

Advanced Topics In Data Science

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A stylized, handwritten signature in black ink, appearing to be 'CH' with a large, sweeping flourish.

Chapter 1: Introduction of IoT:

IoT: Internet of things

describes the network of physical objects that are embedded with sensors, software & other technologies for the purpose of **connecting & exchanging data** with other devices & systems over the internet.

- next stage of internet $\Rightarrow$ Leading to smarter solutions & in some cases also act upon data
- IoT is a connection of multiple devices, consists of things that we could not normally connect to the internet ex fridges, oven - "do not forget the milk"!

ITU: International Telecommunication Union

$\hookrightarrow$ global infrastructure for the inf. society, enabling advanced services by interconnecting things

IoT $\Rightarrow$ When we connect up everyday physical things to the internet ex shoes.

these things gives infos can be used to improve your life or business, "can also feel & intelligently respond".

Why society need IoT?

- receive more data
- control stuff
- automate
- reduce costs
- make things faster
- better decisions
- improve our life quality
- feel more secure

Key factors to IoT evolution:

- Networking capabilities: net speed, wifi - - -
- Improvement on cloud computing: cloud - - -
- Invention on data analytical Tools : AI also,
& improvement in data handling capabilities : deep learning machine.
- Low cost devices, reduced computing : Low cost of
& memory costs microcontrollers.

Ex of IoT in our lives:

- IoT sensors monitors equipment failure before any accident
- Healthcare provides remote controlling of patient health
- Security cameras can better protect people with real time notifications

Prediction of future IoT:

- Smart cities.
- 5G networks.

* IoT Concepts:

- IoT is a global infrastructure for the inf. society enabling advanced services by interconnecting things
- exploitation of identification, data capture, processing & communication capabilities $\Rightarrow$ IoT makes the use of things to offer services of full kinds of apps.
- IoT adds the dimension "Any thing communication"

* IoT components:

1. Sensing & embedding components:

consists of physical, micro appliances, embedded with IoT device, responsible of collecting data or controlling mechanism ex Sensors, Actuators

Sensors work to gather minute data from the surrounding environment,

Known as "detectors" cause the primary function is to detect any change in the environment.

$\Rightarrow$ allows an IoT device to capture data for processing

Actuators "opposite working of sensors". they receive signal, once sensors detect a change, an actuator is required to make something happen based on the trigger

2. Internet connectivity:

IoT requires internet connectivity to interconnect with devices to perform any actions.

<< IoT devices, sensors, cloud >>

>> Protocols

>> IoT Gateway

Protocols: responsible of transferring data in the online world and this transmission can only be possible if 2 devices are connected.

Some of the most IoT wireless protocols include Bluetooth, Wi-Fi, ZigBee, DDS

3. IoT cloud :

data once arrived in the cloud, it needs to be processed

4. IoT analytics and data management:

- involves converting raw data into useful insights that later are interpreted to drive decision making
- analyse situation and formulate decision

5. End-user devices and user interface:

- Where the user control the system, the more user friendly this component, the easier is a user's interaction.
- interaction may be in the device itself or remotely via smartphone
- Design is a major consideration, attractive, ex sounds, color, —

* Fundamental characteristics:

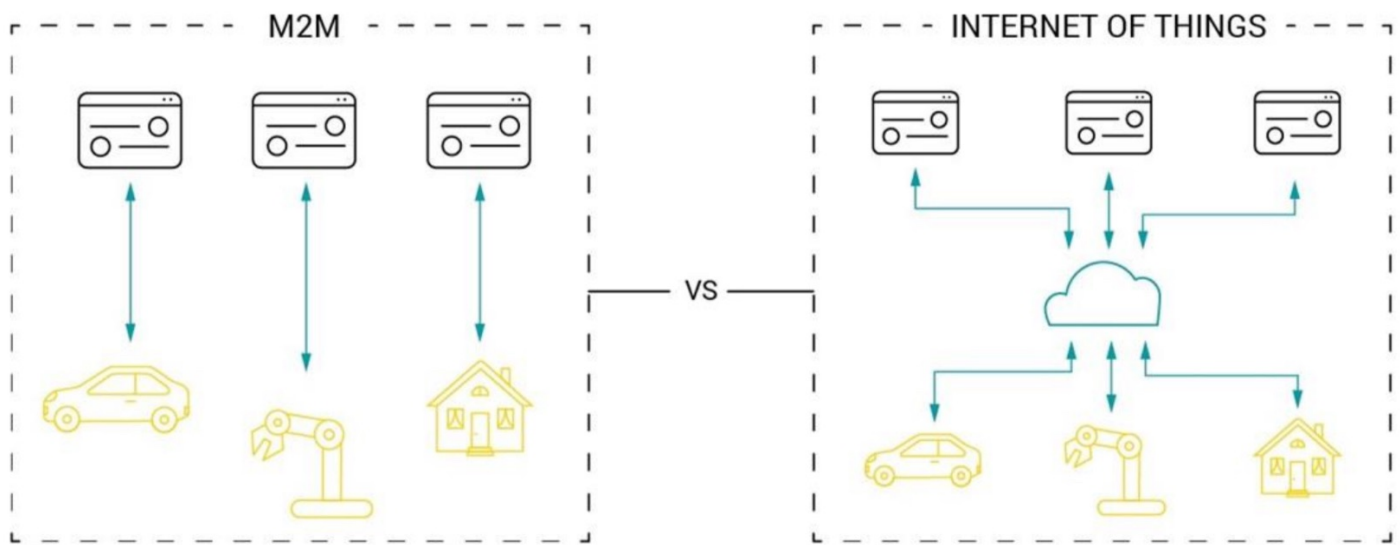
- Connectivity → interconnection, communication
- Heterogeneity → connection with other devices through $\neq$ networks
- things related services: IOT provides thing related services with constraints
ex: limited power supply.
- Dynamic changes: state of device change dynamically
ex sleep, wake, connect - - -
- Enormous scale: no of devices connected, managed
- Intelligence: from big data analytics. (AI)

* IOT high level requirements:

- Identification-based connectivity: "connectivity"
- ^{قابلية التفاعل البيئي} Interoperability: needs to be ensured into heterogeneous & distributed systems
- Autonomic networking: (self managed - - -)
- Autonomic services provisioning: services by capturing communicating - -
- Location based capabilities: some services depends on location infos
- Security

- **Privacy protection** : during data transmission, storage mining - -
- **High quality & highly secure human body related services** :
 << many countries have Laws and regulations on these services >>
- **Plug and Play** : in order to enable - fly generation
- **Manageability** : to ensure normal network operations

*Machine to Machine VS IOT:



M2M: autonomous device communicating directly to another autonomous device. Without human intervention

IOT: may incorporate M2M modes but aggregate data at an edge router or gateway

* Internet of Everything: IOE

IoT in cars, buses, vehicles - - then IOE

IoT is a part of IOE

Components:

- Things
- People "IOE is made by people"
- Data "Is a core of IOE"
- Process

* Challenges in IoT:

- limited processing power & memory
- weak internet connection
- Low power

* IoT and individual privacy:

- 4 Key privacy themes:
- unauthorized surveillance
 - uncontrolled data generation & use
 - inadequate authentication
 - inf. security risks

Chapter 2: Applications of IOT:

class notes

* Smart Grid (at)

Phasor measurement technology

Main components

Smart Grid & renewable energy:



wind, solar, water ---

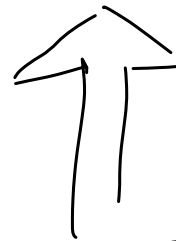
manage the need

Smart home communicate with the grid to enable the consumers manage their electricity usage by measuring home's electricity consumption

grid: determine & manage the source of electricity.

* healthcare:

monitoring & collecting data $\Rightarrow$ stored in cloud



Doctors, Insurance, health company

Chapter 2: IoT applications:

- Smart cities: use IoT to improve quality of citizens' live. Connect the unconnected

- Main components:

- Sensors
- Gateways
- Communication infrastructure
→ to connect gateways for transmitting data.
- Server farms in a cloud based architecture

- Smart cities IoT use cases:

- Pollution control and regulatory analysis through environmental sensing
- improved traffic flow and fuel economy through smart traffic control
- Smart snow plowing based on real time road demand, weather conditions
- Smart cameras to watch for crime and real time automated emergency Alerts. ex Barcelona

*Smart Grid: communication network on top of the electricity grid to gather and analyze data from $\neq$ components to predict power supply and demand $\Rightarrow$ power management

- it introduces 2 ways dialogue where electricity and inf. can be exchanged between utility and consumers.

Main Components:

- Smart appliances: "able to respond signals" peak hours.
- smart meters: 2 ways communication that help create a bridge between power providers and end consumers
- smart substations: located in every region as a sub branch for their main station.
 - $\rightarrow$ monitor the performance of the station
 - control any critical and non critical data

- Phasor measurement technology: maintain stability of the Grid.

Smart Grid and renewable energy:

Smart grid enables newer technologies ex

Wind - solar energy -

smart grid will replace the infrastructure

Healthcare

- real time monitoring - smart medical devices connected to smartphone app, collect medical and health required data, use this data & transfer it to specialists.

ex: blood pressure, oxygen, blood sugar level, weight -

data stored in cloud, shared with authorized person

healthcare IoT use:

- in home patient care
- Hospital equipment
- Drug research
- Pharmaceutical tracking & security

Real time monitoring $\Rightarrow$ - Reduce time needed for patient care in hosp.
- improve patient comfort
- More places in hosp for greatest need of people

Agricultural and environmental :

- IoT includes elements of
- life stock health
 - land & soil analysis
 - climate prediction
 - efficient water use
 - disaster prediction

- Use of smart lighting to increase growth rates and decrease mortality
- detecting sickness before bacterial infection

Agricultural & environmental IoT use:

- Smart ^{irrigation} and fertilization techniques to improve yield.
- Smart lighting
- Drones based land survey
- Robotic farming
- Remote farming
- Farm to market supply chain

Supply chain management:

to track & authenticate products & shipments using GPS and other tech. -

it's easy to understand where goods are located while shipment or storage and where can be shipped - -

- Authenticate the locations of goods at any time
- Track speed of Movement and when Goods will arrive
- Monitor storage conditions of Raw Materials & products: ex some goods like foods, drugs, chemical requires some specific conditions - - -
- Locate Goods in storage
- Administer Goods Immediately Upon Receipt
- Streamline the Problematic Movement of Goods

Government & military :

- internet battlefield , counter attack on enemies -
- monitoring of government infrastructure like highways and bridges.
- government role that play : standardization, frequency spectrum allocation, and regulations

Government & military IoT use :

- Terror threat analysis through IoT device pattern
- Swarm sensors through
- Real time military personal tracking & location services.
- Government asset tracking systems.

* Agricultural & Environment:

Livestock health: إدارة الصحة
microclimate predictions; Land & soil analysis, efficient water usage, disaster predictions
based sensor for prediction bacterial infections or viral infections.

* Supply chain management: $\text{إدارة سلسلة التوريد}$

- Track & authenticate products & shipments
- Track speed of Movement and Arrive time.
- Monitoring storage conditions...

* Government and military:

- Counter attacks
 - monitoring infrastructure like highways and bridges.
- Government plays role in IoT of standardization

Chapter 3:

IoT architecture:

level 1: sensors: devices that detect measures from the environment module or chip that observes the changes happening in the physical world and sends the feedback to the microcontroller or microprocessor (measures values, send raw data, consume power)

- Analog sensor: senses the external parameters (wind speed, solar radiation, light intensity) and gives analog voltage as an output.

analog vs digital:

↓ Interval ex height takes any values in a digital wind speed solar radiation --	↓ specific discrete values. ex: 0 & 1
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$\overset{+}{|} \quad \overset{-}{|}$

Symmetric ; scale.
asymmetric : diode.

$\overset{+}{|} \quad \overset{-}{|}$
0 - 3.5 5

- Digital sensors: produce discrete values (0, 1)

How to choose a sensor?

To know if it is analog or digital circuit.

Analog circuits $\rightarrow$ made up of analog components
ex resistor

digital circuit $\rightarrow$ logic gates, microcontroller chips

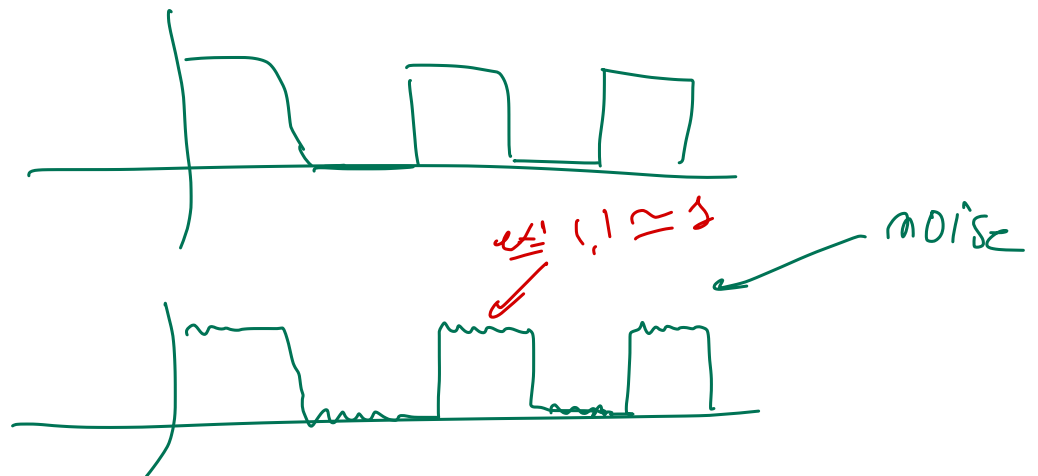
Analog signals $\rightarrow$ affected by external noise $\rightarrow$ error

Digital signals $\rightarrow$ susceptible to noisy environment

$\Rightarrow$ Digital sensors $>$ Analog

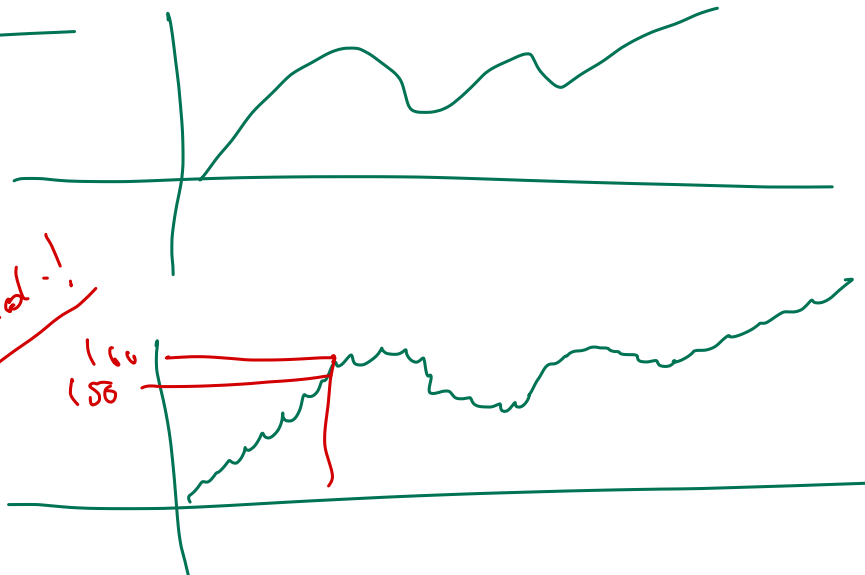
Digital noise:

Binary



Analog noise:

range



1.50 1.58

* Analog to digital Converter: Convert analog to digital (ADC)
analog to digital conversion

$$\frac{\overset{1023}{\text{Resolution of ADC}}}{\underset{5V}{\text{System Voltage}}} = \frac{\text{ADC Reading}}{\underset{\substack{\text{input value in} \\ \text{Volt.}}}{\text{Analog Voltage Measured}}}$$

* Sensors:

Analog pressure Sensor: works on input voltage
output analog
unit is psi

Digital pressure Sensor: Convert analog to digital

apps: - Drones
- leak detection
- Medical detection

apps. - Drones / Water level measure
- Air condition / Food processing measure water T^o

Analog Temperature sensor:

Wind direction sensor: Called anemometer use ultrasonic techniques
apps: - Road tunnels
- Environmental weather stations

Reflex sensor: transmitter & receiver sensor
↓ ↓
emits light detect & capture

light beam

Apps: - Monitor flow of material process.
- Level measurement

Fork sensors: efficient in picking & detecting very small objects size (μm).

Apps: - Power supply control.
- Recognize holes /

Analog Hall effect / Magnetic / Position sensor:

Works on magnetic field.
gives output voltage

magnetic field + $\longrightarrow$ output $\nearrow$

Apps: GPS positioning / Current sensing / Metal detector

Radar Sensor: transmit short microwave signals that travel at light speed.

Solar radiation sensor: use photovoltaic diode for radiation

Apps: energy apps / Irrigation

Humidity sensor: calculates the humidity

Apps: Refrigerators / Weather stations
- Air compressors - Medical systems

Air quality sensor: monitor number of SO_2 CO_2 O_2

Apps: - Air cleaning
- Health agencies
- Homes and Hospitals
- Industrial apps

Light sensor: Captures light & convert it to current.

Apps: TV, cameras.

Toys. / Automatic street light control

Rainfall sensor: to measure the amount of rainfall

Soil moisture sensor: the amount of salt & moisture in the soil.
+ °C, humidity.

Water level sensor: calculates the depth of water in lakes.

Apps: - Surface water Apps.
- water level monitoring - Groundwater tanks

Level 2: Local processing & local storage:

data here is locally stored & processed.

Microcontrollers: small computing devices, easily connectable to hardware

Microcontroller Vs microprocessor:

↓
is microprocessor
+ memory
built in.

↓
without memory.

Arduino : - small programmable device
- easy to connect - open source - RAM 2KB

Raspberry Pi : linux - PC - cheap -

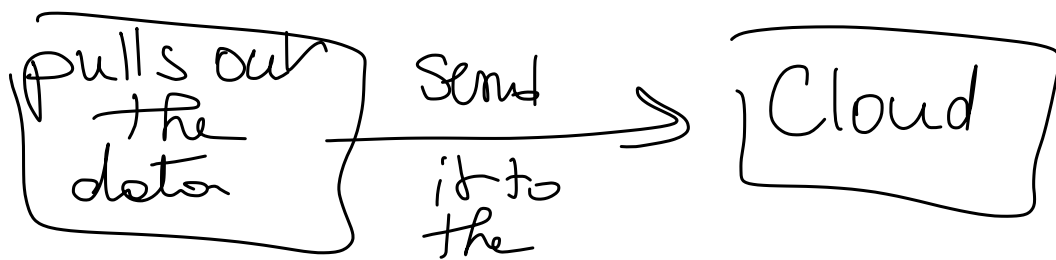
Wearable : - smart device + microcontroller
- can worn on the body
- implant or an accessory

↑ استشعار

↓
تسجيل

Wearable ex Trackers.

Level 3: Network & Internet :



4 protocols : http - -

in the cloud data is aggregated / stored /

inference from data .

analog I/O: used where you want to detect or control an event which involves a range of values.

digital I/O: used when you need to detect or control an event which is binary

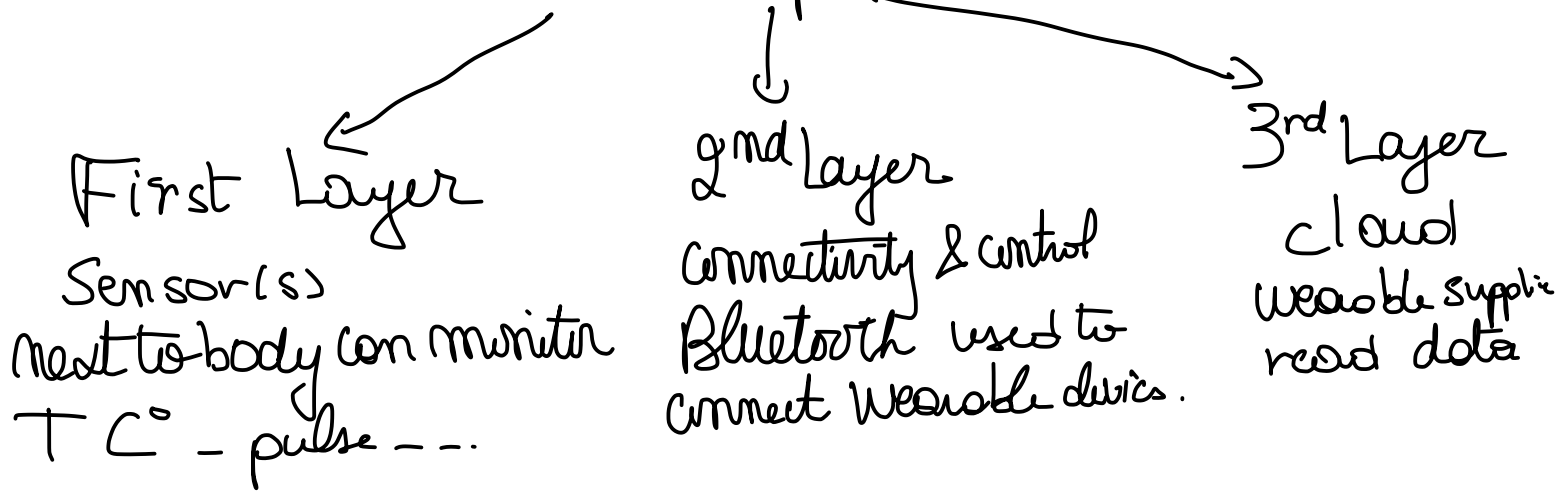
$$\frac{\overline{xy} - (\bar{x})(\bar{y})}{\overline{x^2} - \bar{x}^2}$$

$$\begin{aligned}\overline{xy} - (\bar{x})(\bar{y}) &= \frac{\sum \overline{xy} - (\bar{x})(\bar{y})}{n} \\ &= \frac{\sum \overline{xy} - n(\bar{x})(\bar{y})}{n}\end{aligned}$$

$$\overline{x^2} - \bar{x}^2 = \frac{\sum x^2}{n} - n\bar{x}^2 = \frac{\sum x^2 - n\bar{x}^2}{n}$$

$$\Rightarrow \frac{\frac{\sum \overline{xy} - n(\bar{x})(\bar{y})}{n}}{\frac{\sum x^2 - n\bar{x}^2}{n}} = \frac{\sum \overline{xy} - n(\bar{x})(\bar{y})}{\sum x^2 - n\bar{x}^2}$$

Wearable: - Smart electronic device with microchips
- Can be worn on body as an implant or accessory
- have some computing tasks as phone PC...
- Some can be put on and take off
- other cases as implanted devices ex micro ships



Wearable devices such as "activity trackers" are an example of IoT such as electronic ... software, sensors effectors that enable objects to exchange data through internet without human intervention

Level 3: network & internet:

hardware that connects previous devices,
pulls the data & send it to cloud storage

4 protocols: CoAP (Less secure M2M).

MQTT (// //)

HTTP (web protocol)

XMPP functions as chat

Level 4: Cloud Processing storage:

data here are collected to make predictions based
on stored info.

Data is aggregated

// // stored
Inference from data