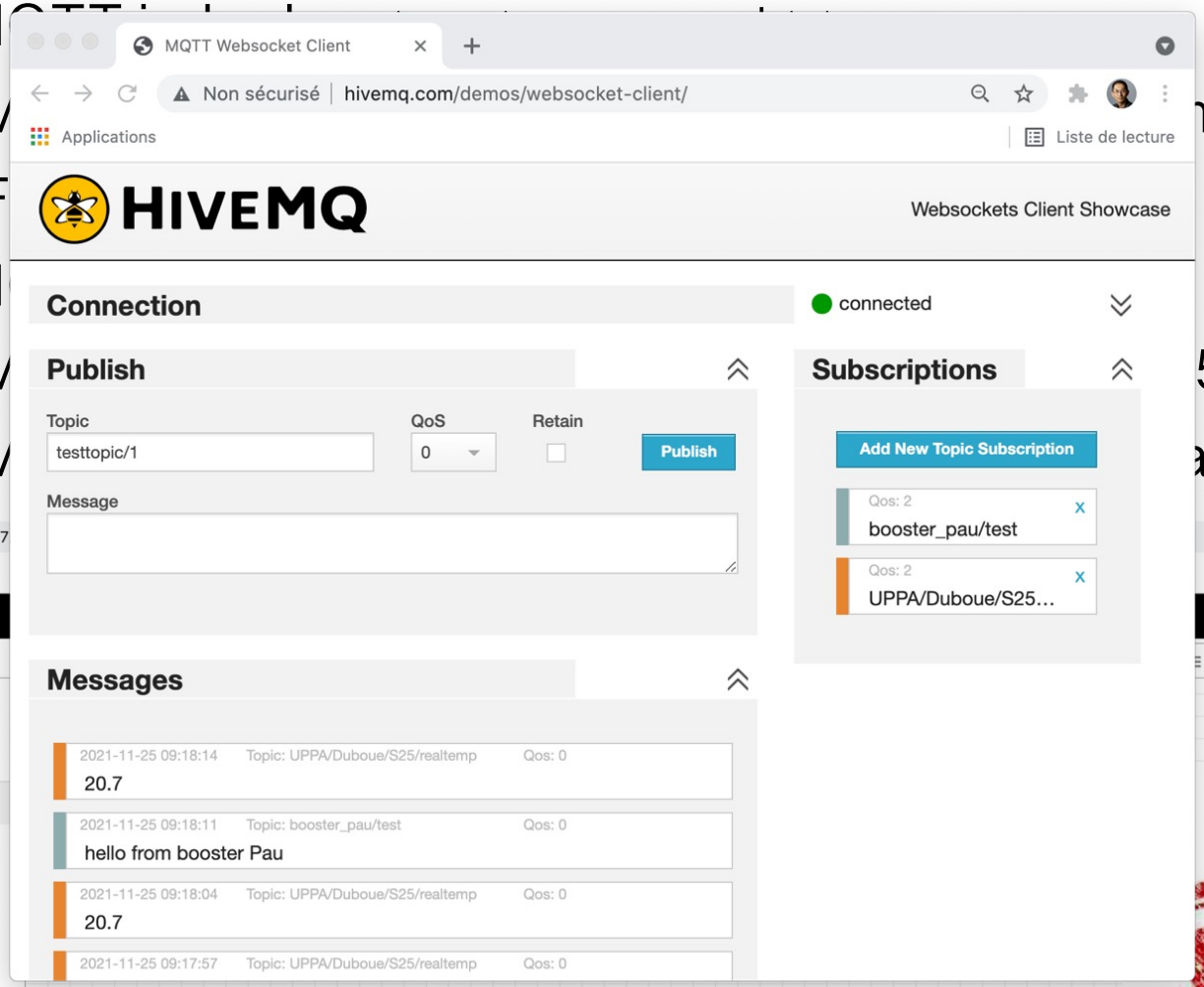
Simple MQTT Node-RED flow

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



mp

5/realtemp

am@univ-pau.fr

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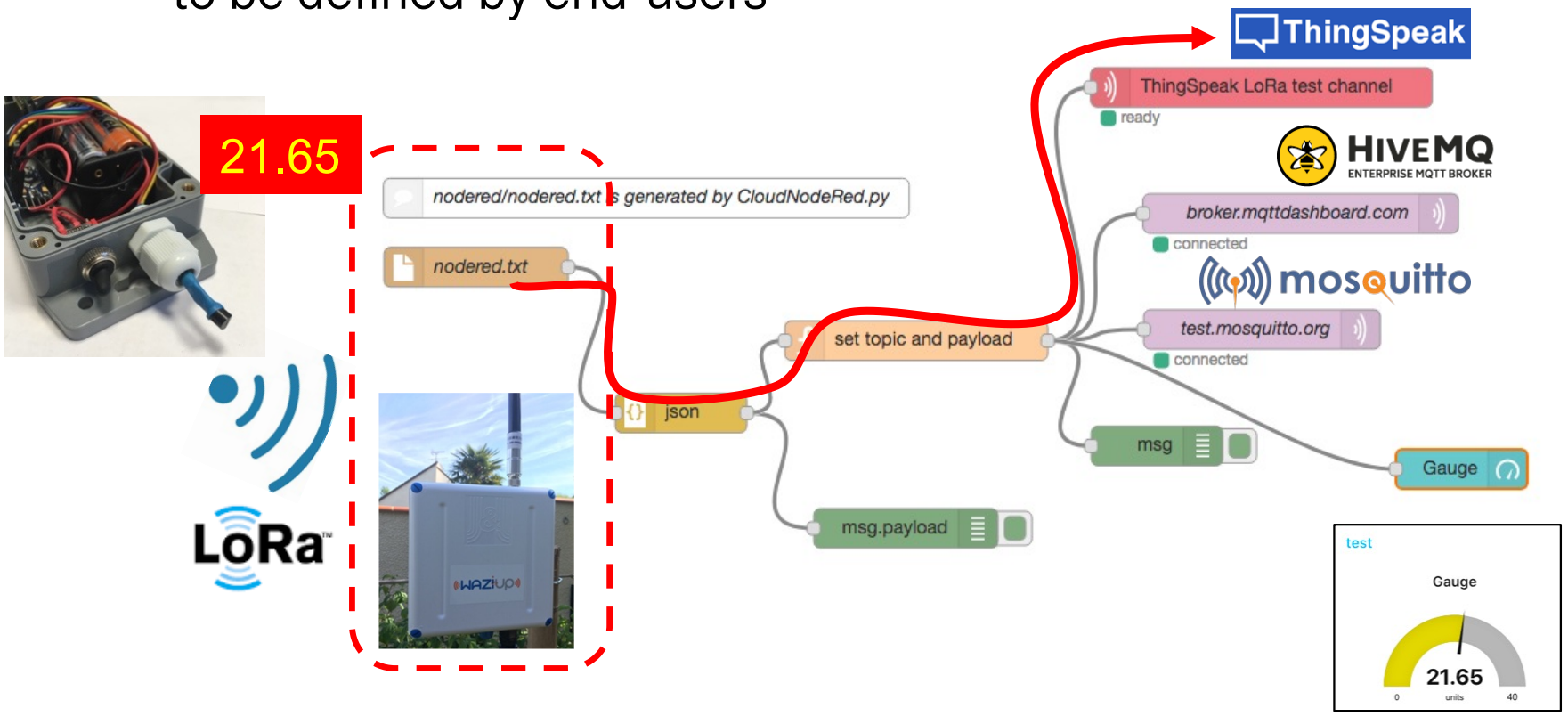
Node-RED enabled IoT gateway

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



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Generalizing interactions?

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Adding interactions?

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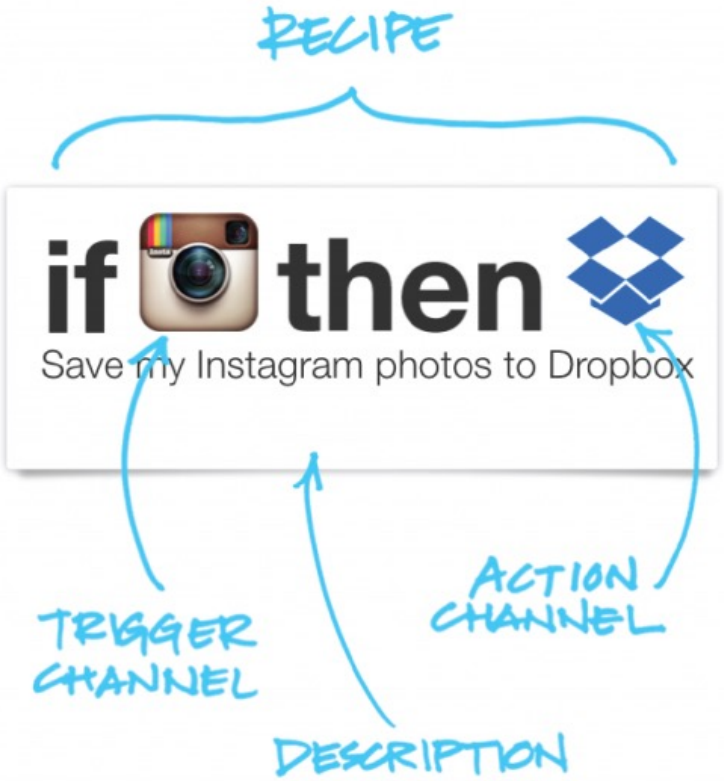
IF THIS THEN THAT applets



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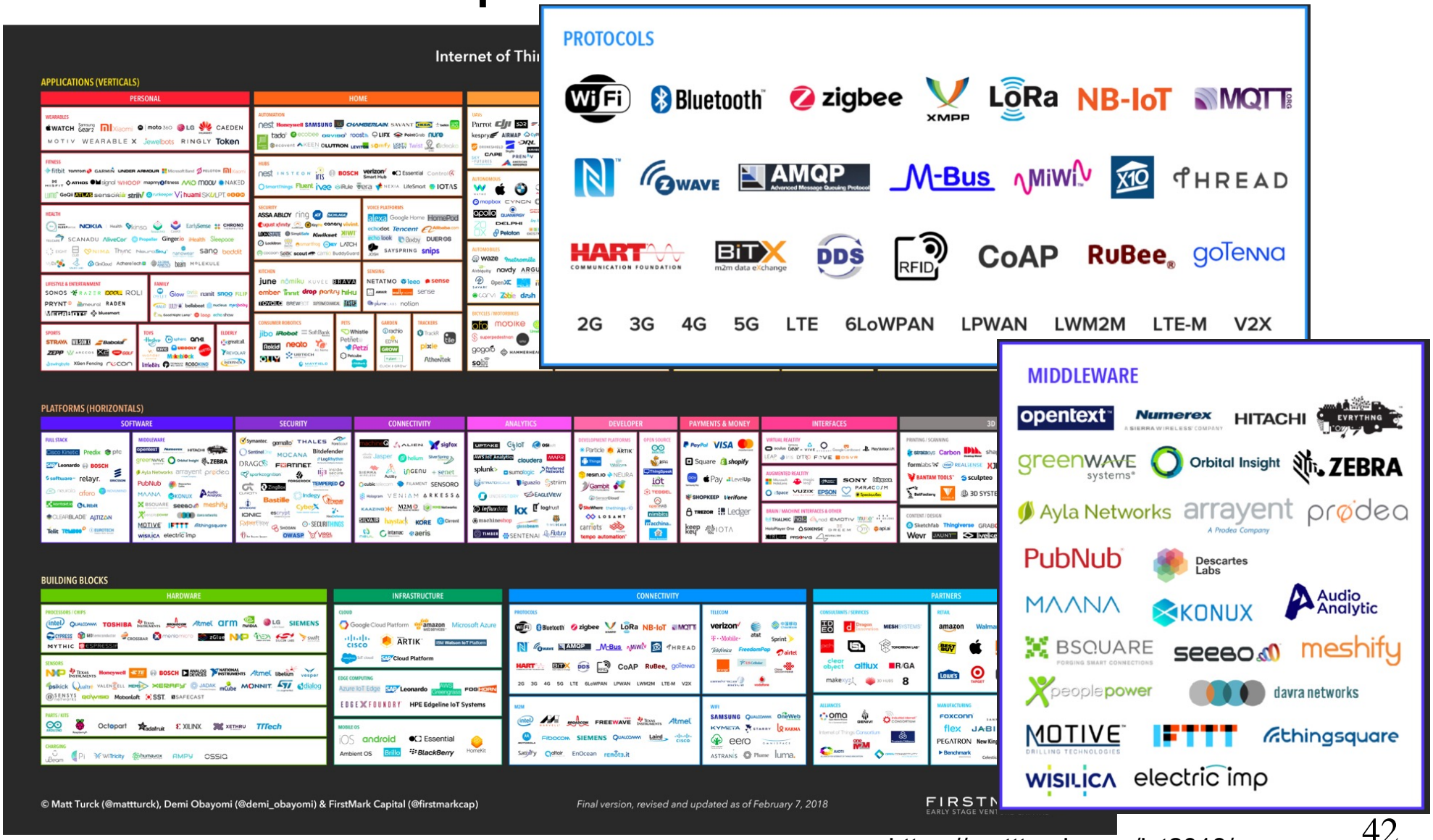
IoT landscape



https://mattturck.com/iot2018/

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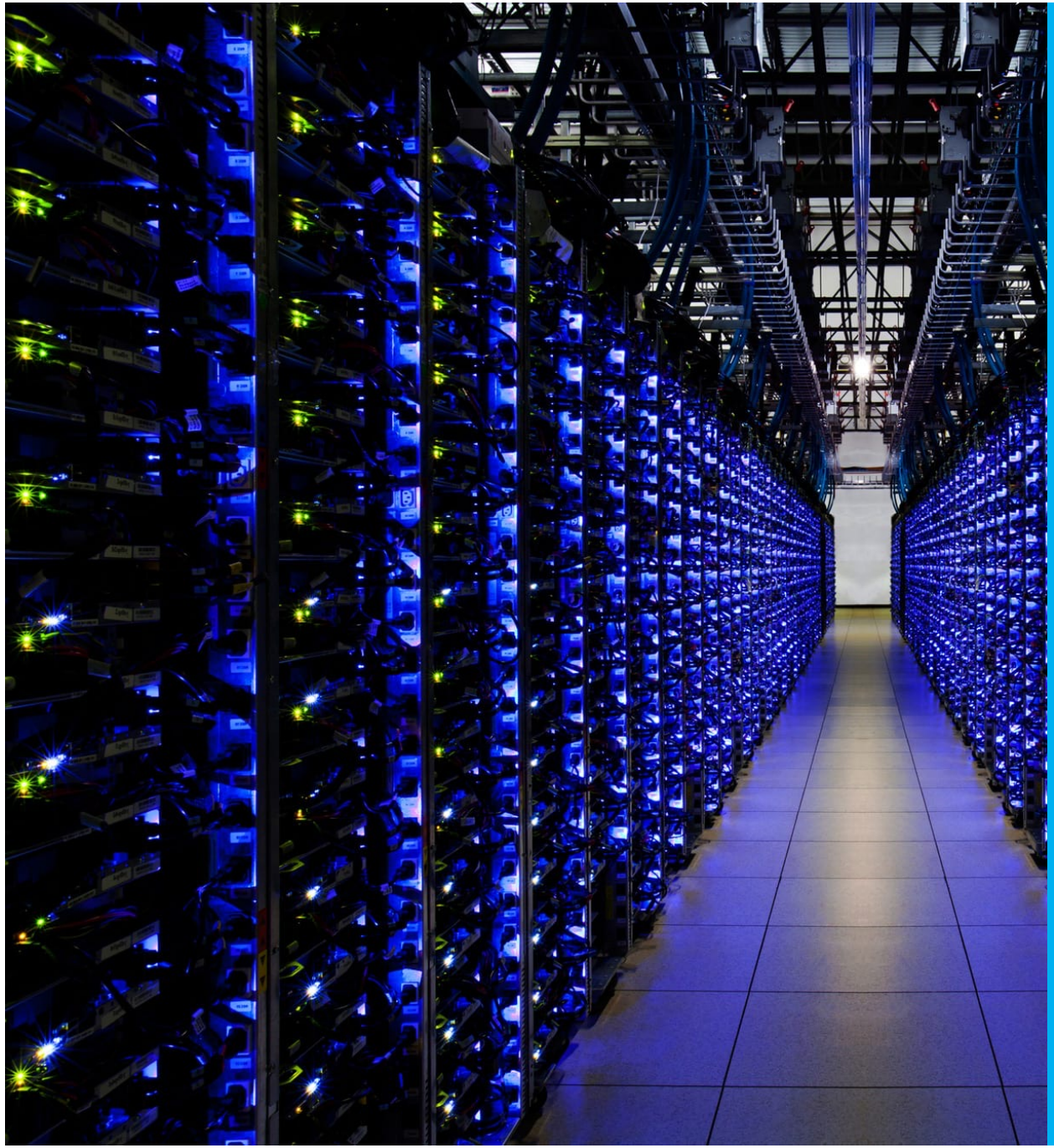
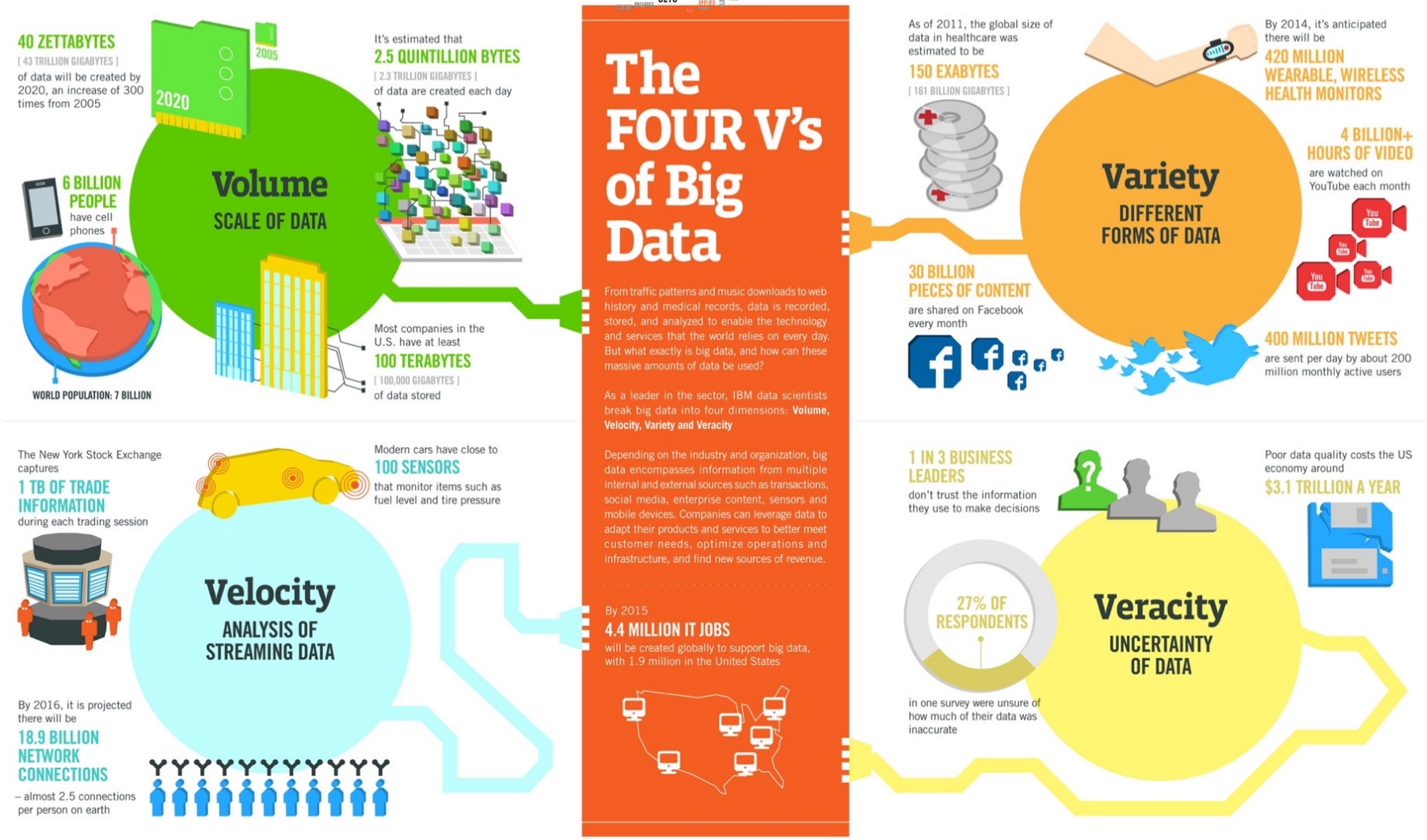


IOT
BACKOFFICE

IoT usually means …



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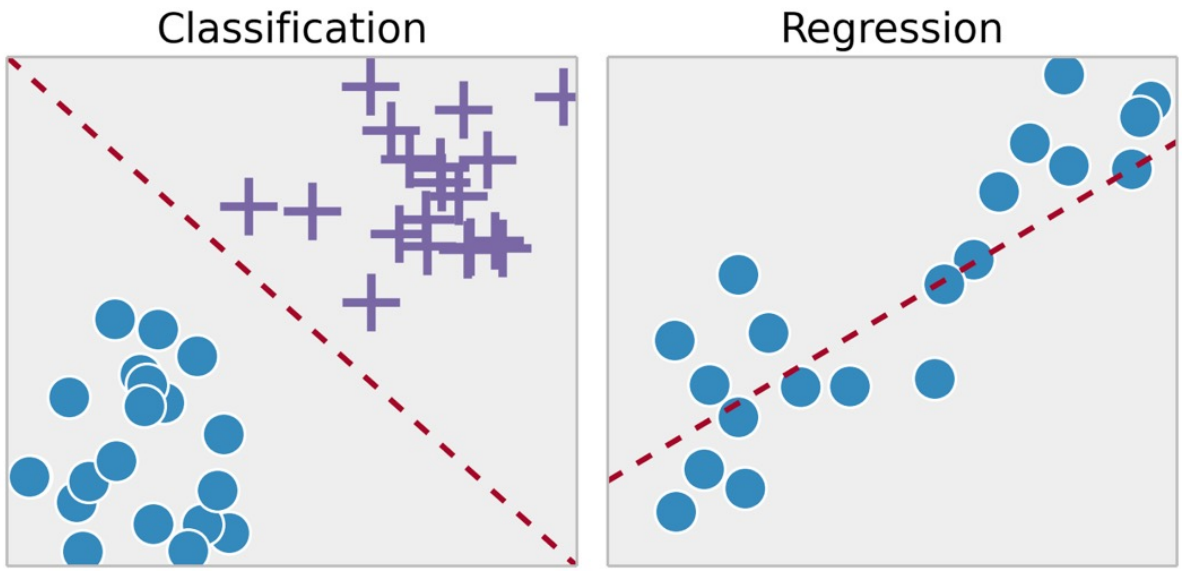
…but also how to analyse the data

- What is the meaning of the collected data?
  - Classification
- Can we predict how the data will evolve?
  - Prediction using Regression methods



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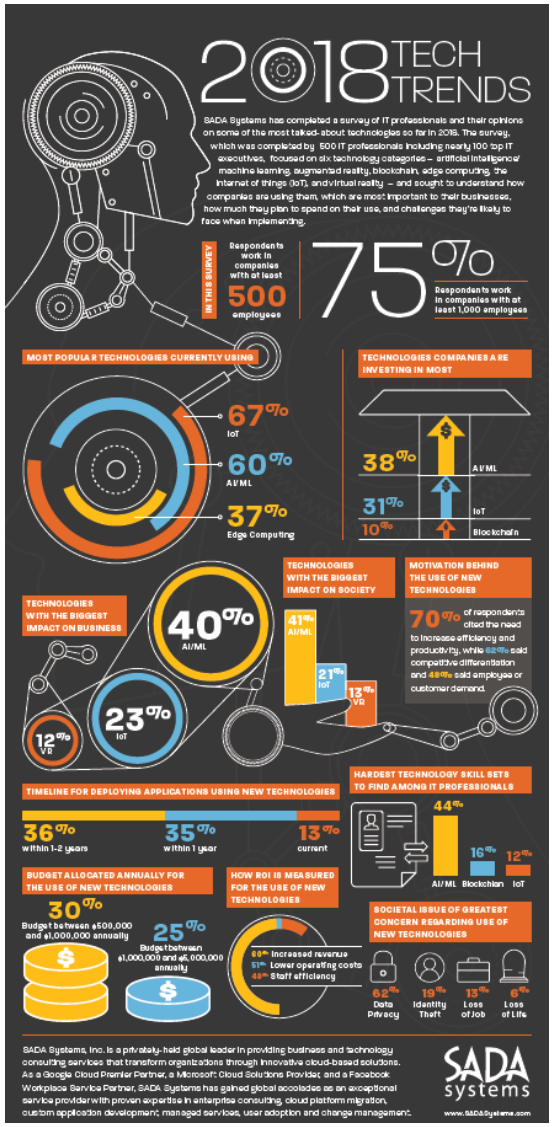
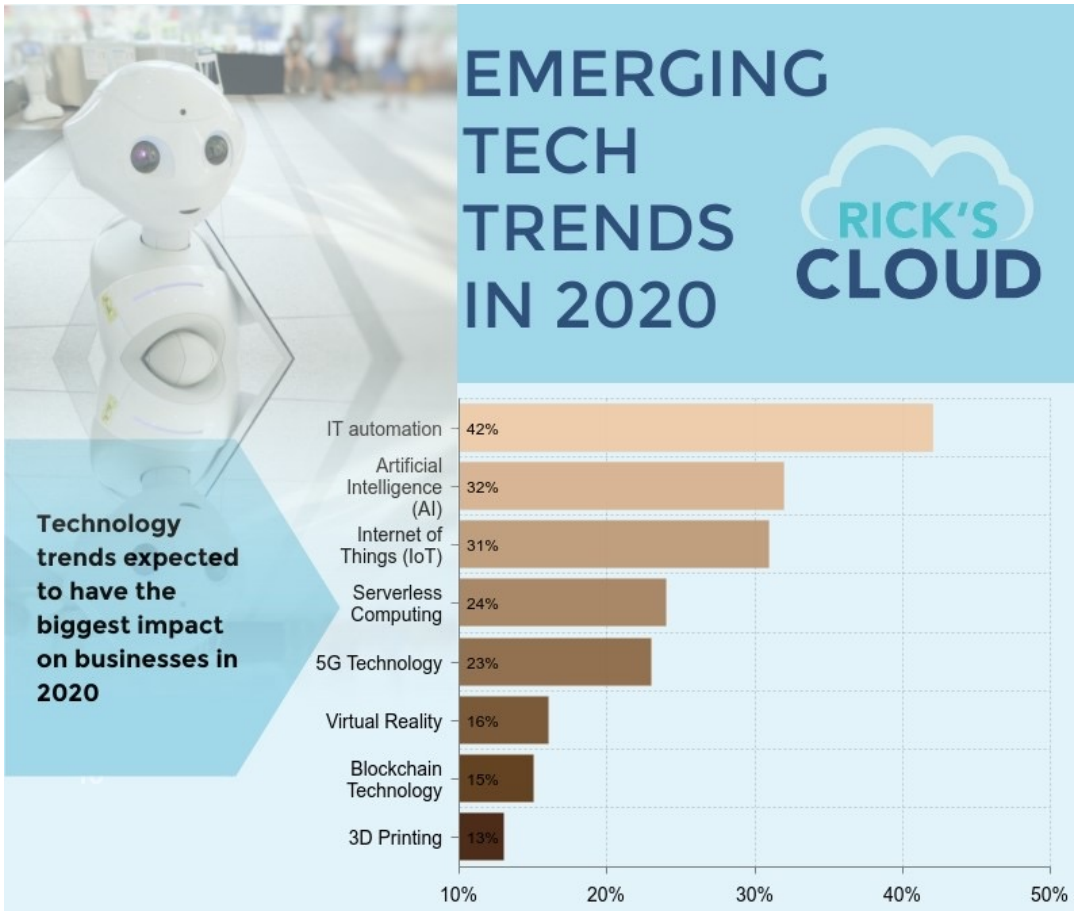
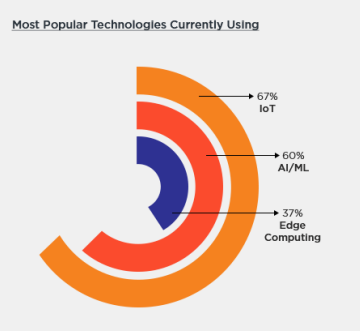
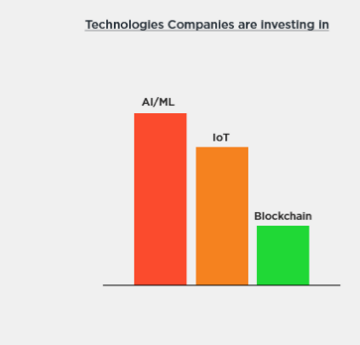
Analysing IoT data: what's the trend?









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

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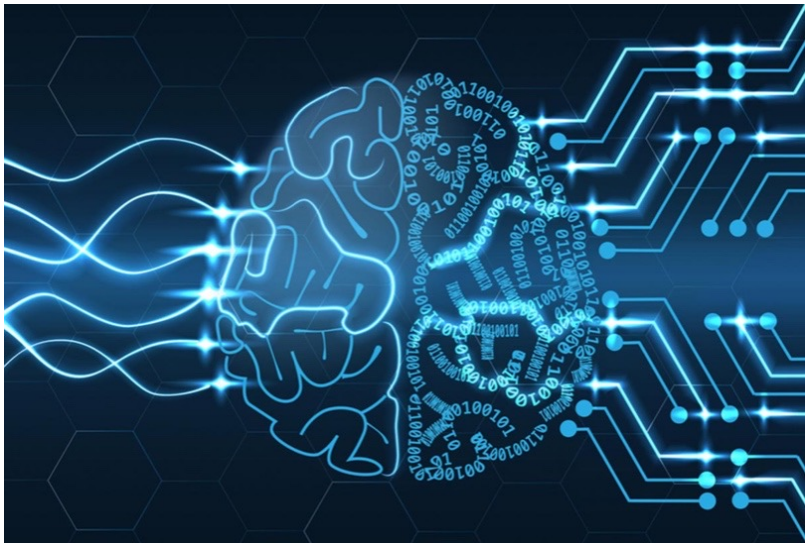
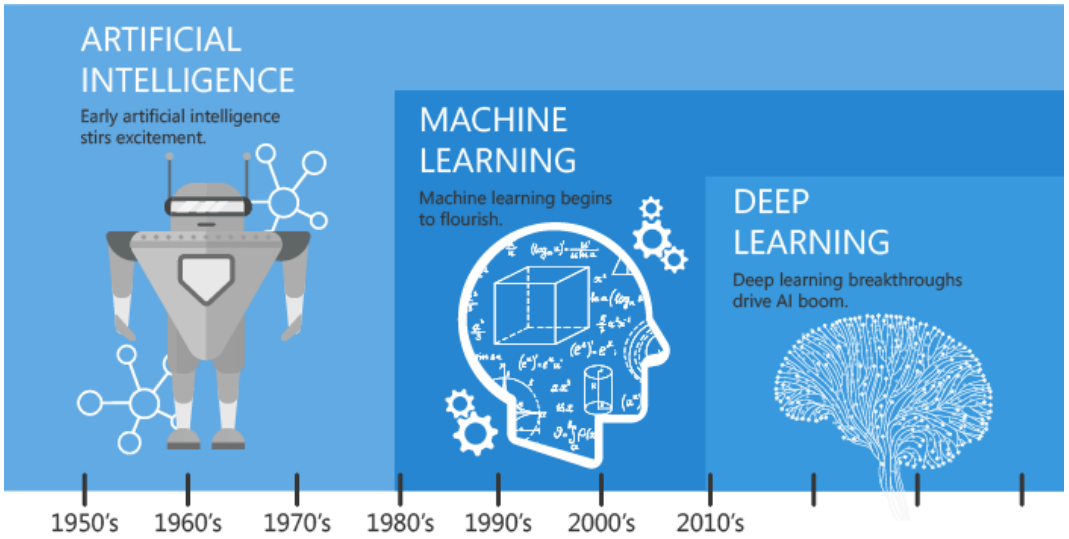
The raise of Artificial Intelligence

- 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.

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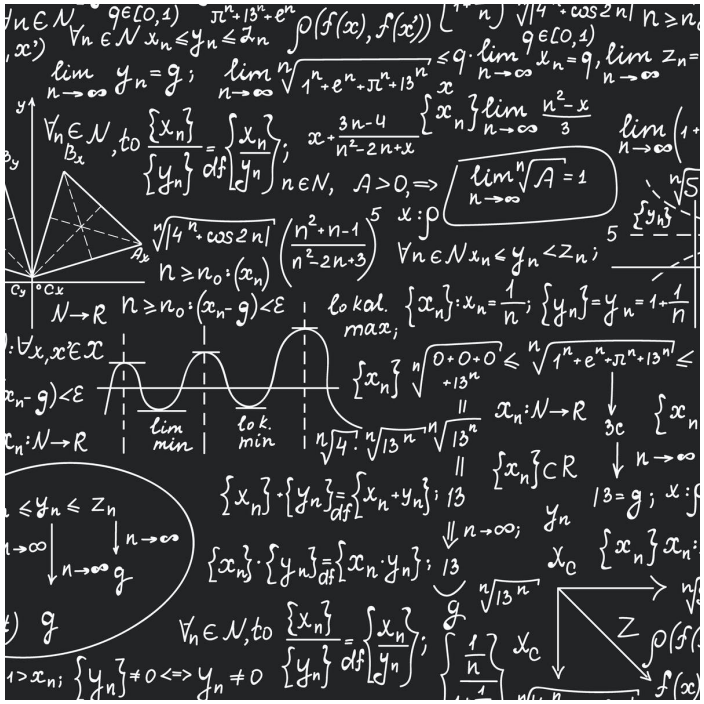
AI: (now) a serious science!

- 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.



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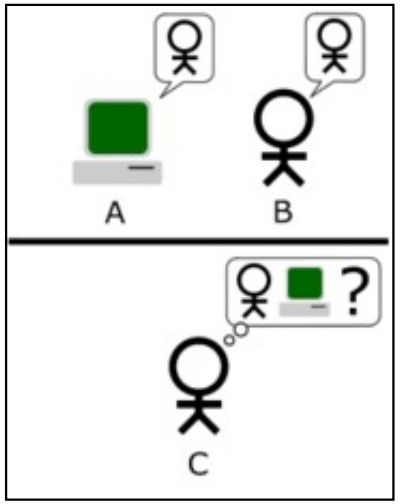
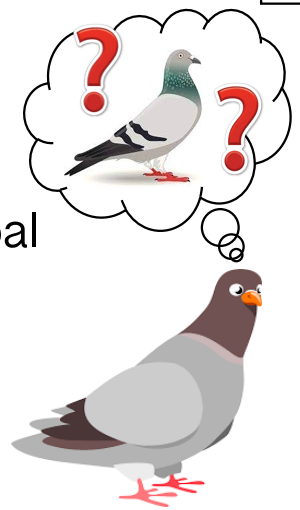
The Turing Test

- 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]





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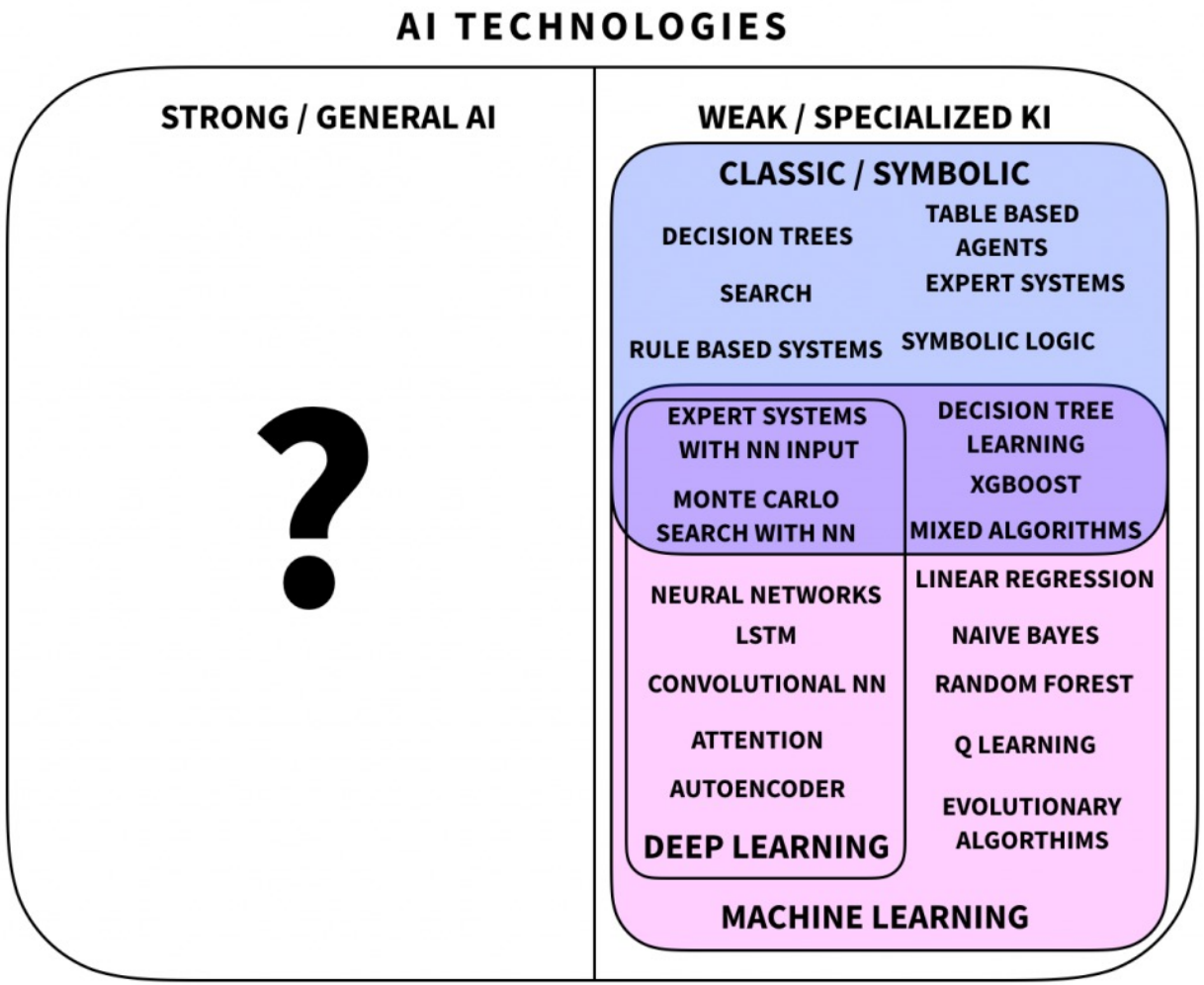
Reflection

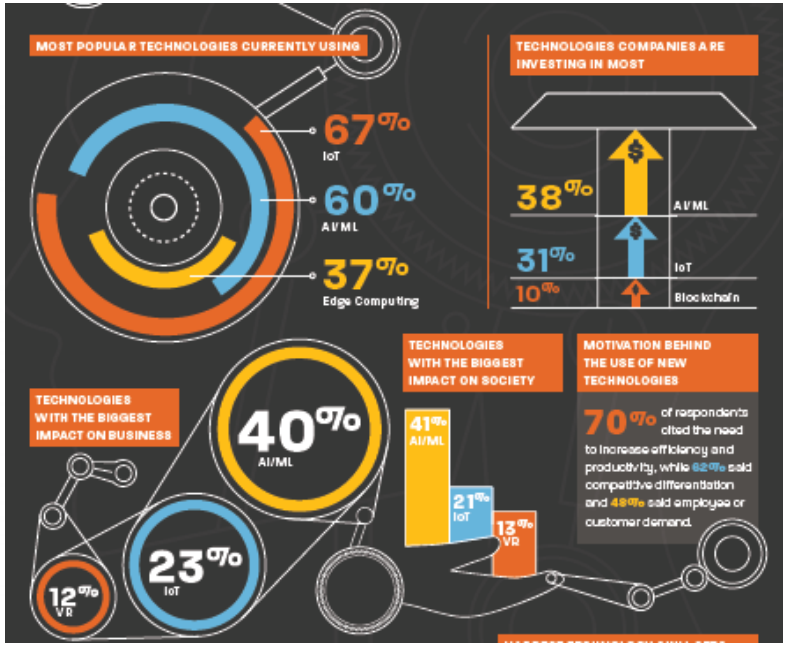
if AI can be more **rational** than humans in some cases, why not?

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.

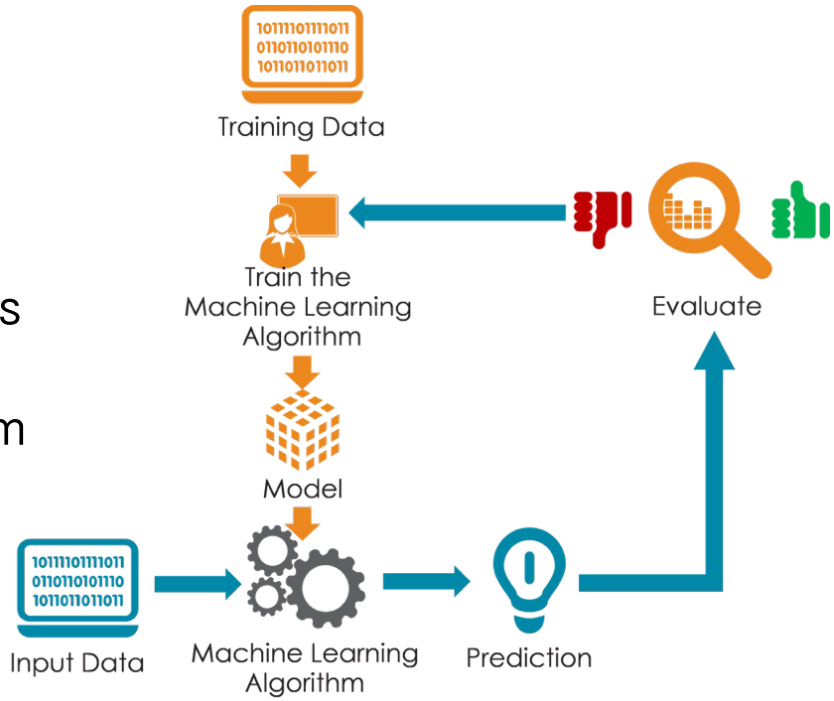
AI Technologies





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



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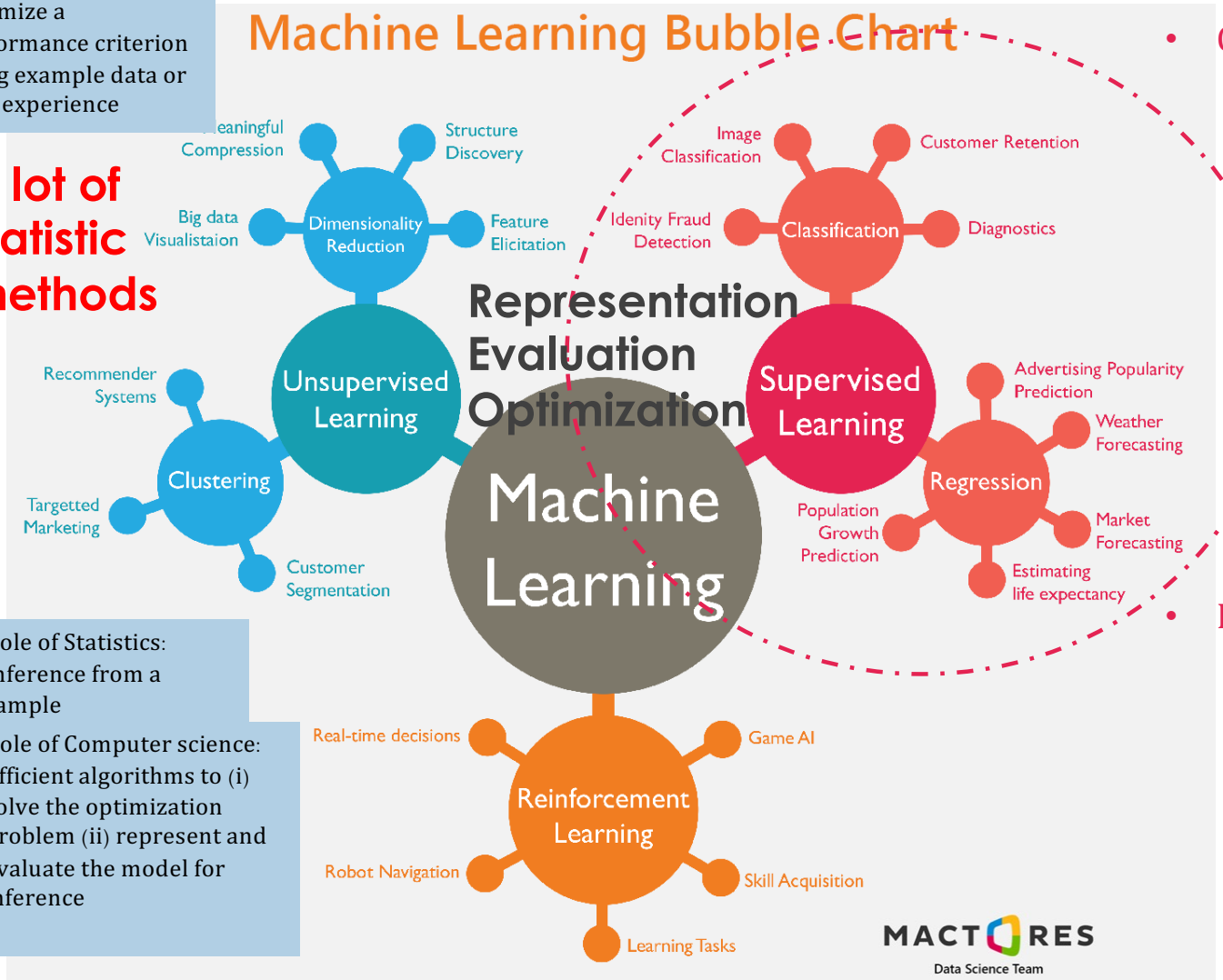
Machine Learning Techniques

Optimize a performance criterion using example data or past experience



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
  - ...

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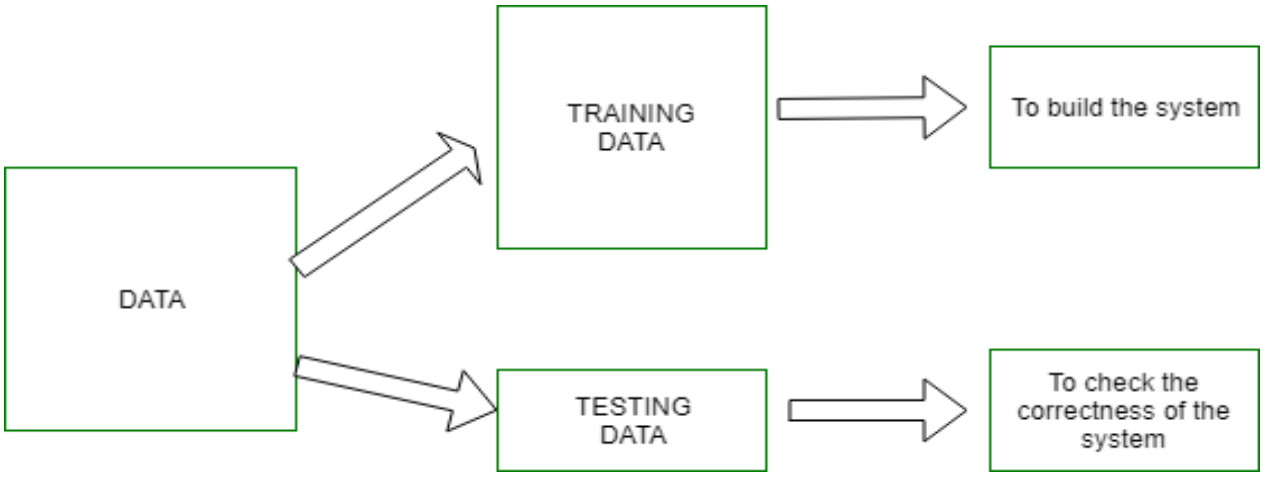
Supervised Learning

- 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*.

Commonly called datasets



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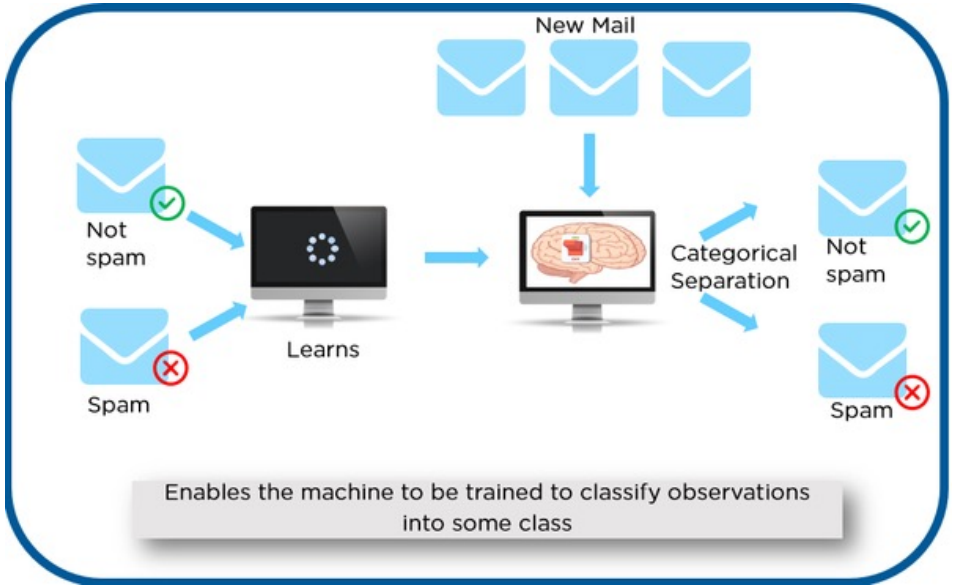
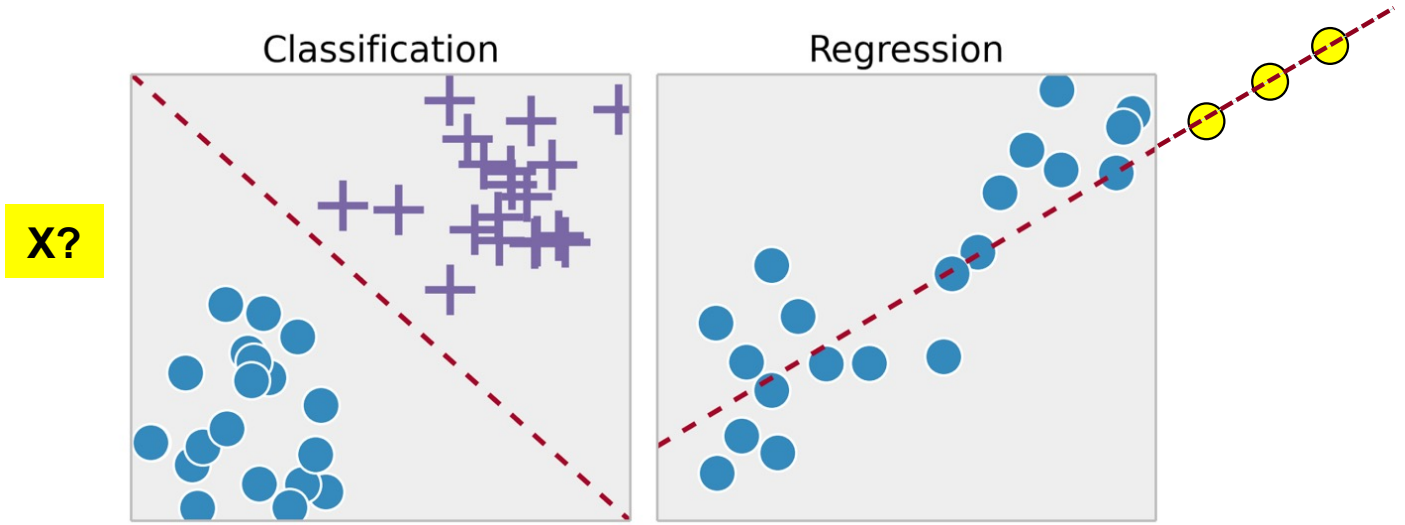
Spam Mail Example

- 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).



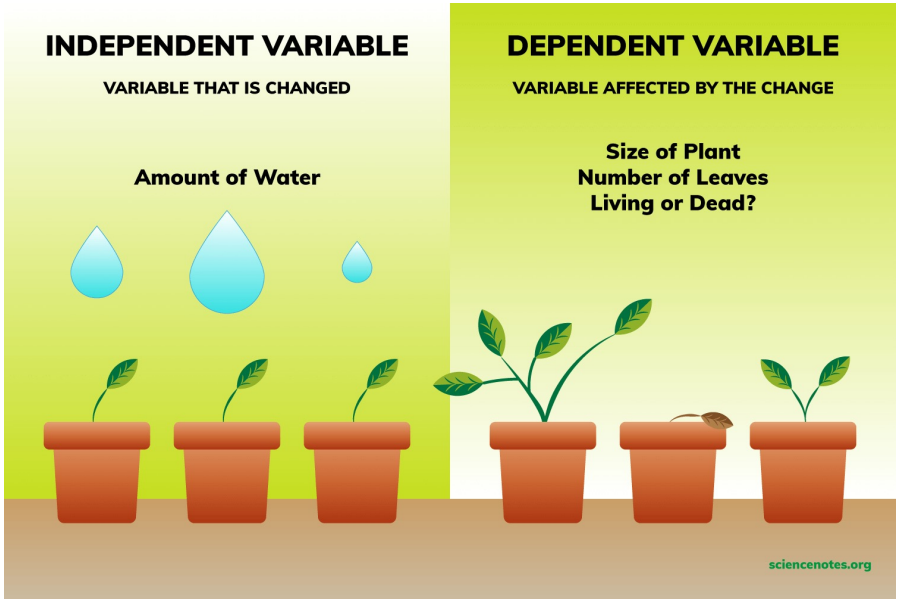
Types of Supervised Learning

- **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.*



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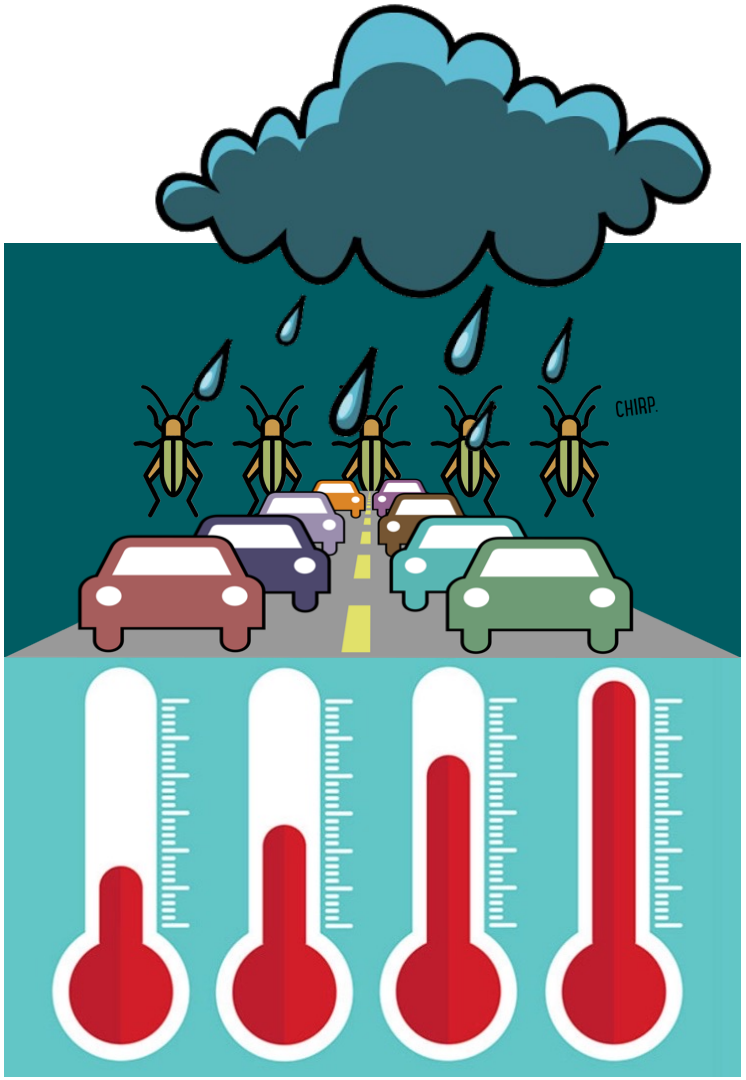
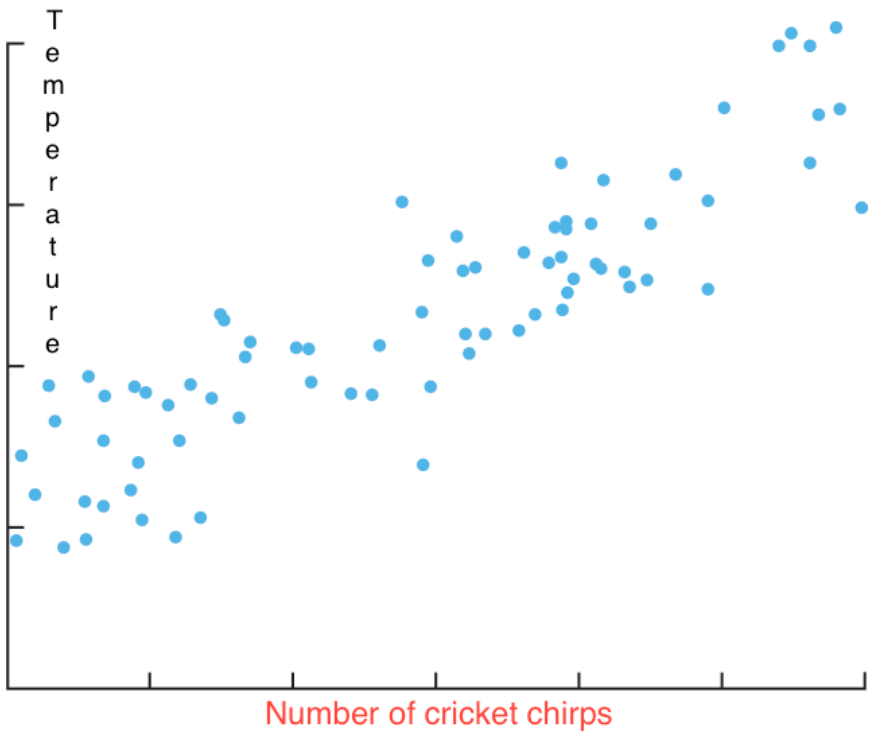
Types of Regression

- **Simple regression:** single independent variable x for a single dependent variable **Y**.
  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 of datasets

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



- Agriculture
  - Soil moisture for optimized irrigation
- Environment
  - Pollutant concentration for public safety and alarming system
- Electricity
  - Power demands for optimized production
- …

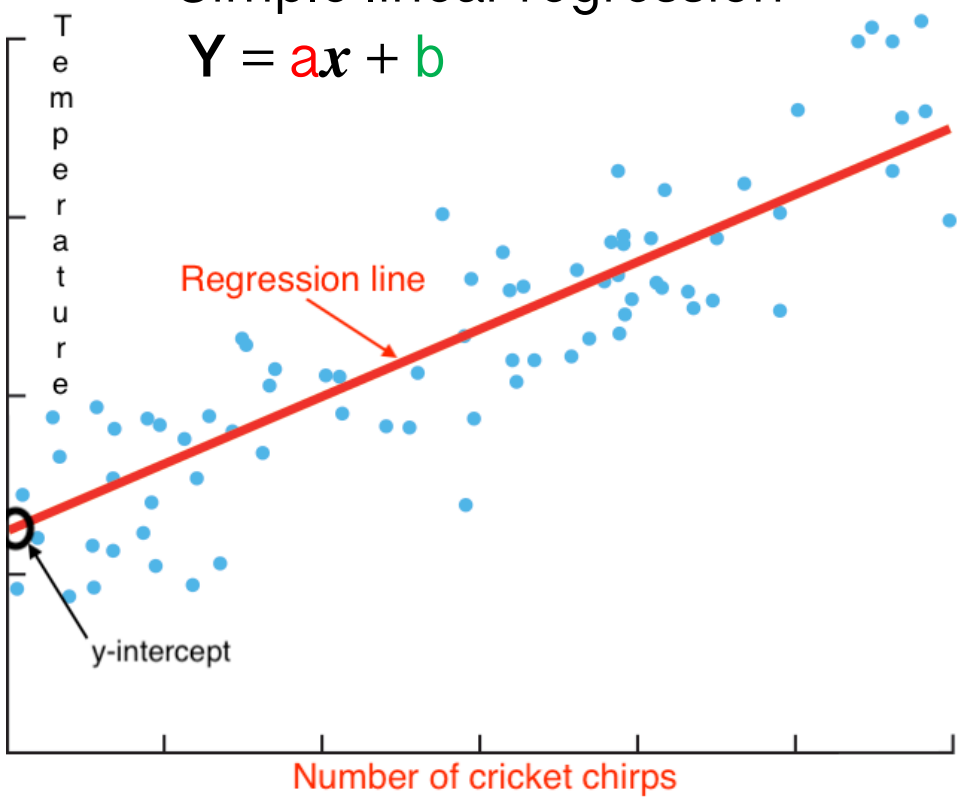
Linear Regression

- A linear relationship to predict the (average) numerical value of **Y** for a given value of $\boldsymbol{x}$ using a straight line, called the ***regression line***.
- Knowing the *slope* and the **y**-intercept the objective is to predict the average **Y** from $\boldsymbol{x}$.
- Real world problem can be multivariate
- Multiple linear regression

$$\mathbf{Y} = a_1\boldsymbol{x}_1 + a_2\boldsymbol{x}_2 + a_3\boldsymbol{x}_3 + \ldots + a_i\boldsymbol{x}_i + b$$

Simple linear regression

$\mathbf{Y} = a\boldsymbol{x} + b$



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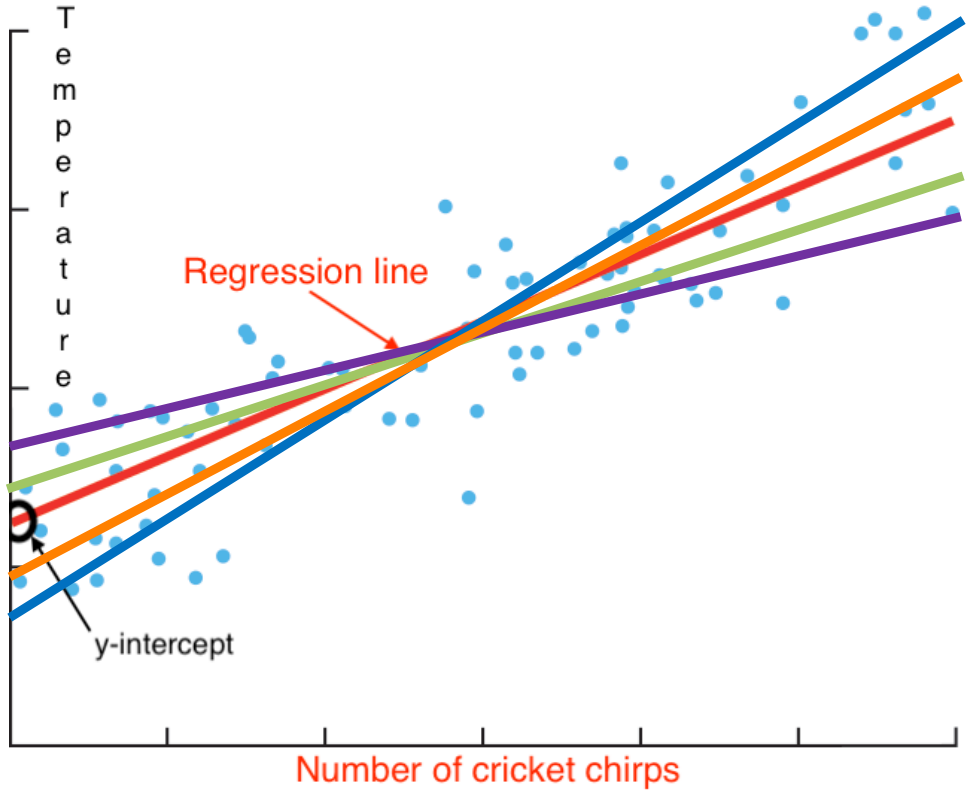
Then what?

- What is the best regression line?
- How can we find it?



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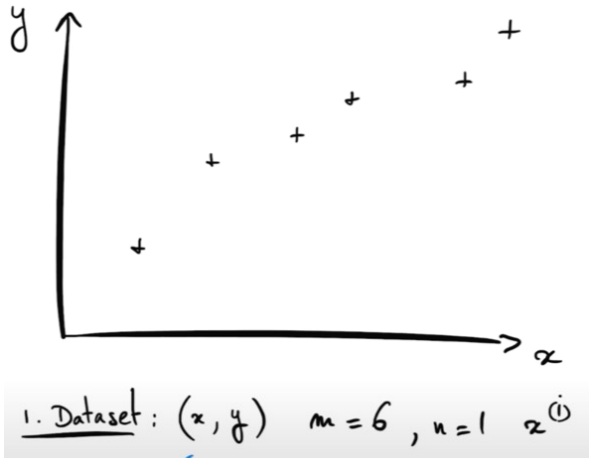
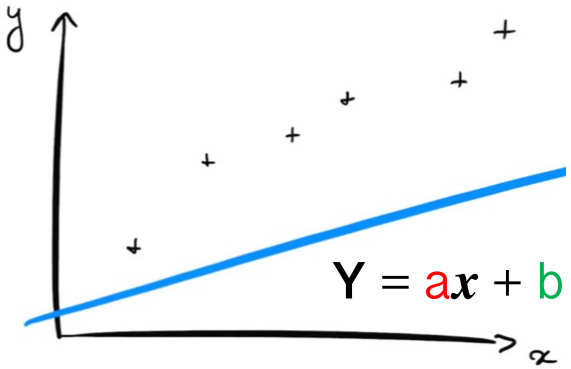
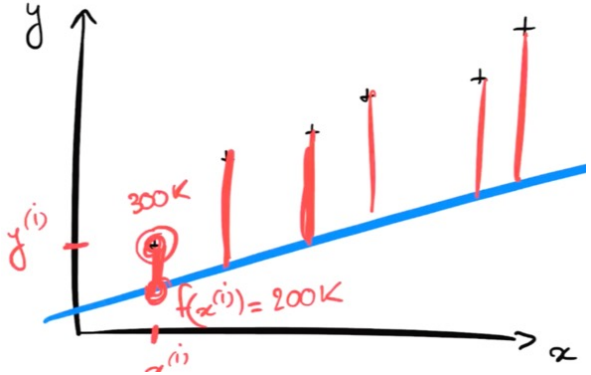
The need for a cost function







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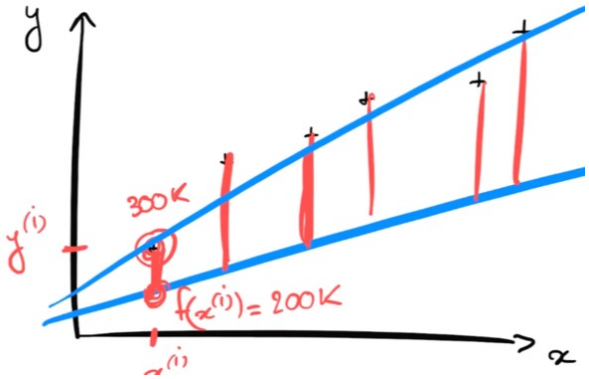
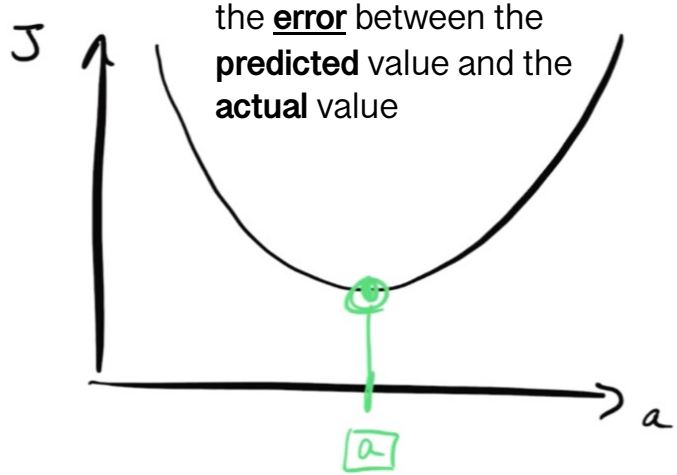
$$J(a,b) = \frac{1}{2m} \sum_{i=1}^{m} \left(f(x^{(i)}) - y^{(i)} \right)^2$$

A **cost function** will help to figure out the best possible values for a and b which would provide the best *regression line* for data points



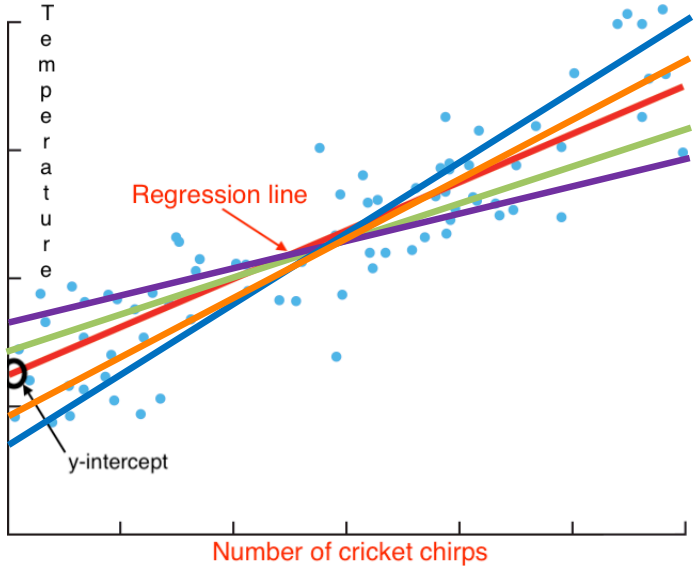
this search problem is converted into a minimization problem of the **error** between the **predicted** value and the **actual** value



Pictures rom https://www.youtube.com/watch?v=wg7-roETbbM (Machine Learnia)

Why do we call it Machine Learning?

- The number of data points can be very large!
- The number of possible regression lines can be very large!
- Trying in a brute force approach can take years, even with state-of-the-art supercomputers!
- Exact methods also need very complex & long operations to be conducted!
- It is called AI/ML because we "tell" the machine to efficiently find the best solution
- "tell"=implement "intelligent" algorithms!



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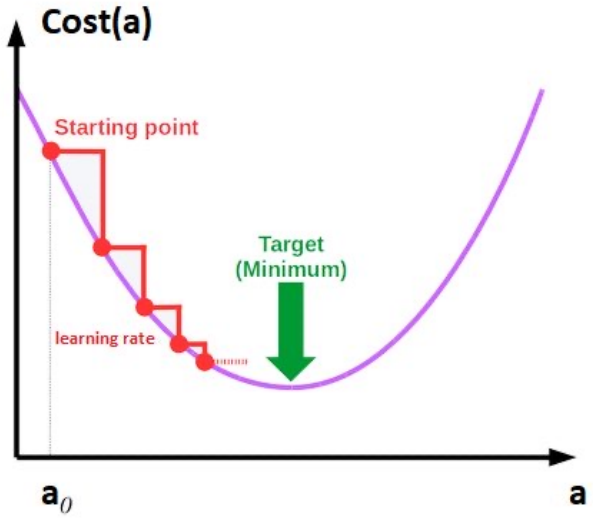
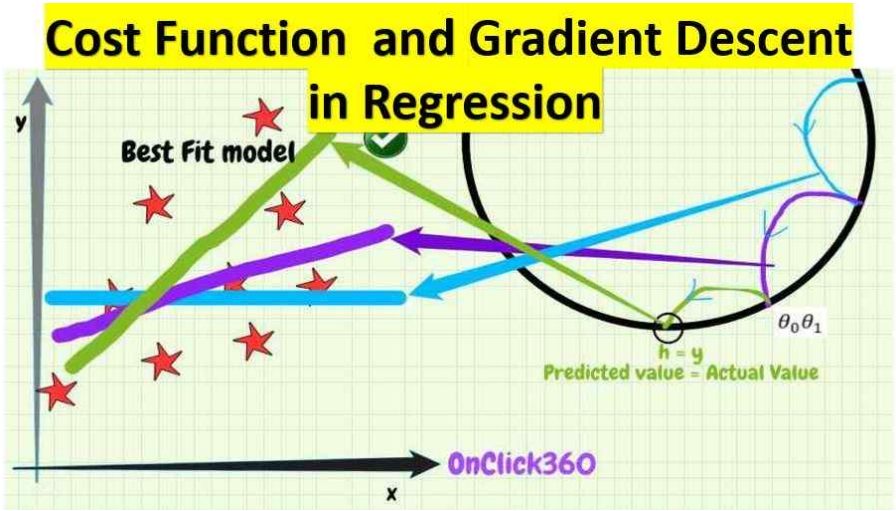
e.g. Gradient Descent method

- Gradient Descent is a method of updating a and b to reduce the error (Cost Function)
- The idea is to start with arbitrary 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/

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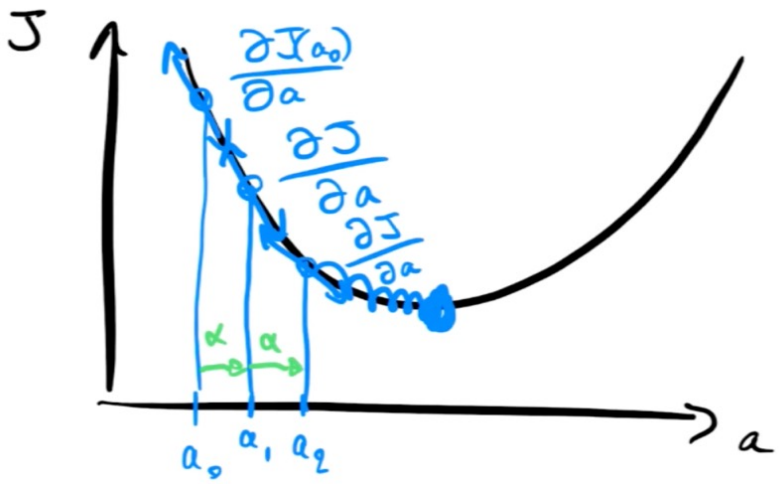
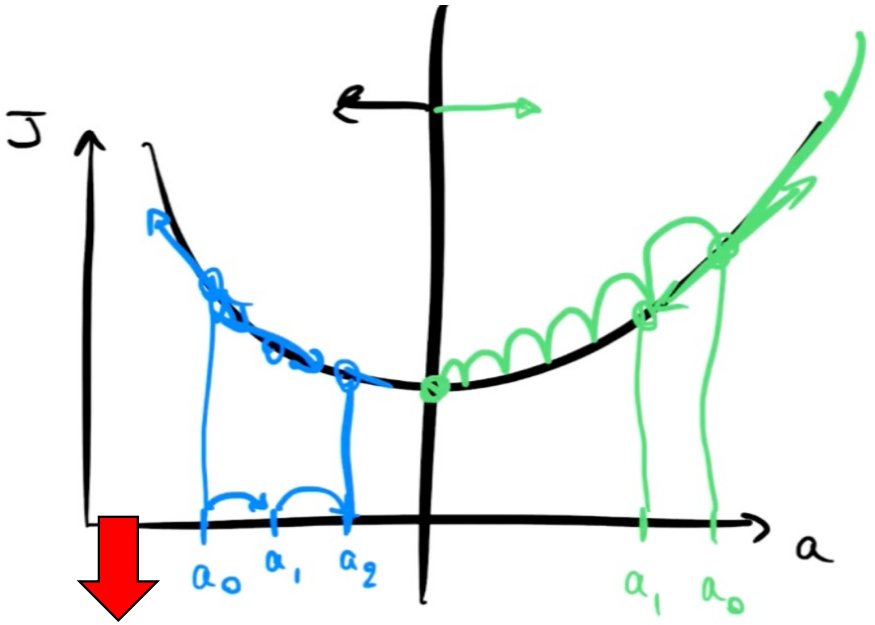
Why is it more "intelligent"?

$$J(a,b) = \frac{1}{2m} \sum_{i=1}^{m} \left(f(x^{(i)}) - y^{(i)} \right)^2$$



$$a_{i+1} = a_i - \alpha \frac{\partial J(a_i)}{\partial a}$$



$$\frac{\partial J(a_i)}{\partial a} < 0, \text{ so } -\alpha \frac{\partial J(a_i)}{\partial a} > 0$$

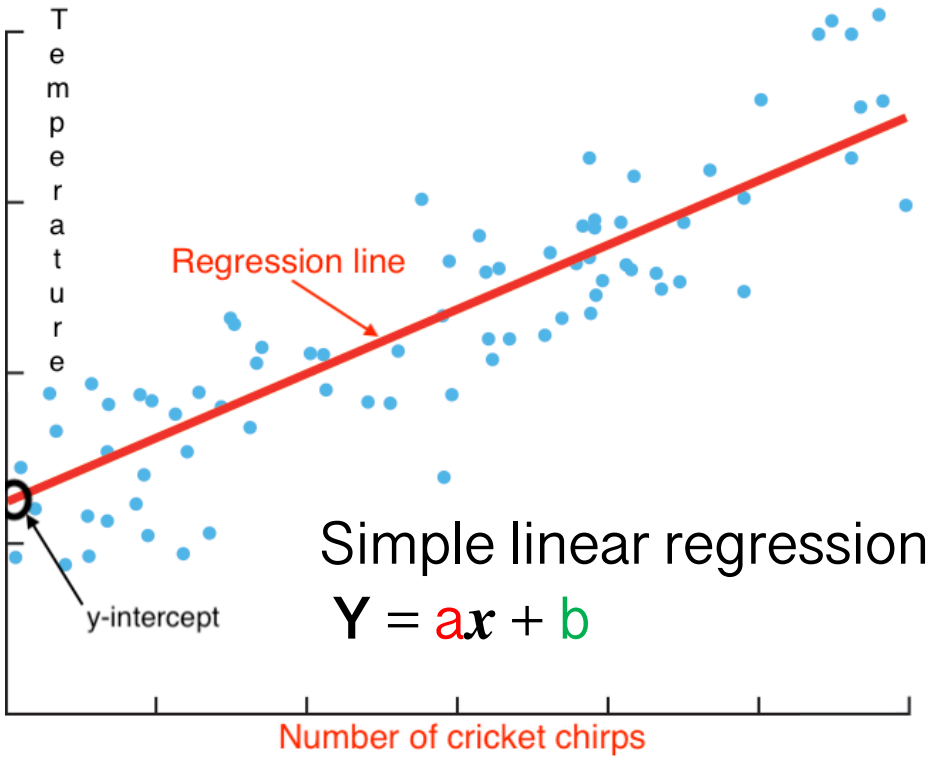
So $a_1 > a_0$

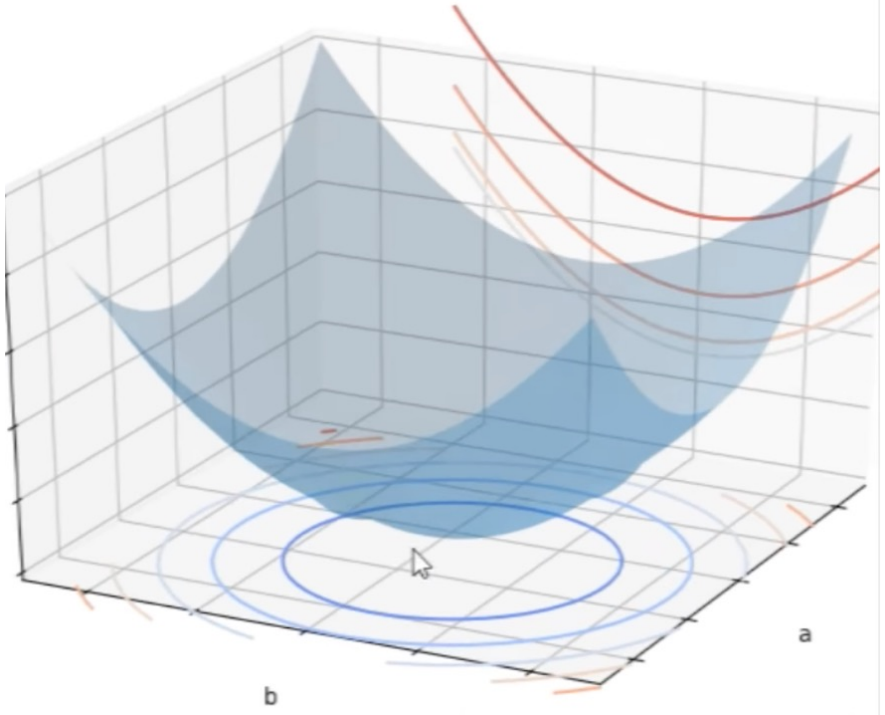
The algorithm converges automatically!

Pictures from https://www.youtube.com/watch?v=rcl_YRyoLIY (Machine Learnia)

Why do we need that "intelligence"?

- With a simple line, we need to search for both a and b
- That already gives a large surface!
- So the search space can be huge!





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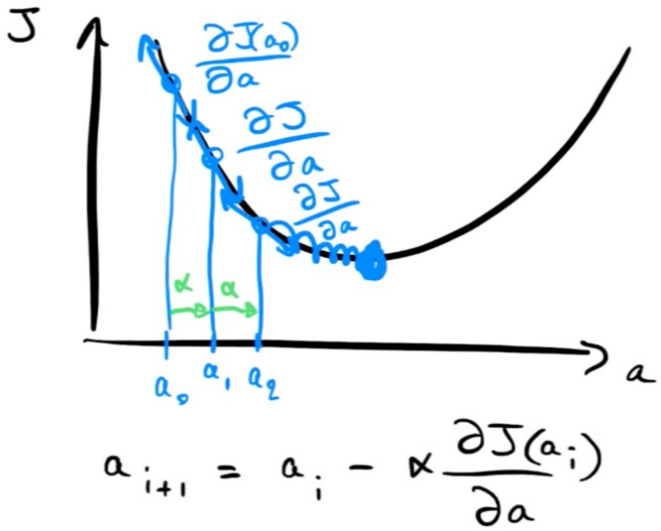
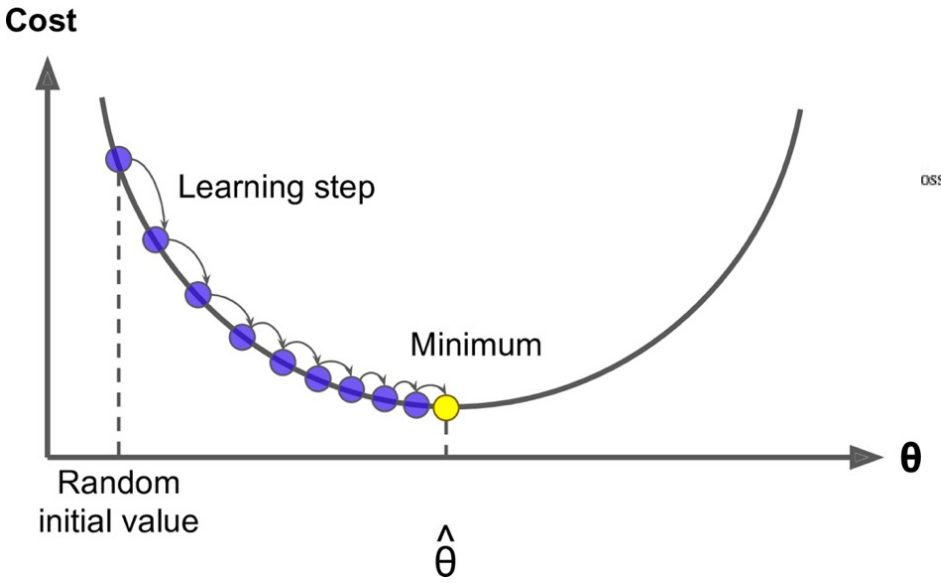
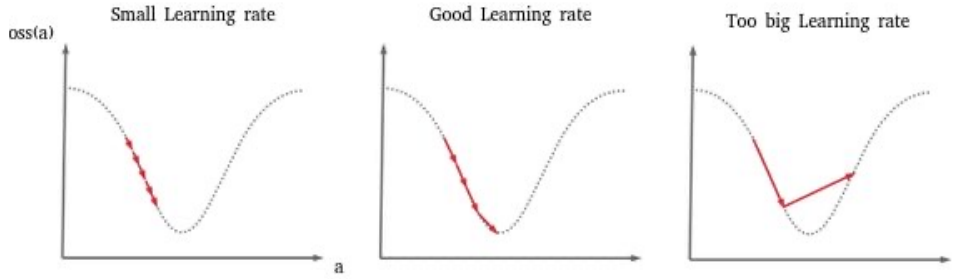
Learning Rate α

- A smaller *learning rate* could get closer to the *minima* but takes more time to reach the *minima*
- A larger *learning rate* converges sooner but there is a chance that you could overshoot the *minima*.







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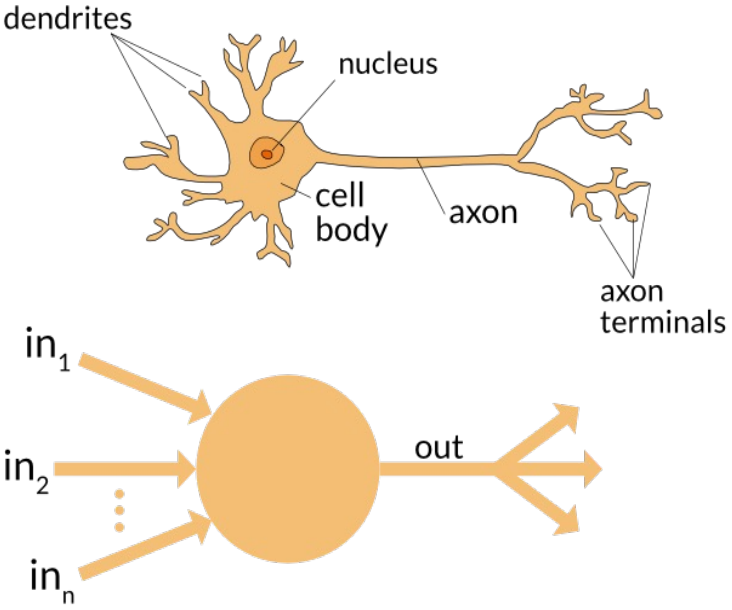
More like humans?

- In early AI ages, researchers wanted to mimic the human brain seen as a network of neurons
- 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



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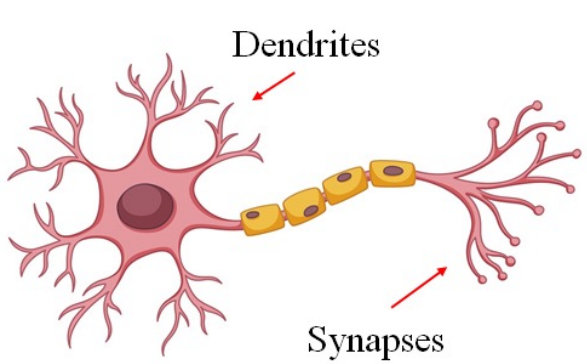
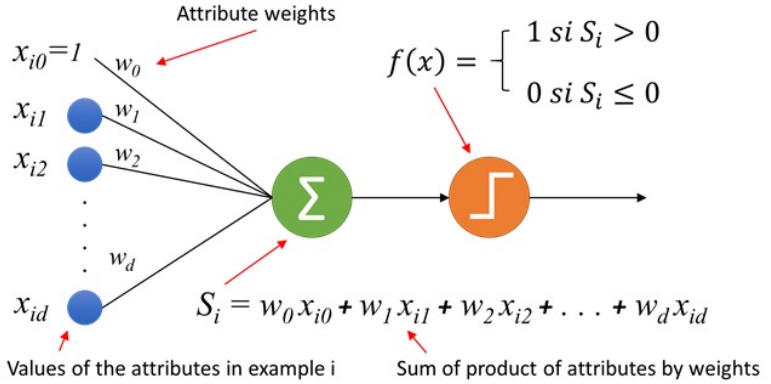
How does a Perceptron work?

- 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

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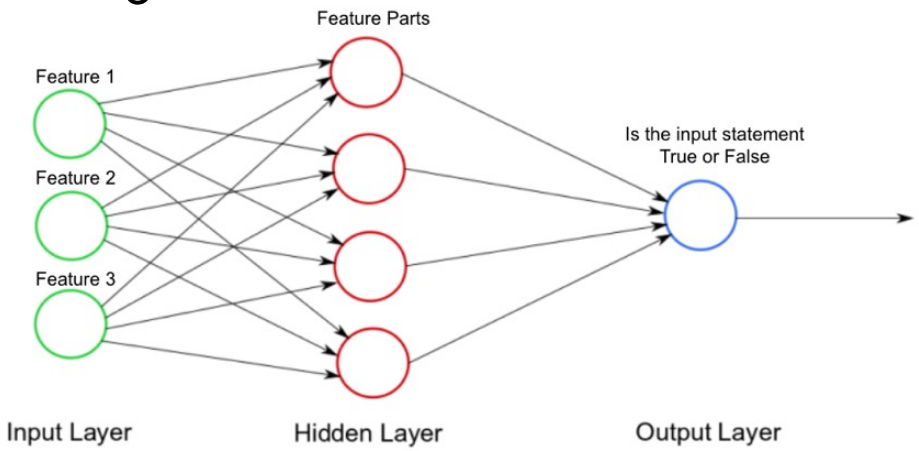
Neural Networks

- 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.



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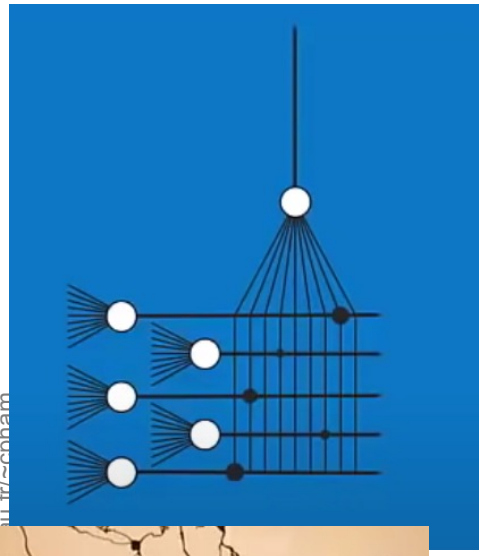
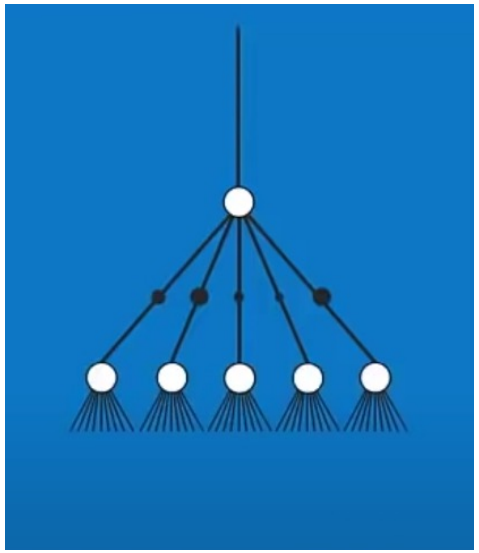
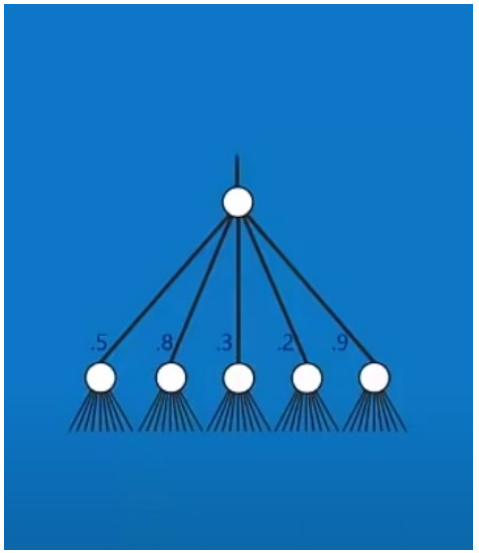
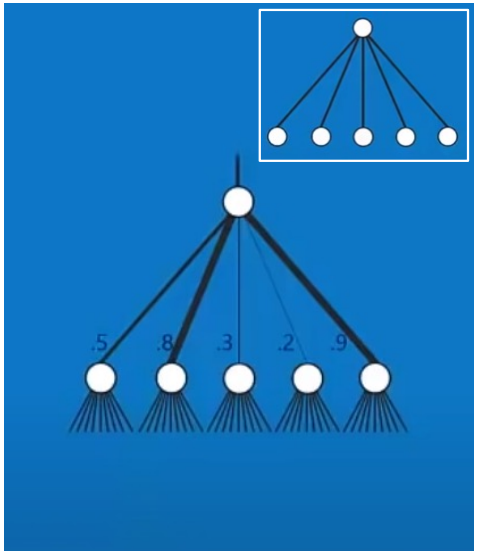
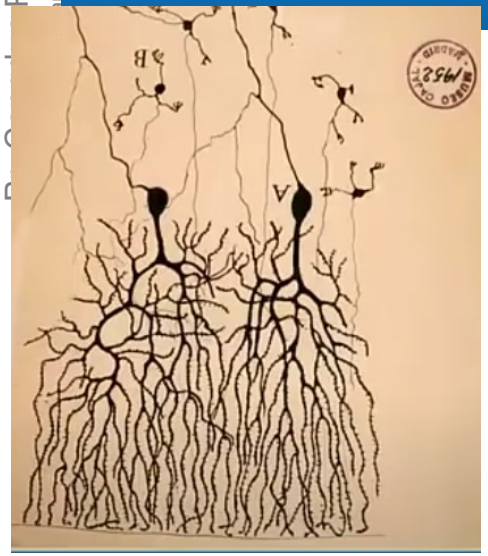
Neural Network in a nutshell

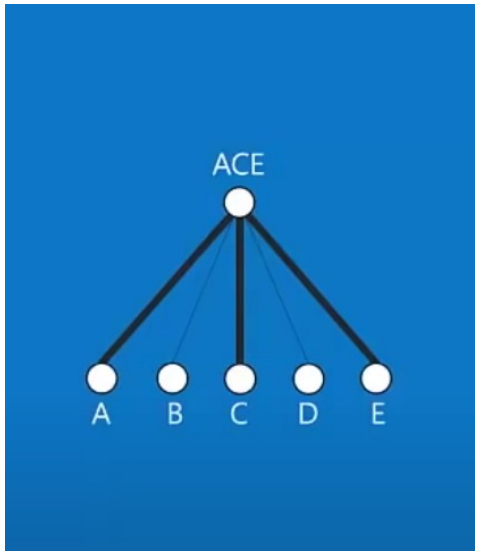


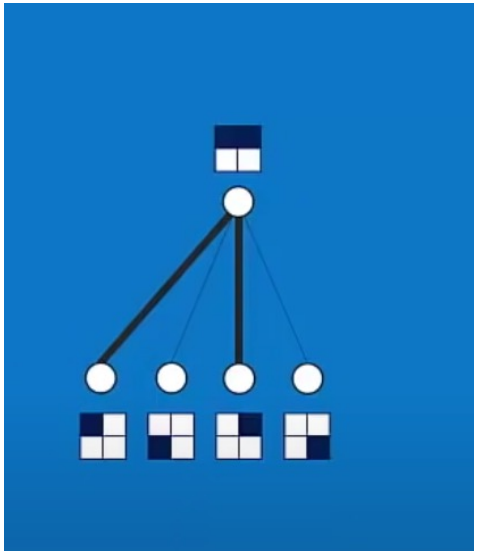


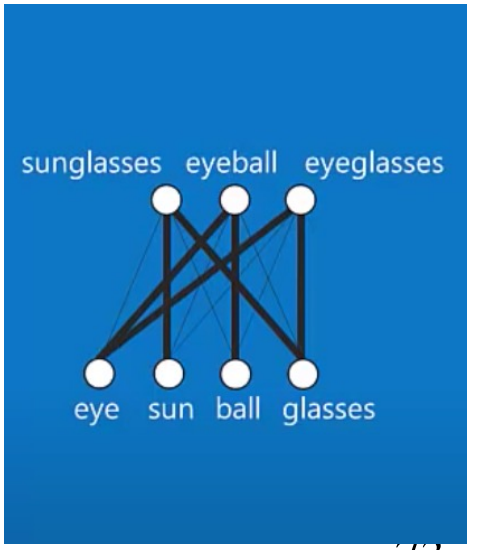








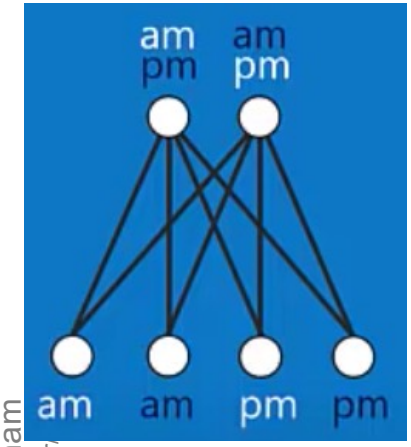


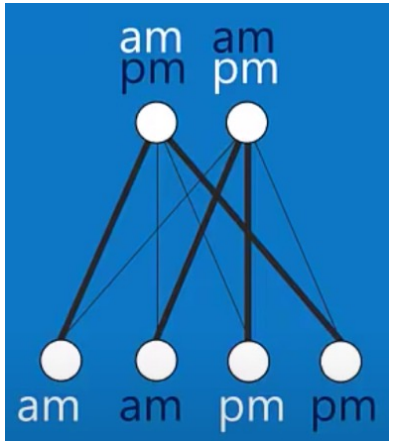


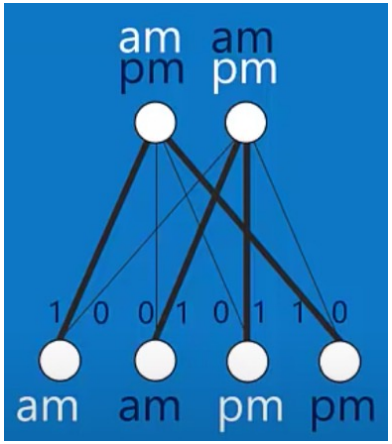
Pictures from https://www.youtube.com/watch?v=Q9Z20HCPnww (Brandon Rohrer)

Shawarma guy example (1)

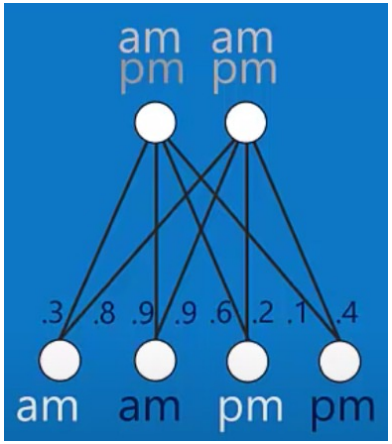
Pictures from https://www.youtube.com/watch?v=Q9Z20HCPnww (Brandon Rohrer)



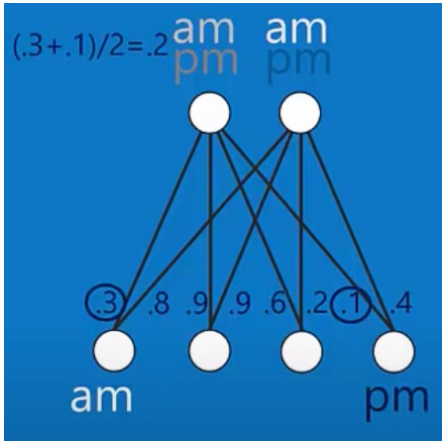




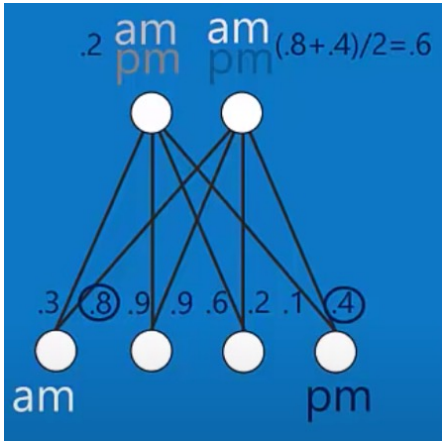
Sometimes he works mornings, sometimes evenings



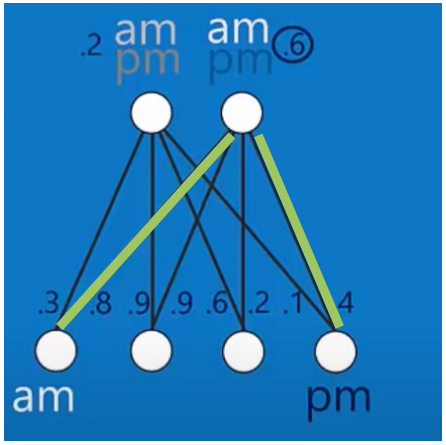
Start with random weights



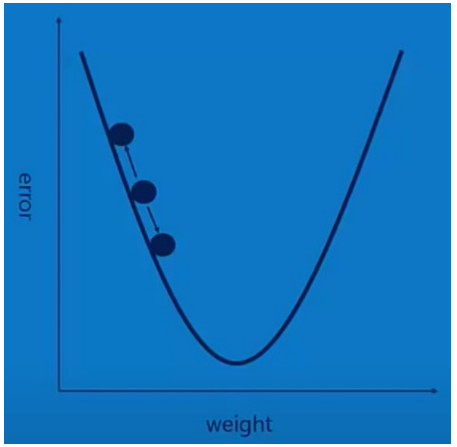
Observed on a given day



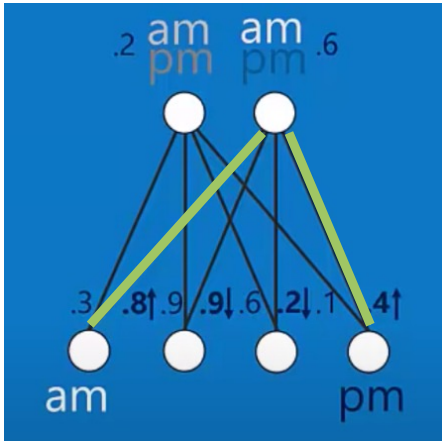
Error=1 - .2 = .8



Error=1 - .6 = .4

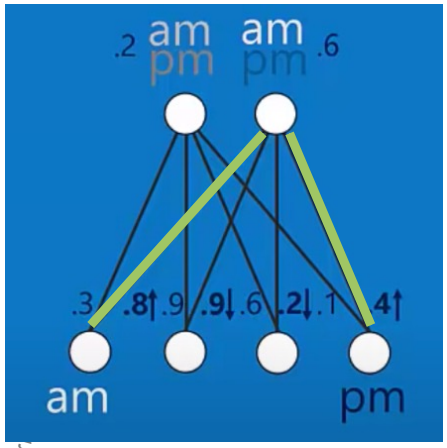


Here comes again our Gradient Descent methods!

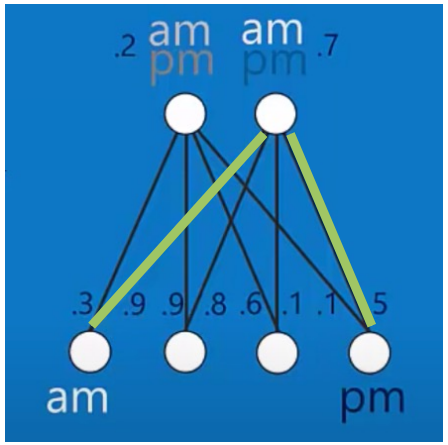


Shawarma guy example (2)

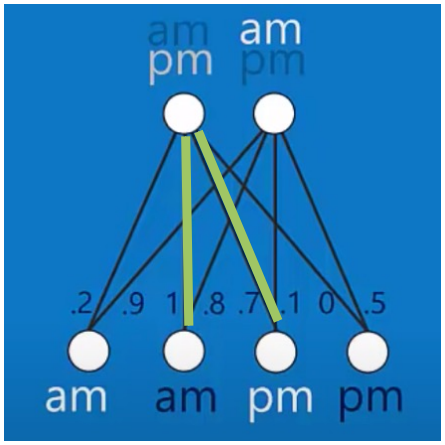
Pictures from https://www.youtube.com/watch?v=Q9Z20HCPnww (Brandon Rohrer)



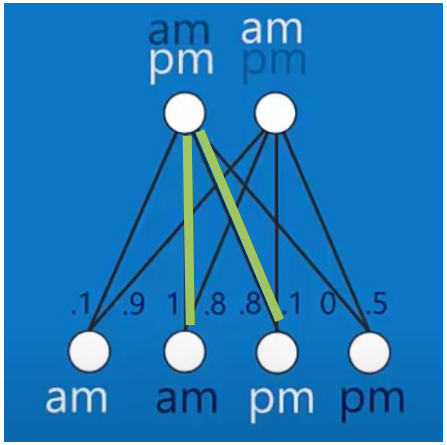
am pm Increase active links, decrease inactive links



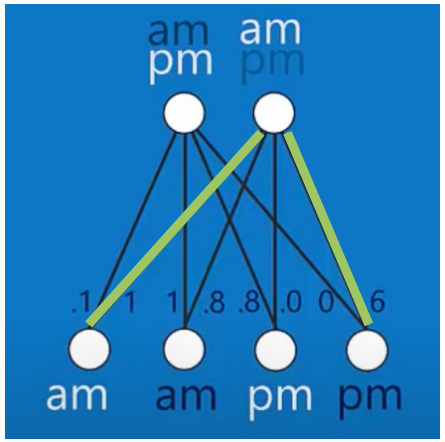
Error=1 - .7 = .3



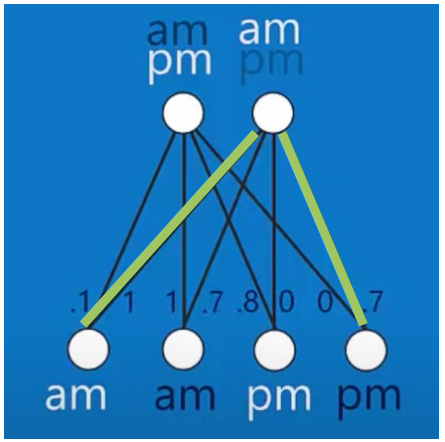
am pm The next day



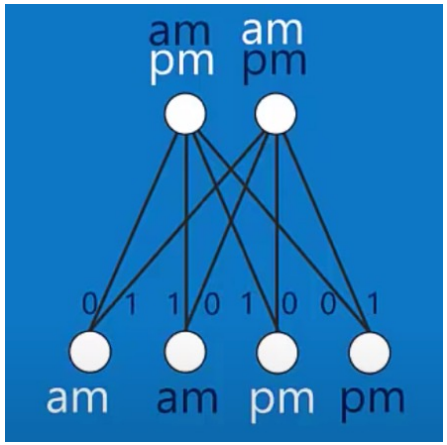
am pm The next day



am pm The next day



am pm The next day……..

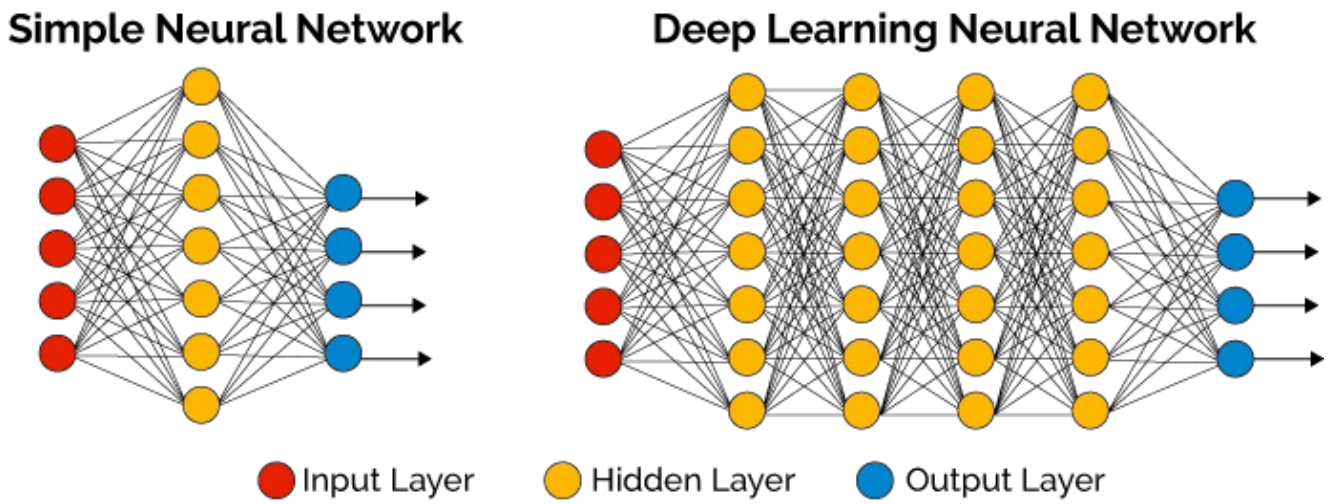


Eventually, weights don't change anymore!

At this point you have a trained model!

Deep Neural Networks

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



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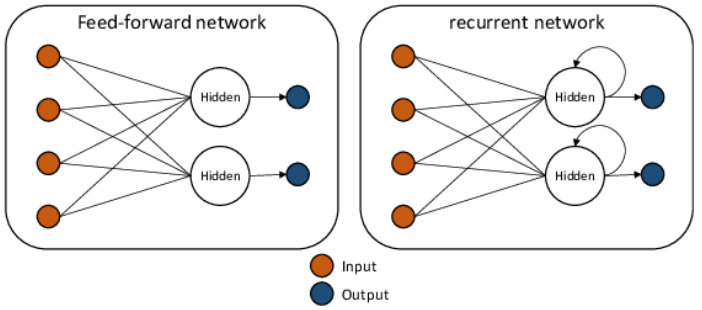
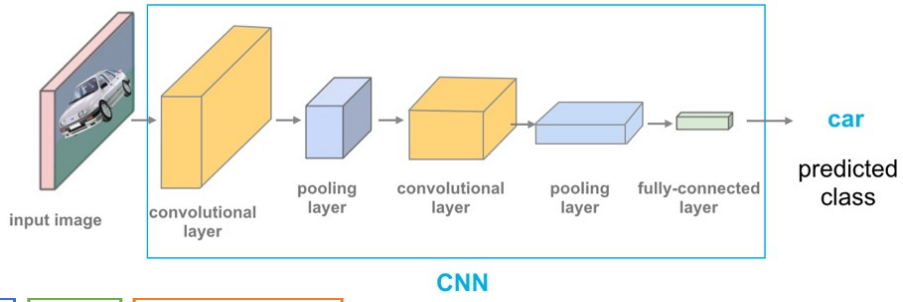
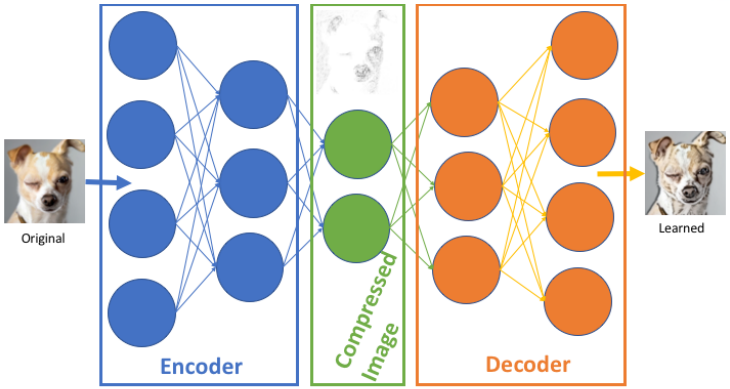
Types of Deep Neural Networks

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







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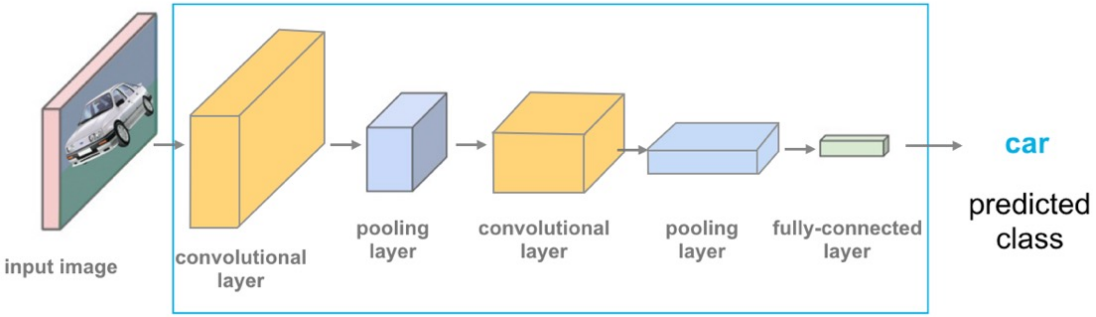
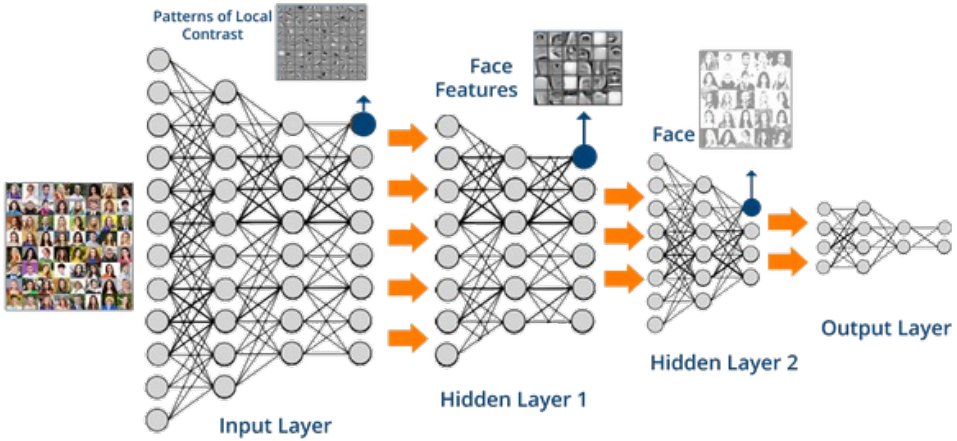
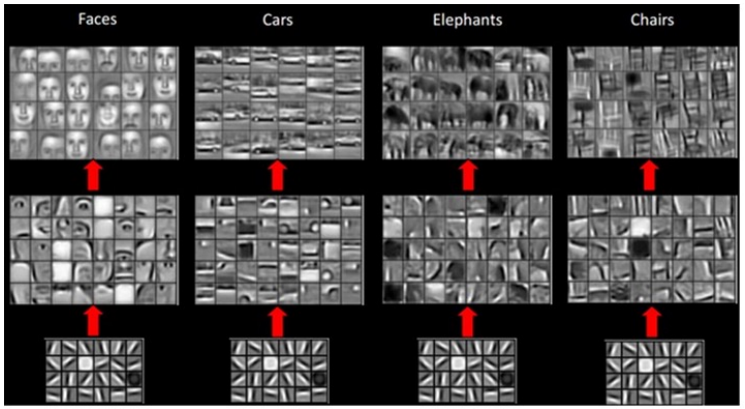
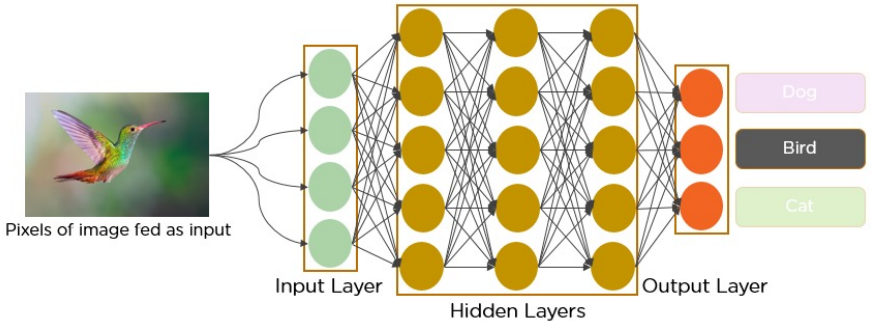
Convolutional Neural Networks

- Contain five types of layers
- Each layer has a specific purpose, like summarizing, connecting or activating
- CNN are good at image classification and object detection









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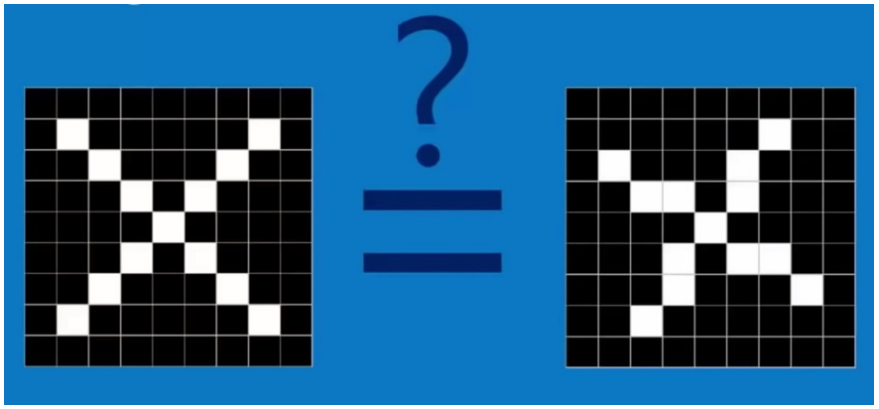
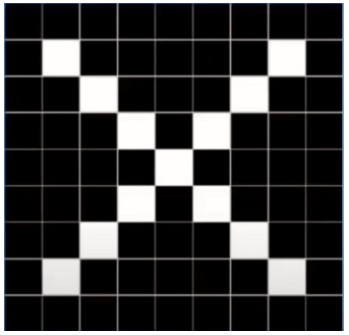
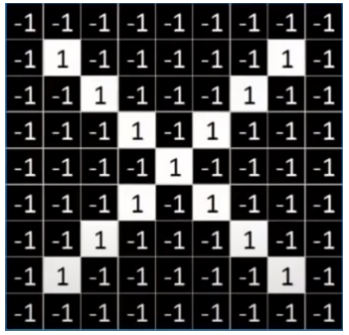
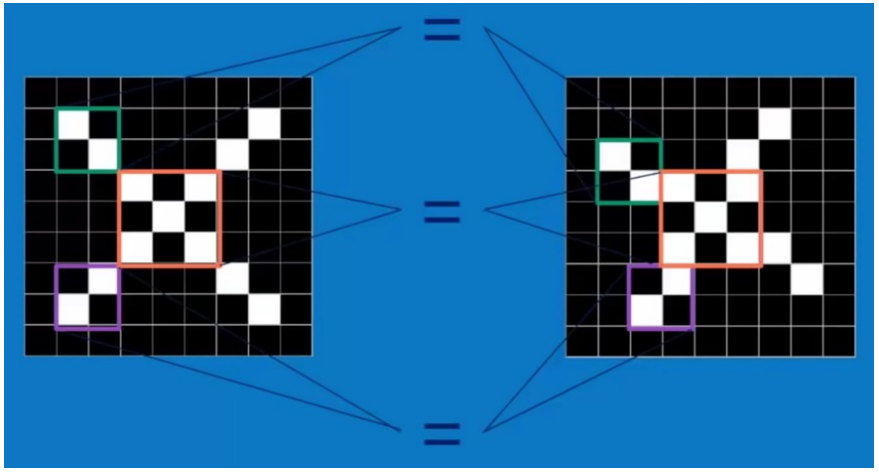
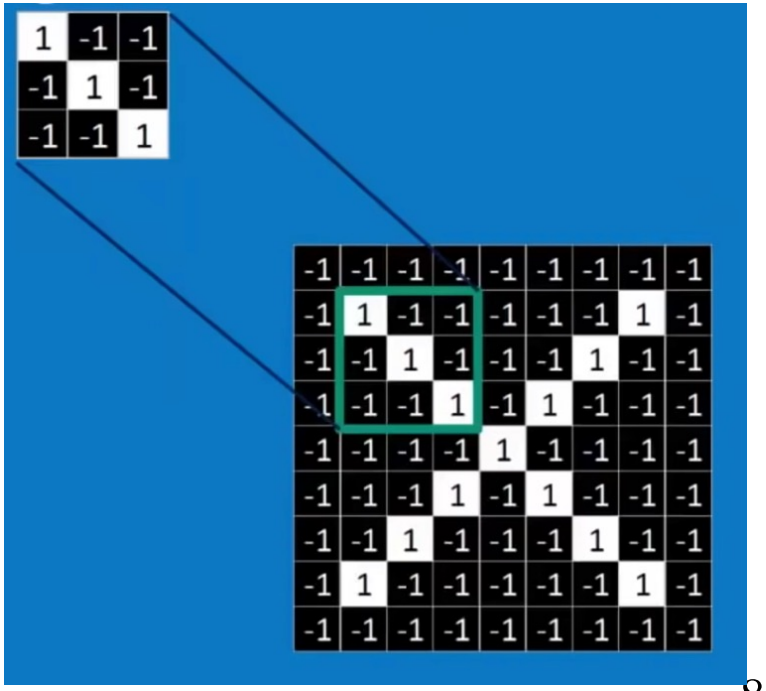
What is a convolution?

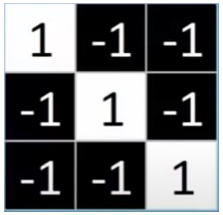


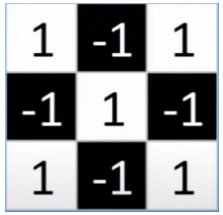


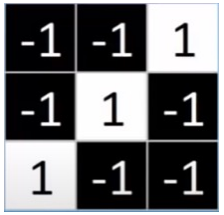












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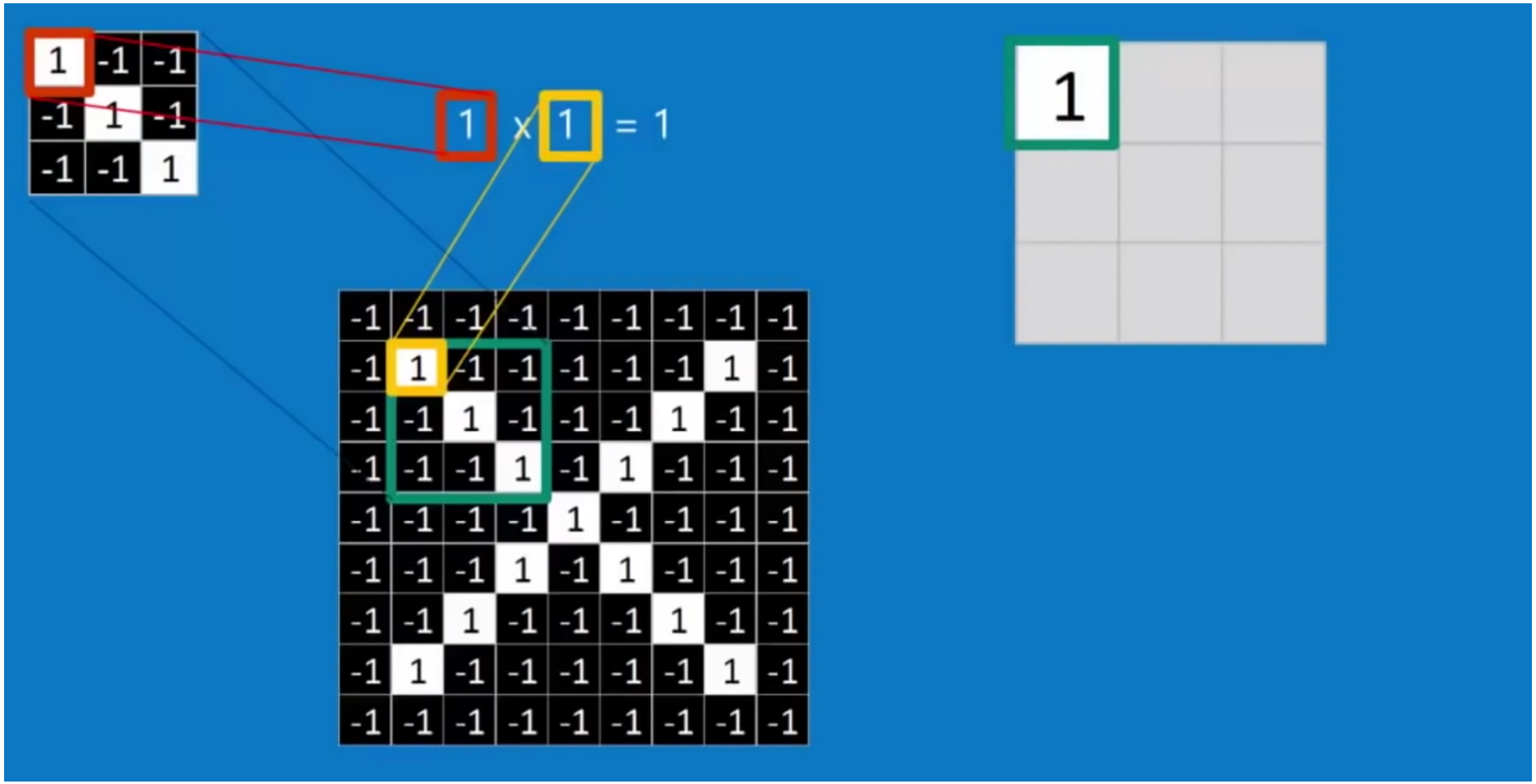
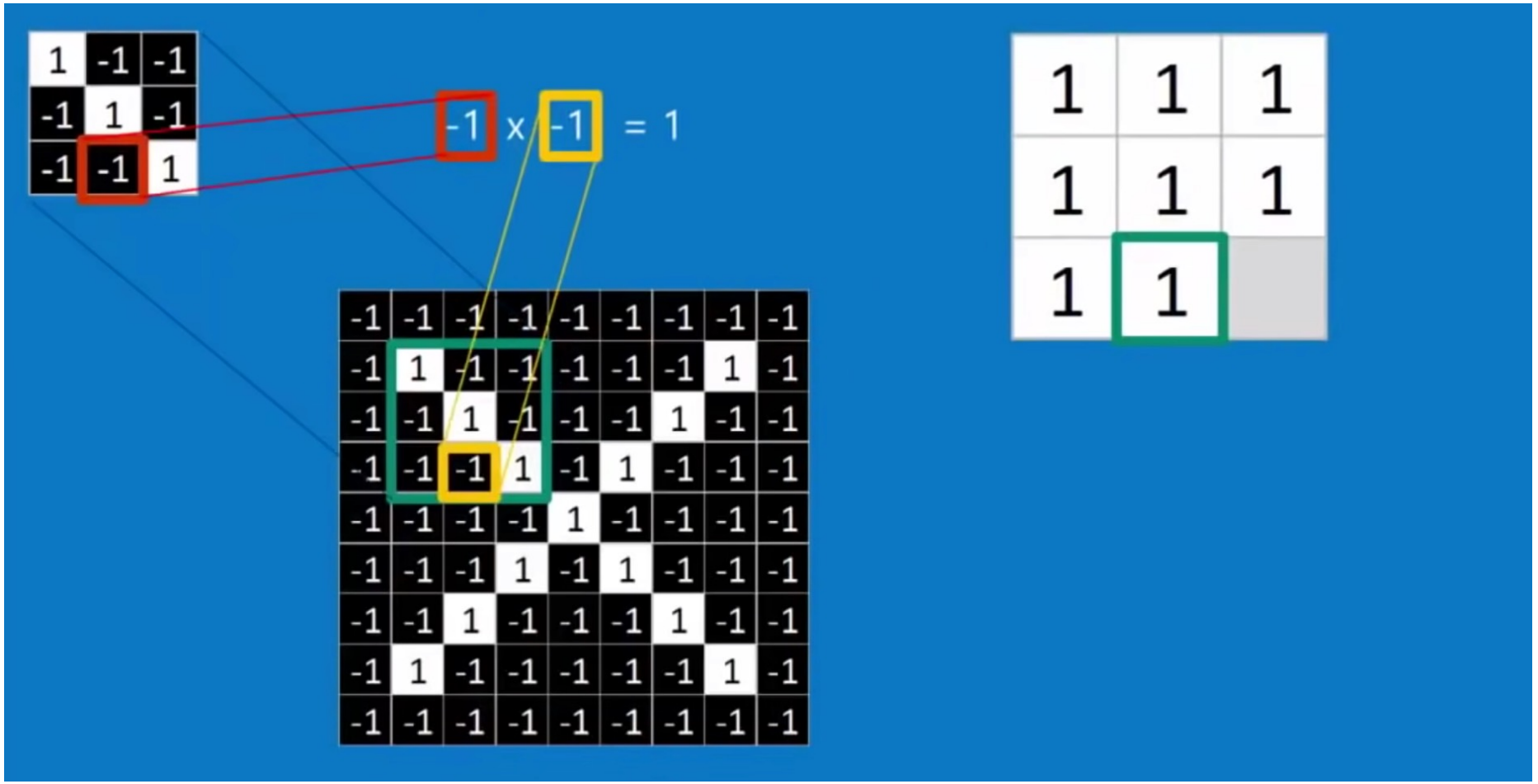
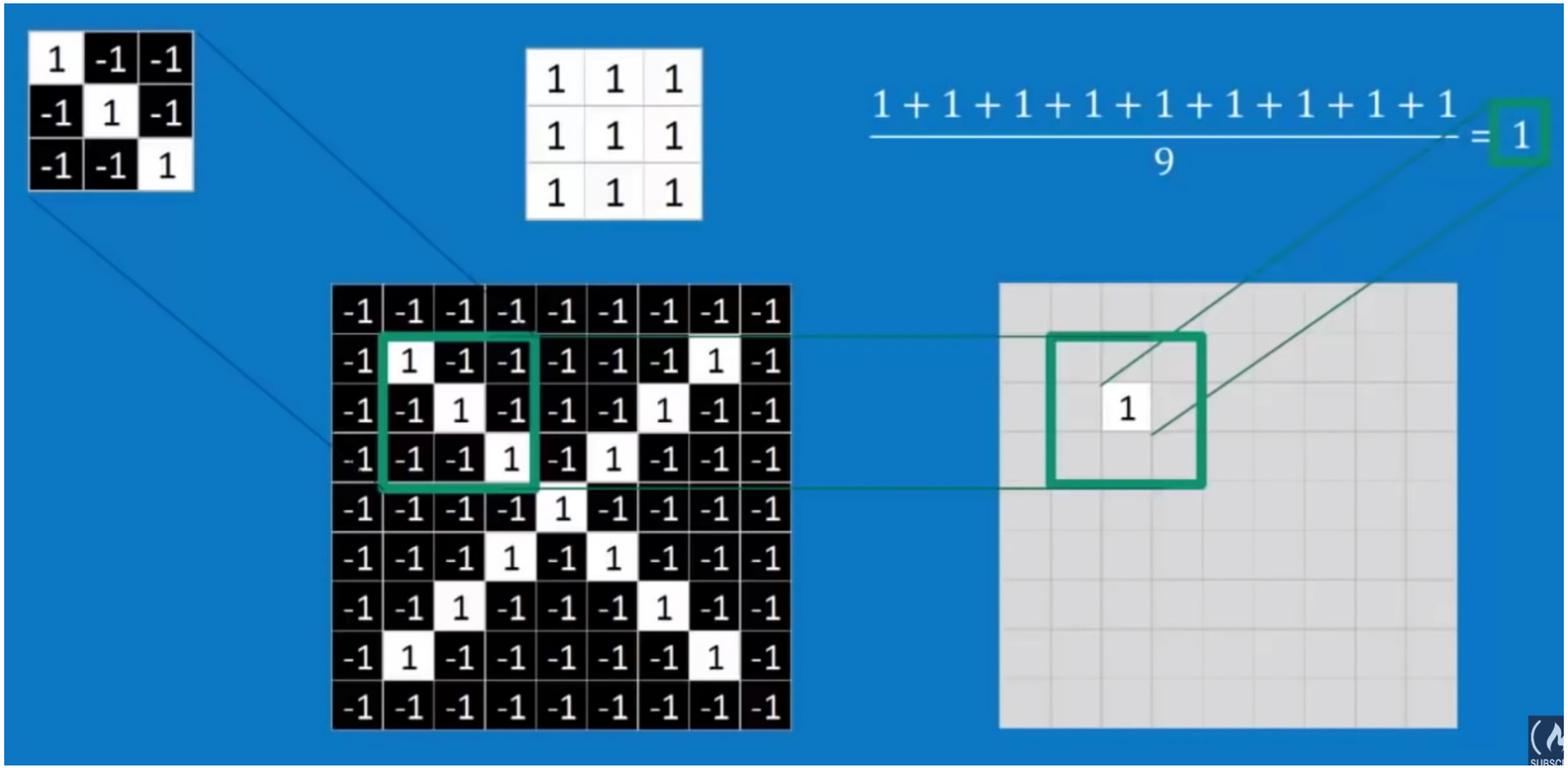
Running the convolution (1)



Running the convolution (2)



Running the convolution (3)



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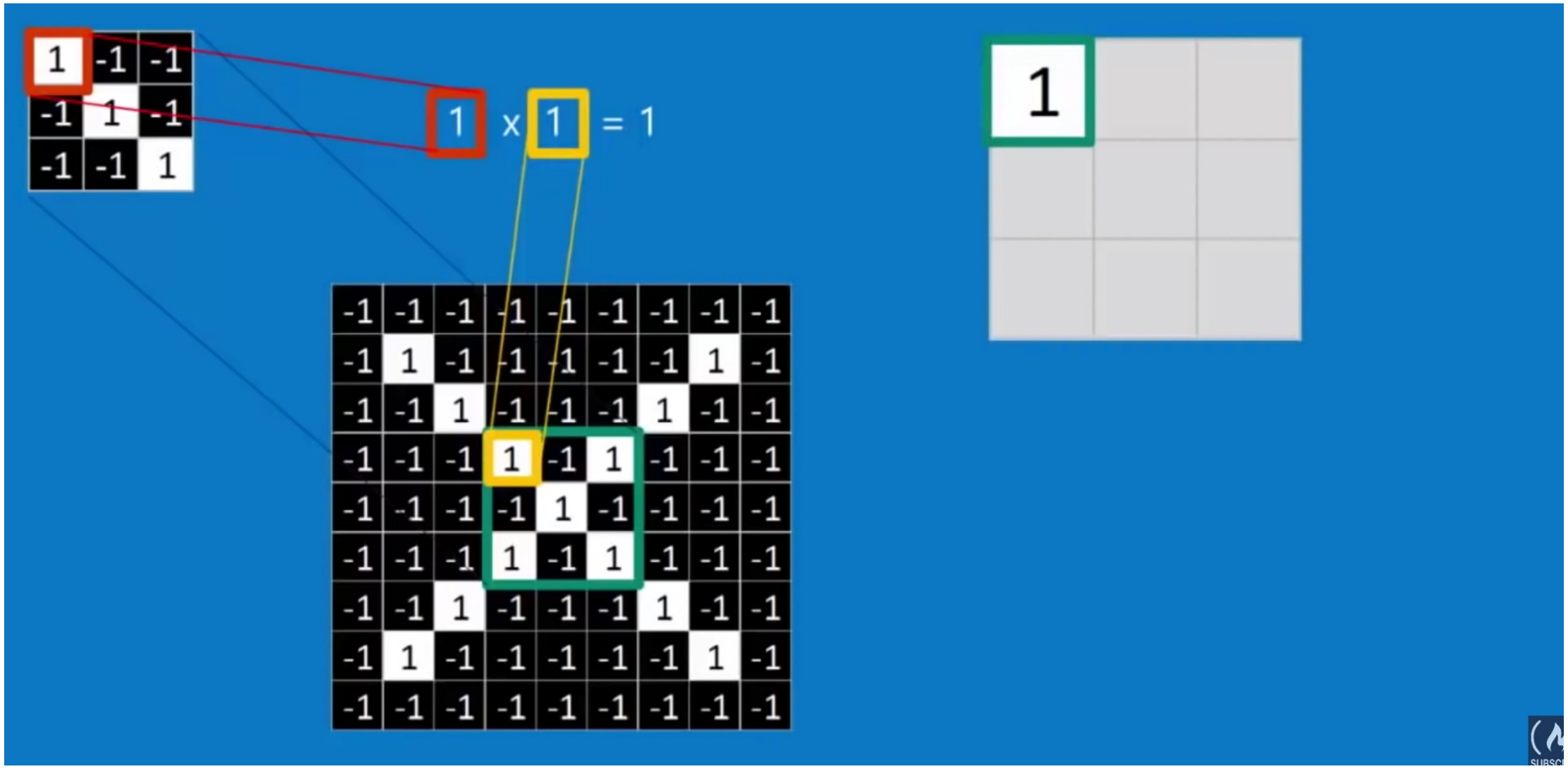
Running the convolution (4)



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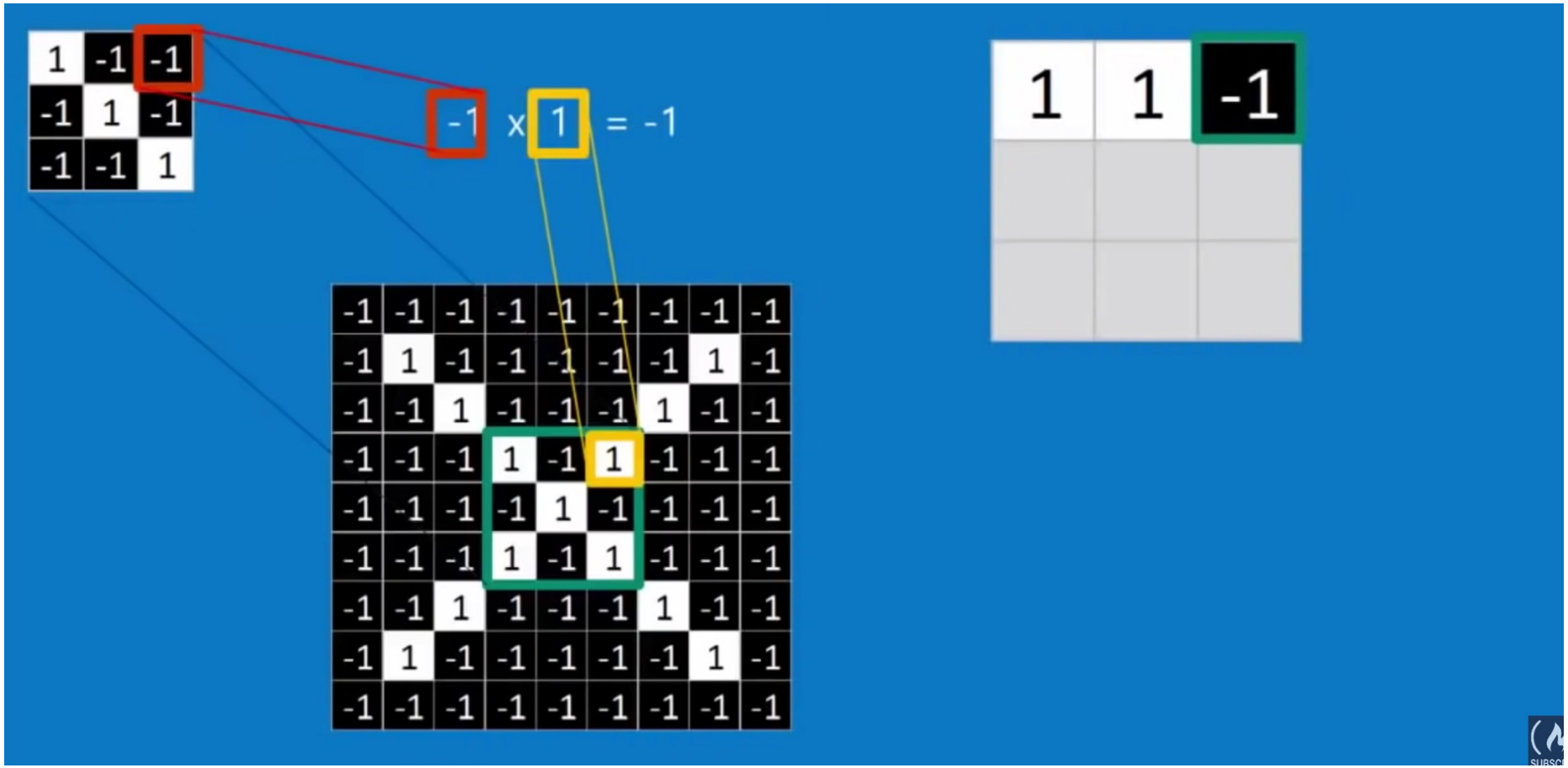
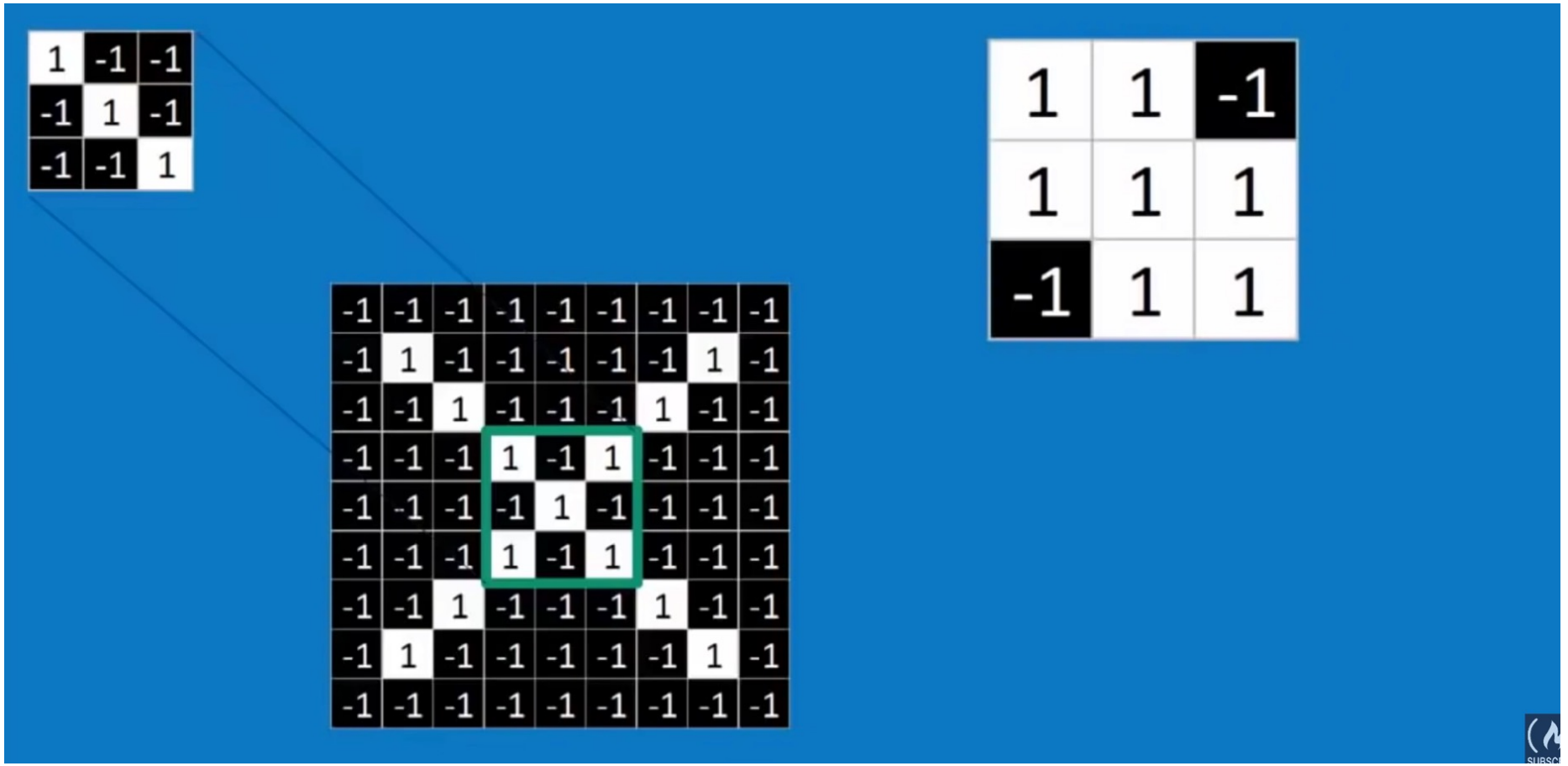
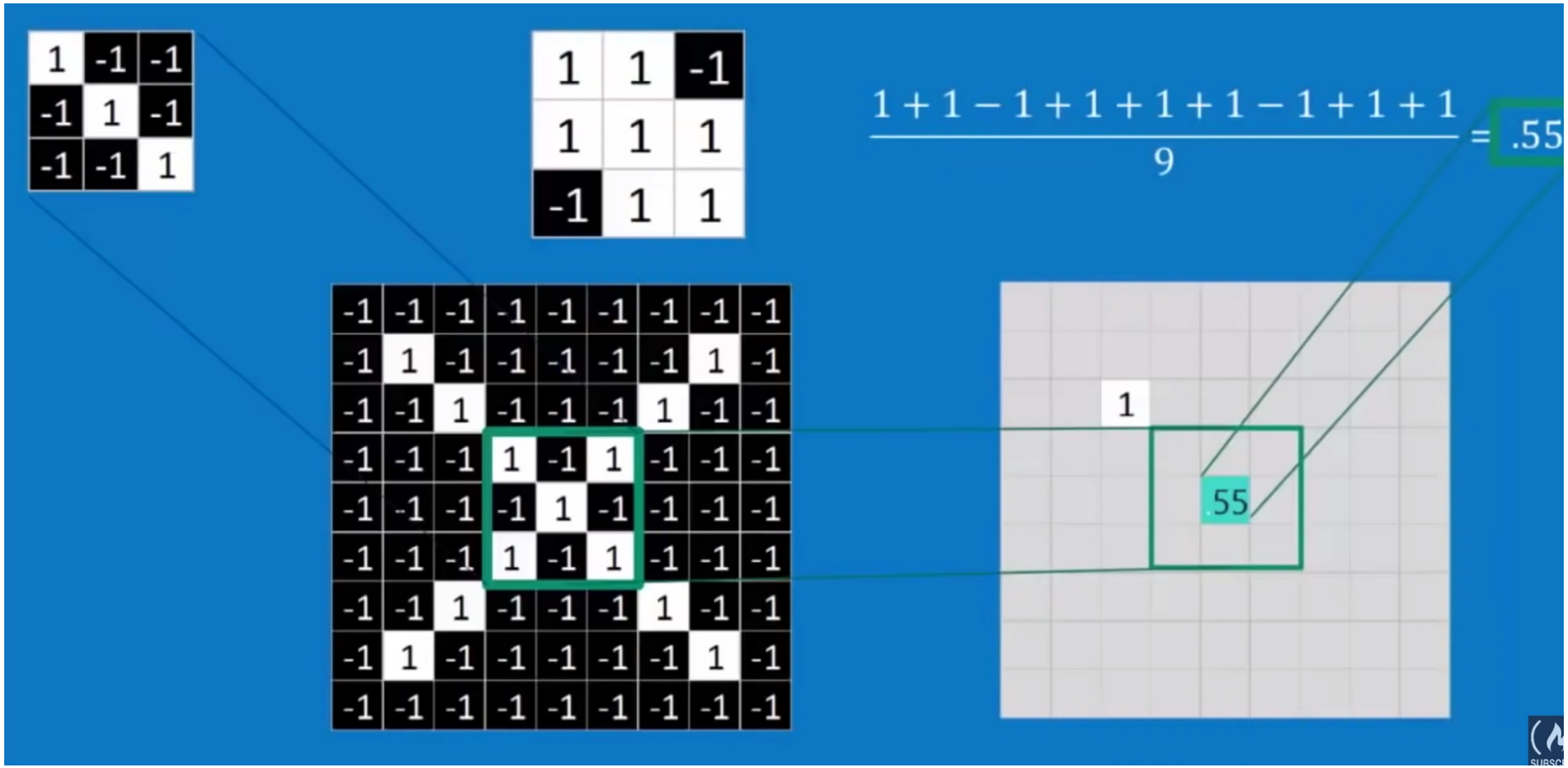
Running the convolution (5)



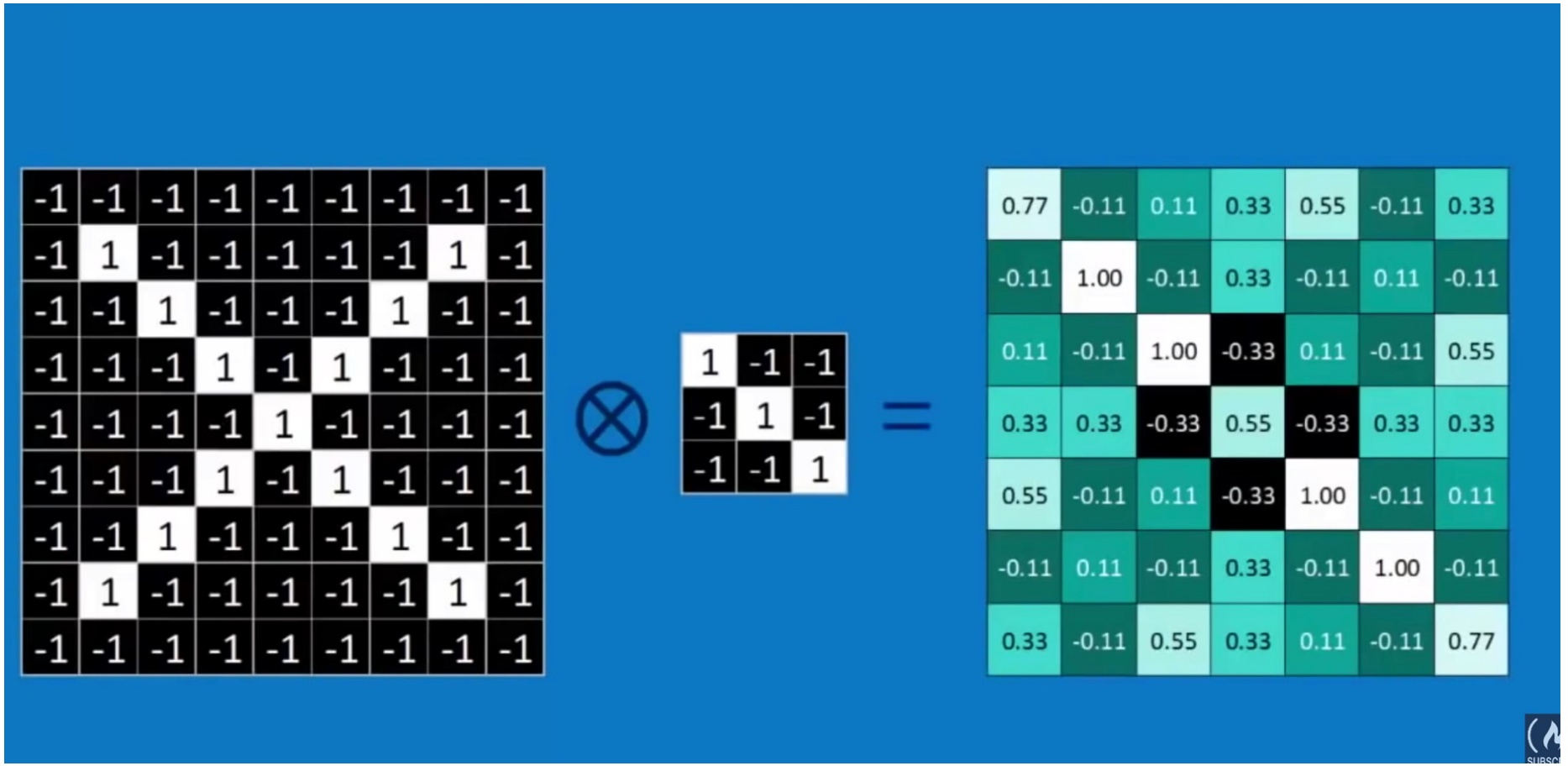
Running the convolution (6)



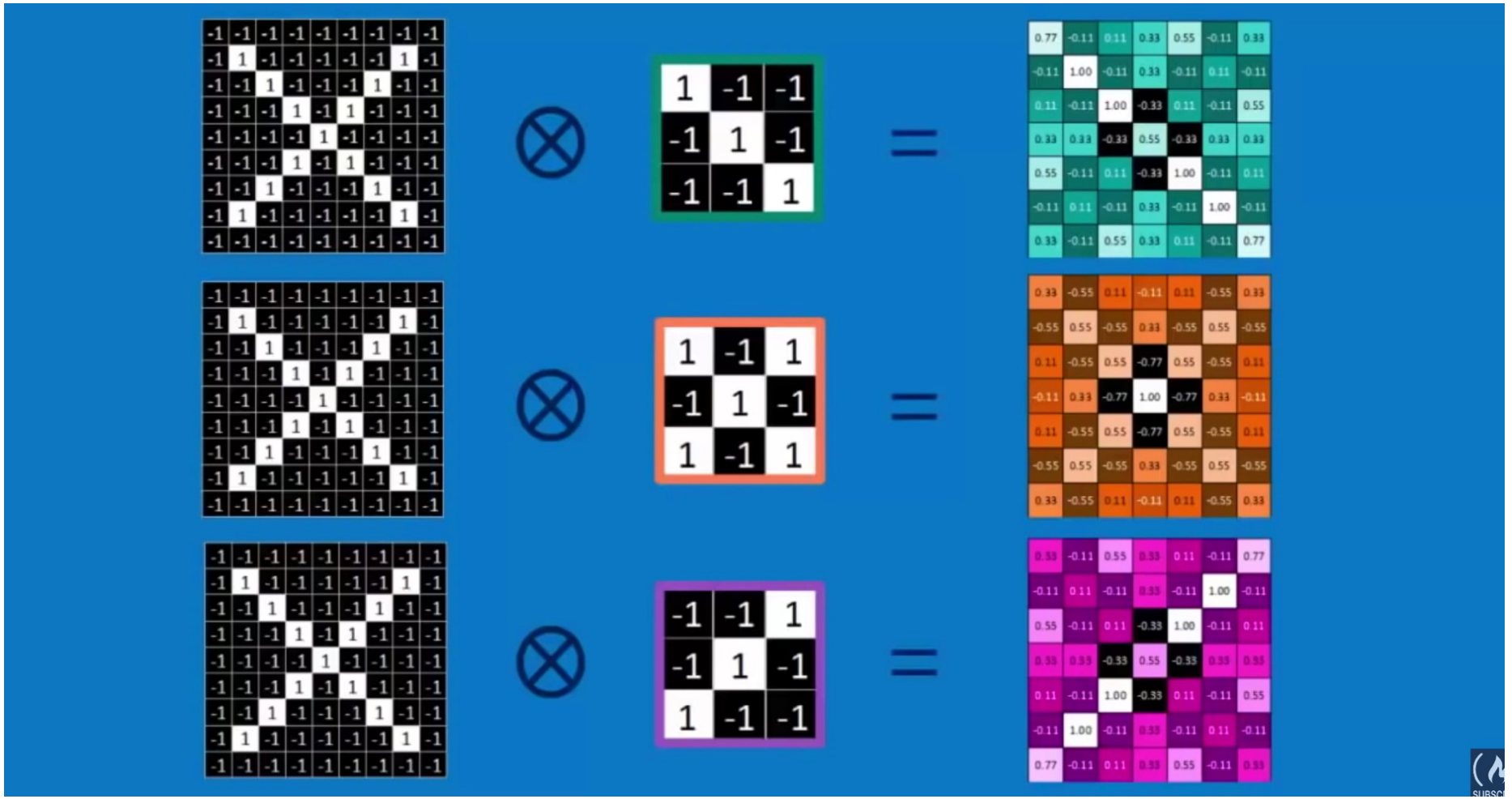
Running the convolution (7)



Running the convolution (8)



1 image = stack of filtered images



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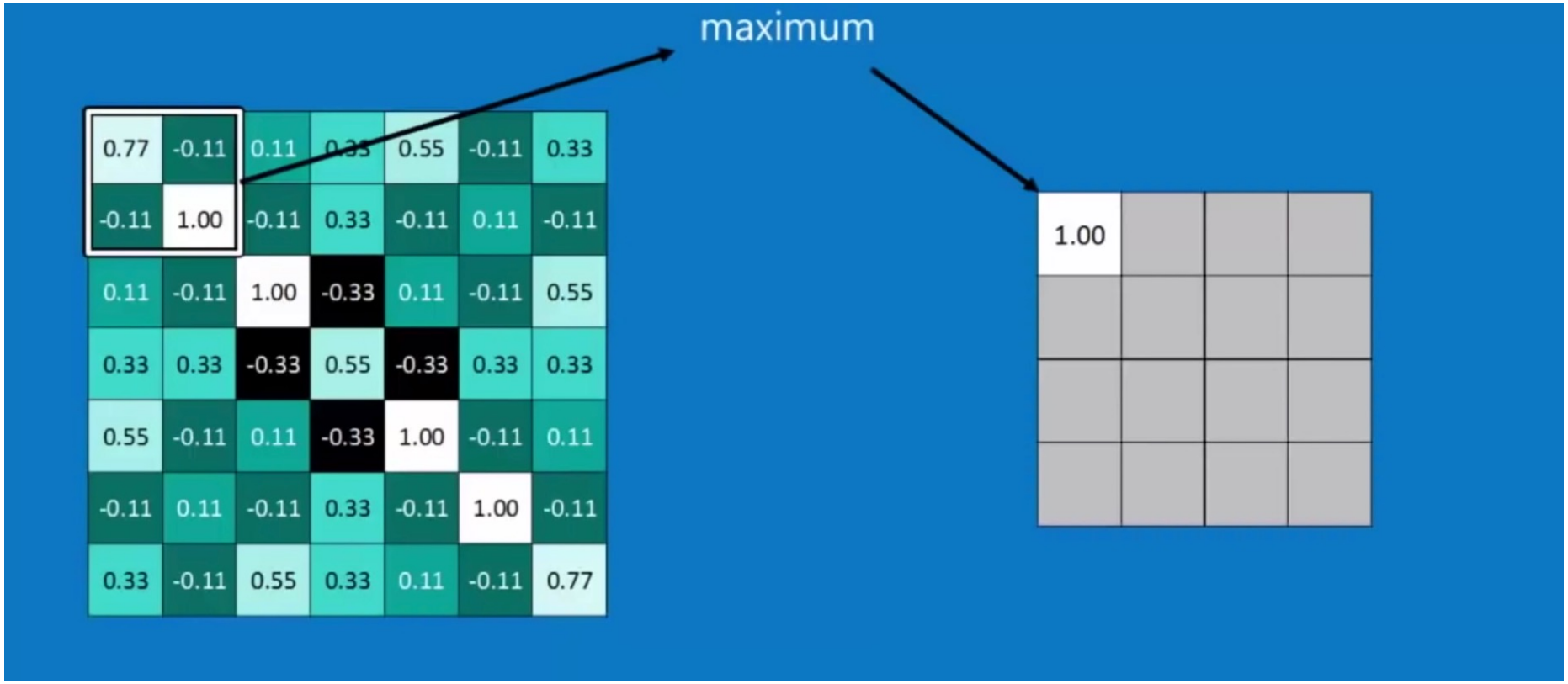
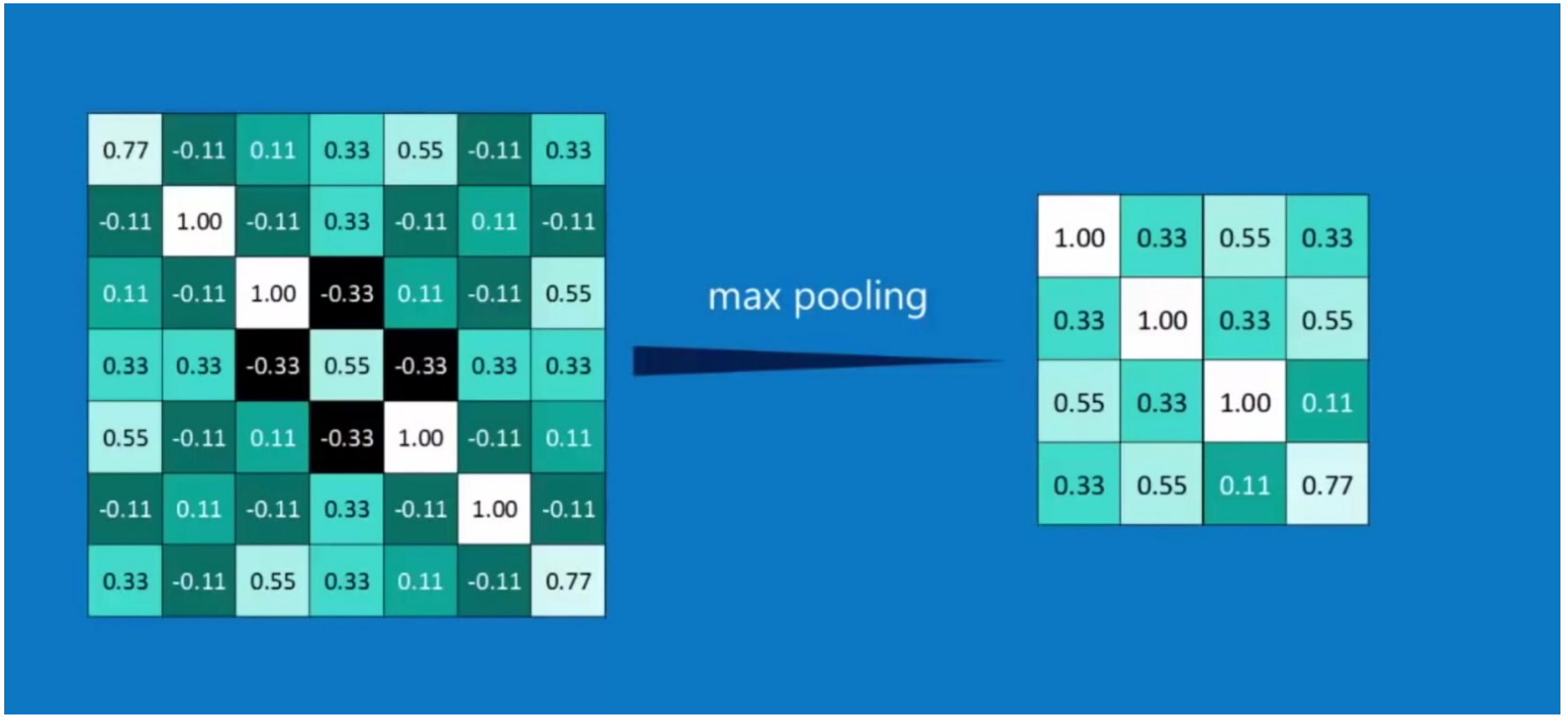
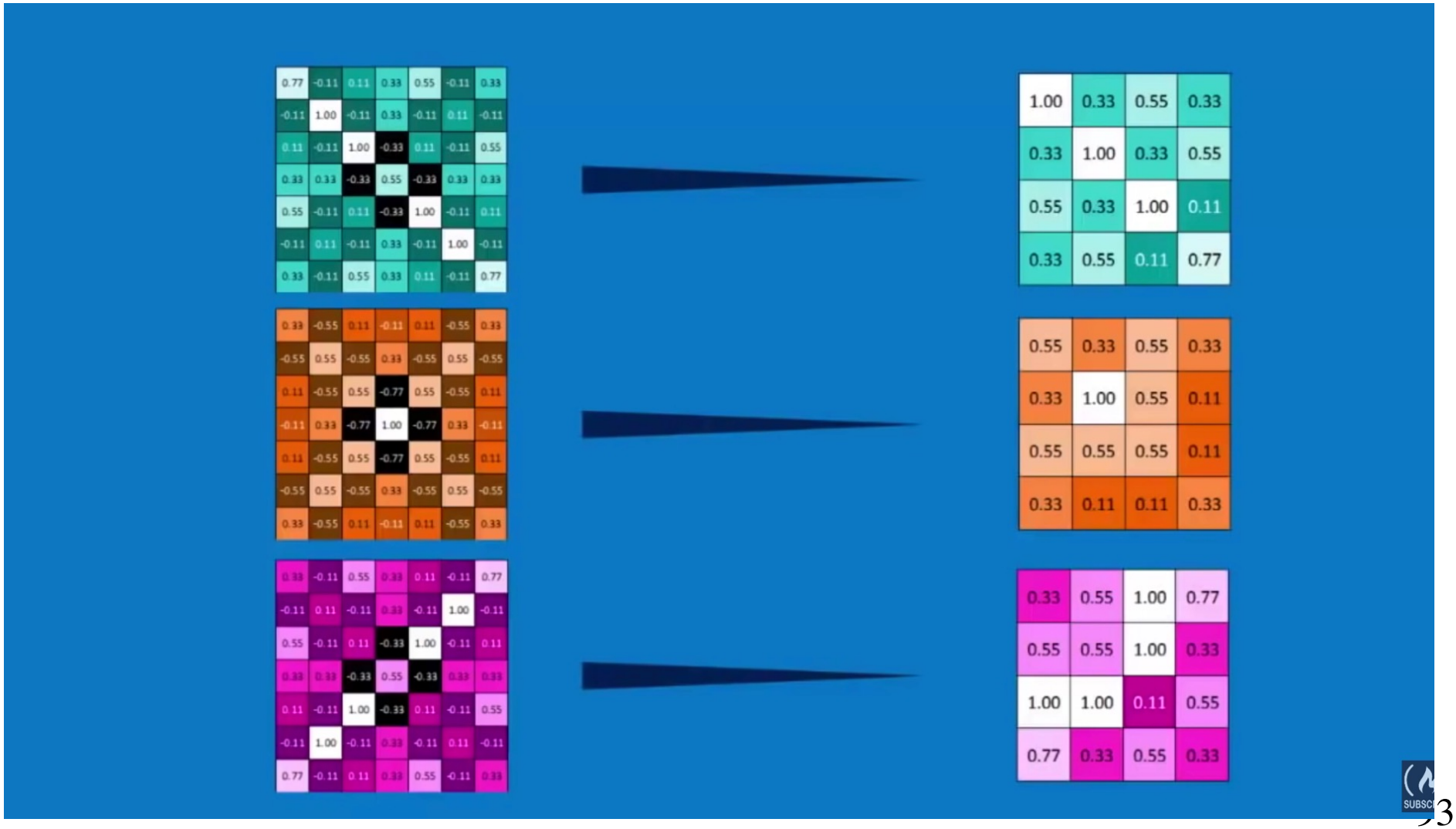
Next, Pooling = reduce the size



At the end of pooling



Do the same for stack of images



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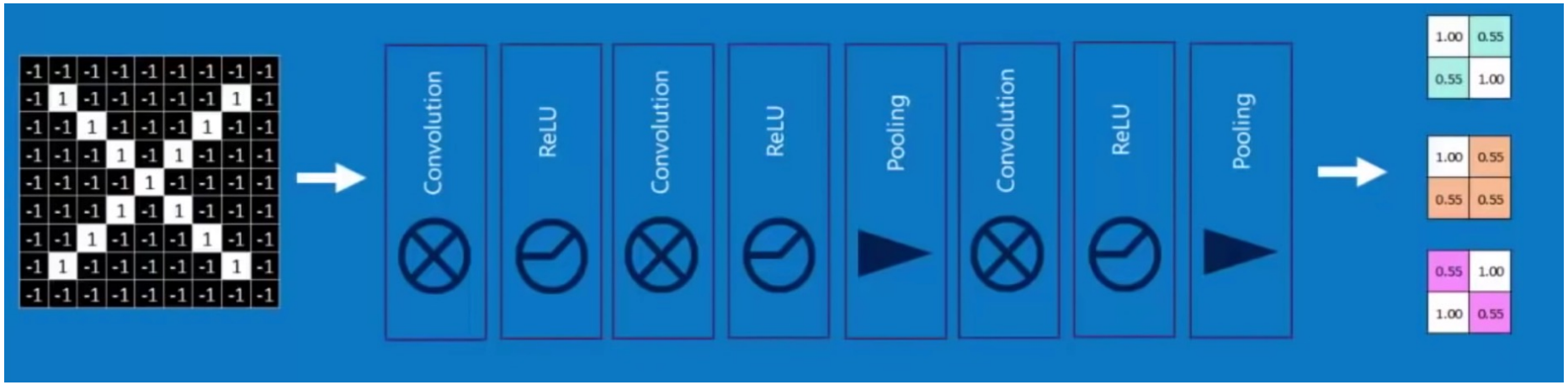
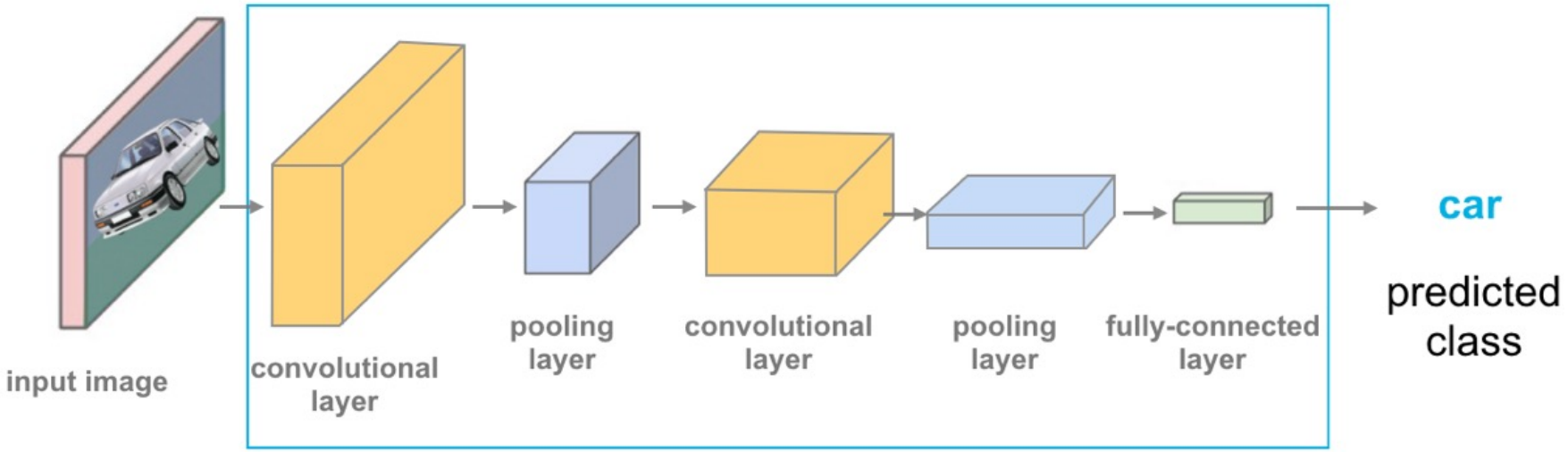
Layers can be repeated!

Watch the video on YouTube https://www.youtube.com/watch?v=FmpDIaiMIeA (Brandon Rohrer)





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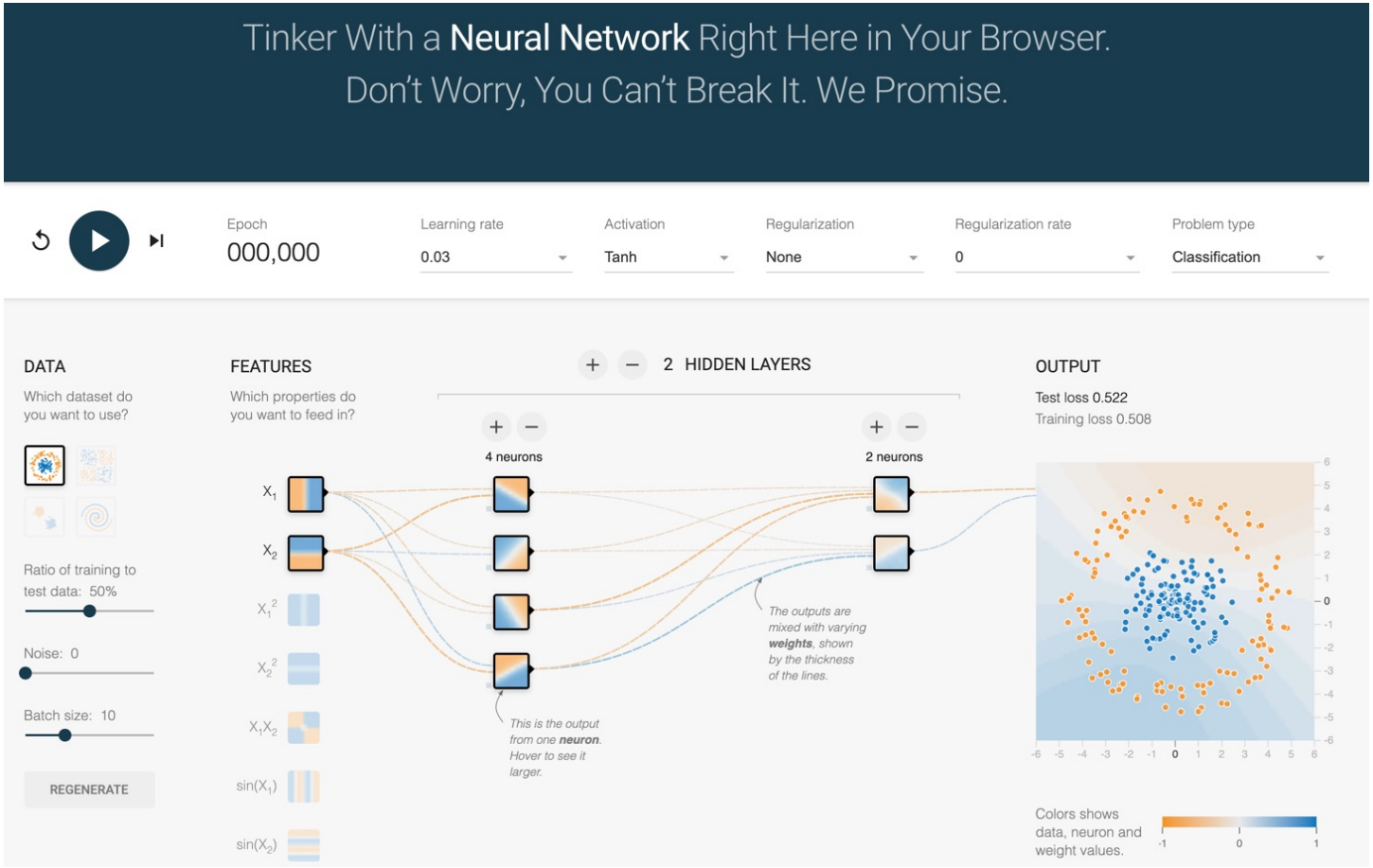
Want to try DeepLearning?

- https://playground.tensorflow.org/



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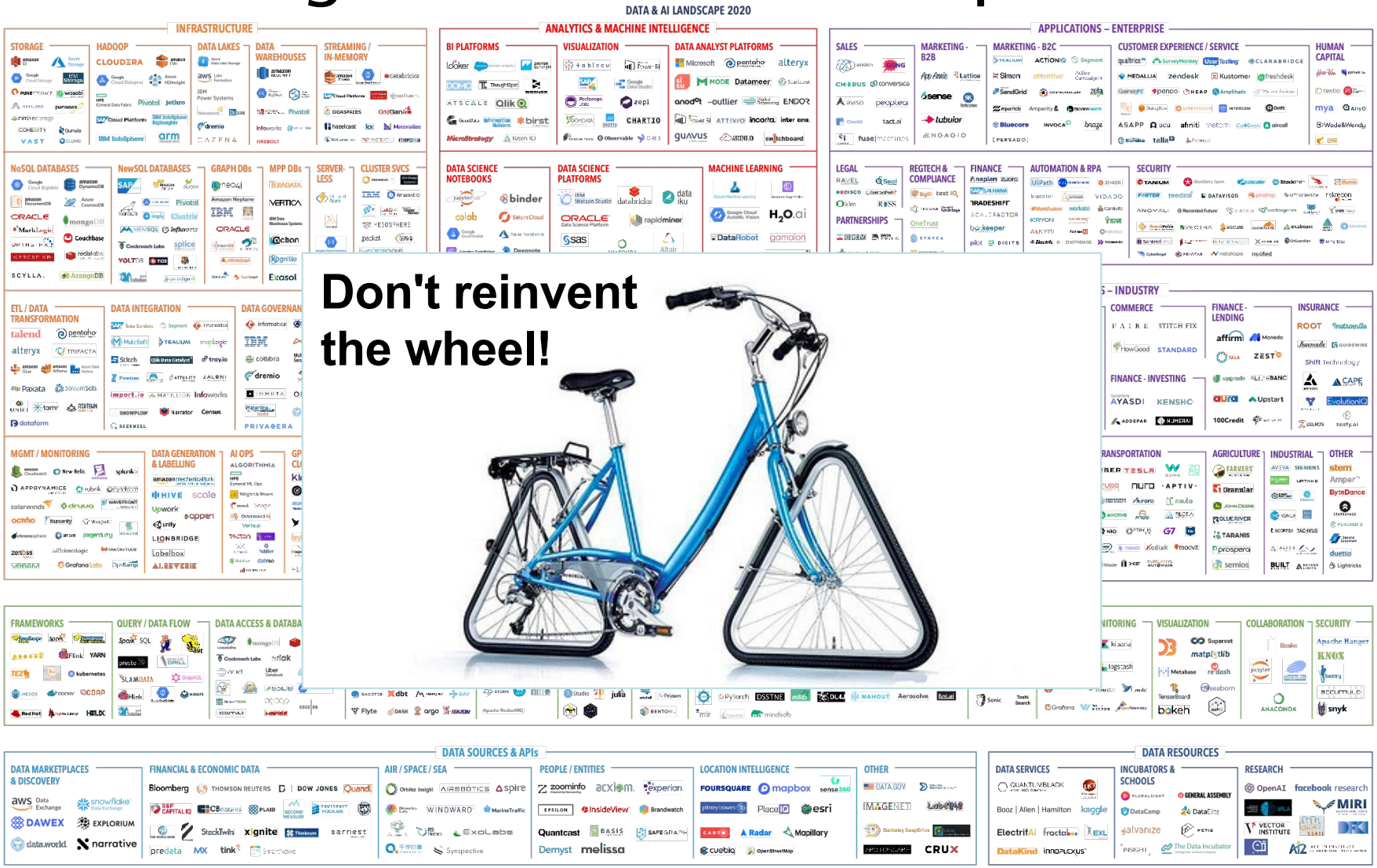
The BigData & AI Landscape



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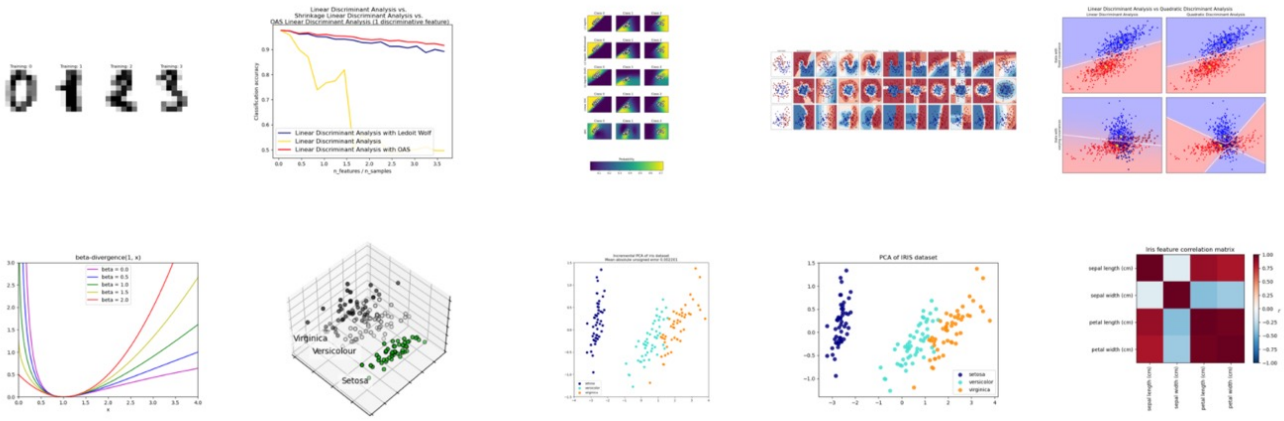
Package: pandas

- Python Data Analysis Library
- pandas is a fast, powerful, flexible and easy to use open source data analysis and manipulation tool, built on top of the Python programming language
- pandas provides fast, flexible, and expressive data structures designed to make working with “relational” or “labeled” data both easy and intuitive
- it aims to be the fundamental high-level building block for doing practical, real-world data analysis in Python.
- https://youtu.be/_T8LGqJtuGc

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: TensorFlow

- TensorFlow is an end-to-end open source platform for machine learning and deep learning
- It has a comprehensive, flexible ecosystem of tools, libraries and community resources that lets researchers push the state-of-the-art in ML and developers easily build and deploy ML powered applications
- "TensorFlow is more of a low-level library whereas Scikit-Learn comes with off-the-shelf algorithms, e.g., algorithms for classification such as SVMs, Random Forests, Logistic Regression, …"
  [https://stackoverflow.com/questions/61233004]
- https://www.tensorflow.org/
- https://www.tensorflow.org/overview

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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/

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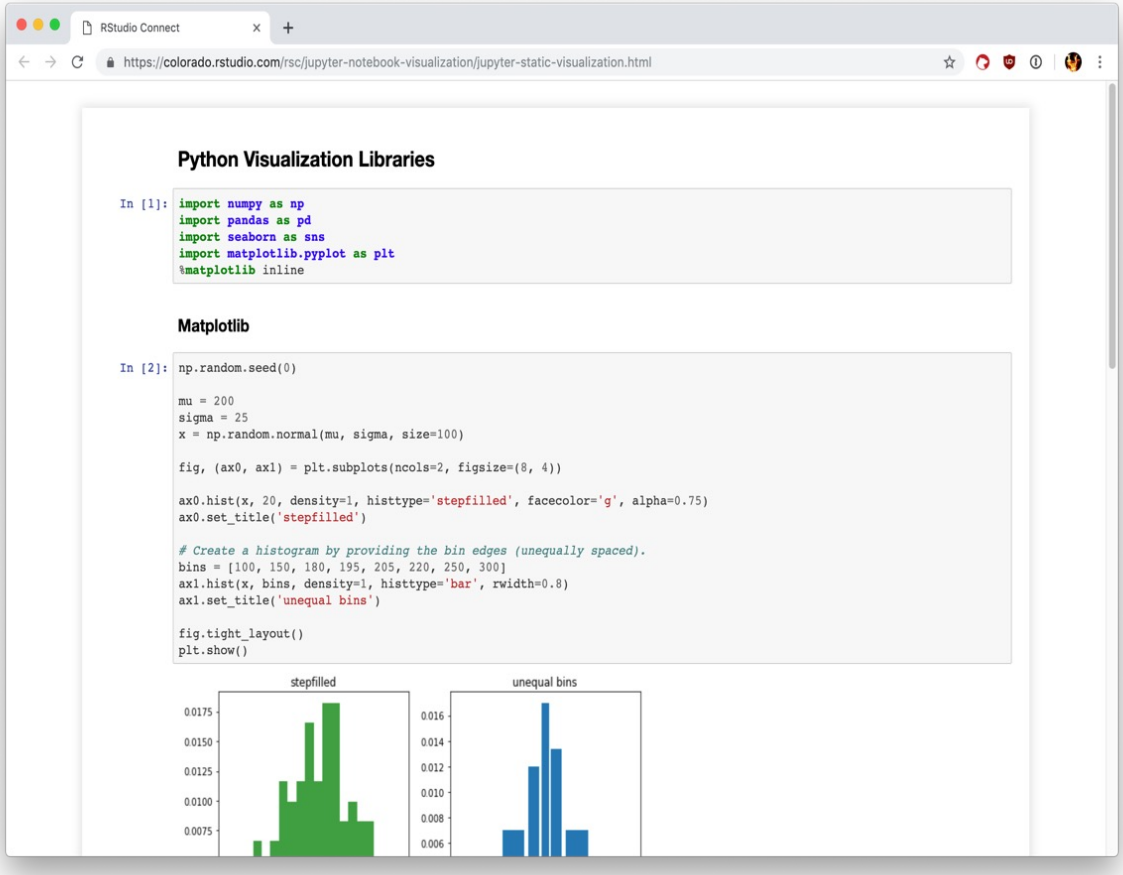
Jupyter Notebook

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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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"

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IOT_2: Unleash the power of IoT data

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

OneTech Booster

Capsule Booster – 2022

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WAZIUP

IoT – from idea to reality

WAZIHUB

HUBiquitous

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

PRIMA PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

Intel-IrriS

RESILINK

Advanced and disruptive IoT/AI technologies targeting the smallholder community for increased resilience