Artificial Intelligence of Things (AIoT)

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Outline

- ❖Part 1: Introduction of IoT
- ❖Part 2: Introduction of AI
- ❖Part 3: Introduction of AIoT
- ❖Part 4: IoT and AIoT applications

Artificial Intelligence of Things (AIoT) Applications

Title: 1-How will Artificial Intelligence and Internet of Things change the world

Geospatial World, Published on Dec 12, 2017

Introduction of IoT

IoT: Challenges and Opportunities

IoT Analytics The Challenges and opportunities

presented by VITRIA technology

VITRIA®

IoT: Challenges and Opportunities

2-IoT: Challenges and Opportunities

Introduction of IoT

Part 2

- **The Internet of Things** (IoT) is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment **[2]**

- **IoT** is defined as a system of interrelated *Physical Objects*, *Sensors*, *Actuators*, *Virtual Objects*, *People*, *Services*, *Platforms*, *and Networks* **[5]** that have separate identifiers and an ability to transfer data independently

Introduction of IoT

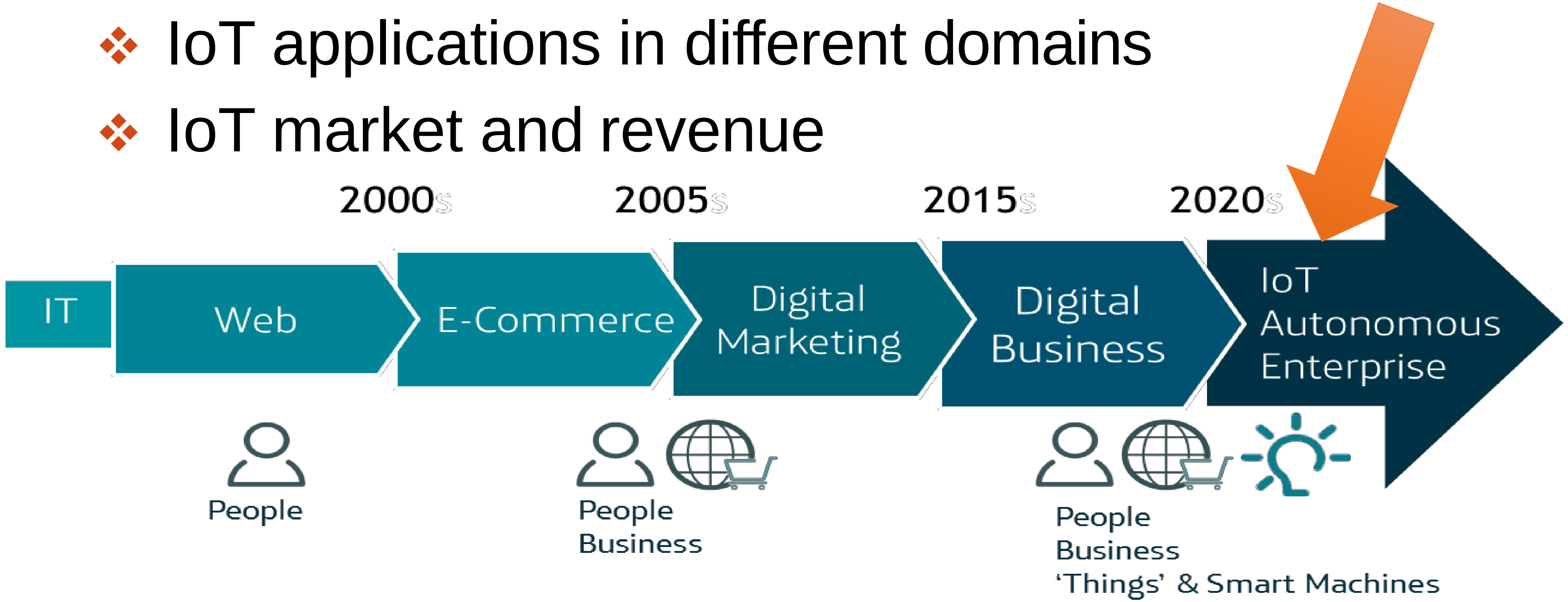
Part 2

- Practical examples of #IoT application today include precision agriculture, remote patient monitoring, and driverless cars.
  - IoT is the network of "things" that collects and exchanges information from the environment [7]

- IoT is sometimes referred to as the driver of the *fourth Industrial Revolution* (Industry 4.0) by industry insiders
  - IoT has triggered technological changes that span a wide range of fields

Internet of Things (IoT)

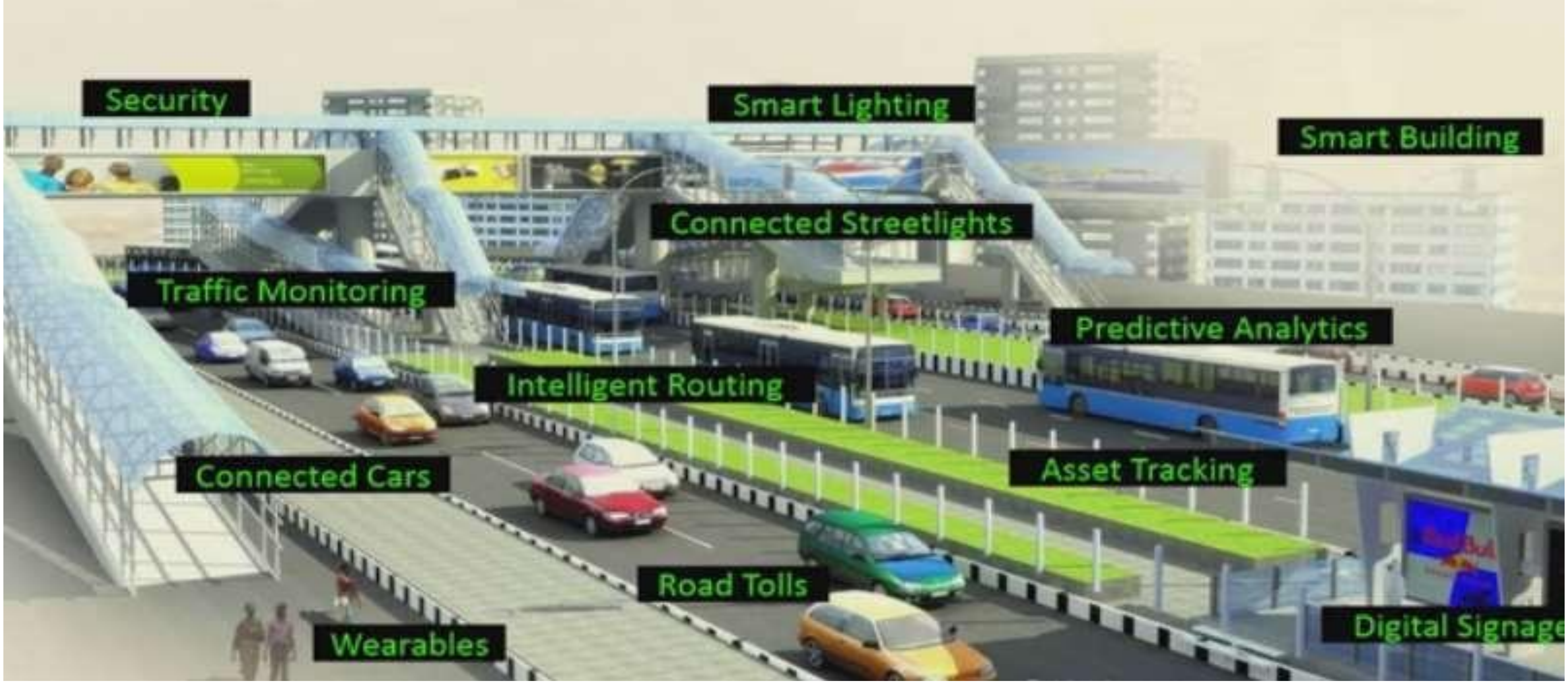
- What is IoT
- Sensors
- IoT applications in different domains
- IoT market and revenue



IoT products include

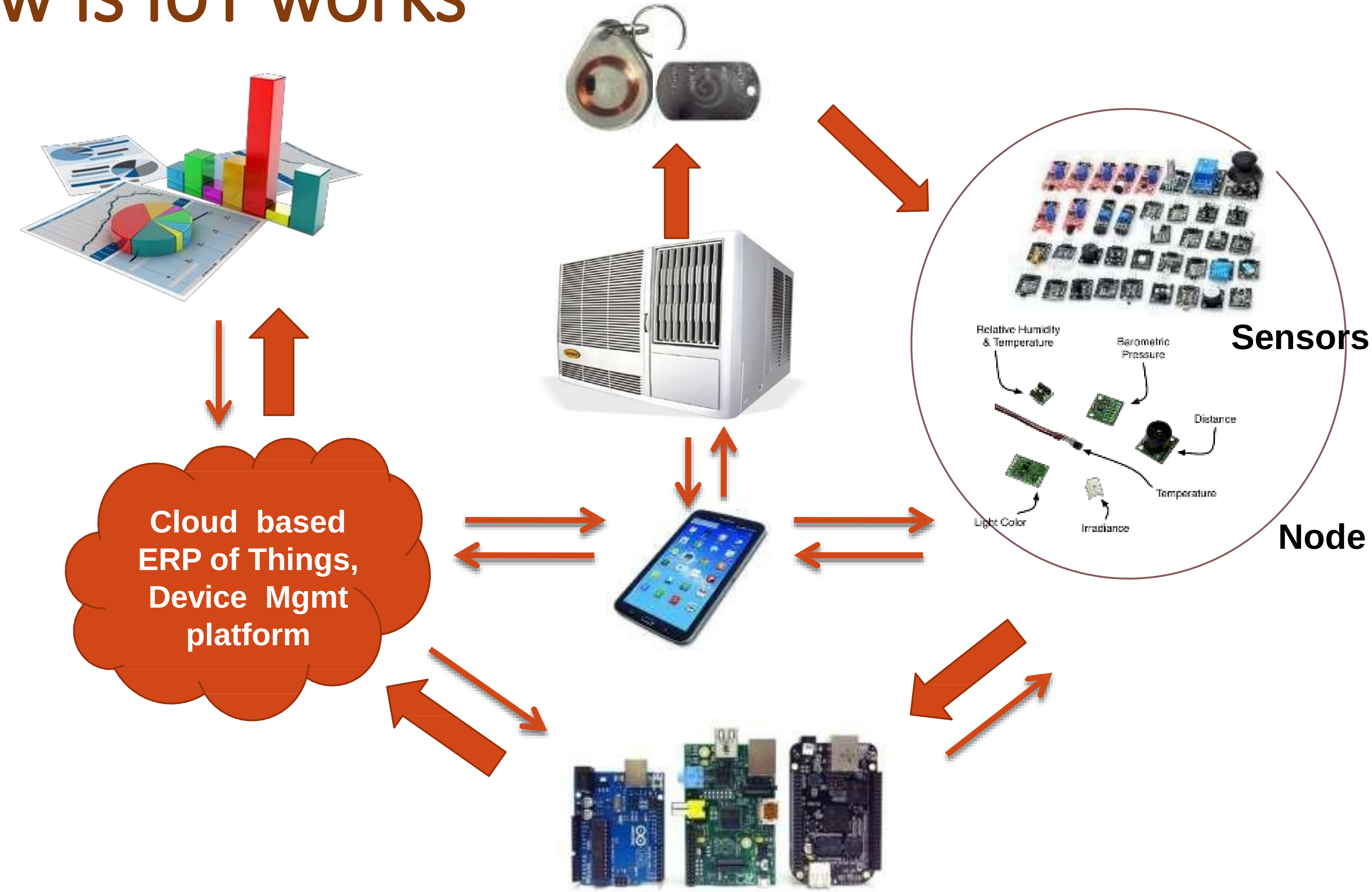
- Smart socks (to measure running form)
- The Connected water bottles (to gather water- consumption data.)
- Internet-connected e-cigarette
- First electric-toothbrush by P&G-Oral in 1963 now “World's First Available Interactive Electric Toothbrush”
- The Mimo baby monitor is a body suit that monitors a baby's body temperature, motion, and breathing patterns
- Sleep monitors

IoT is Everywhere

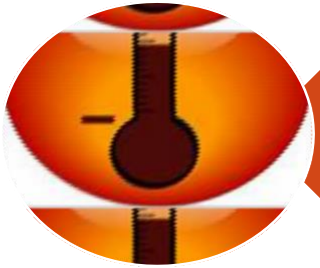



@CRASingapore
IoT Market Maturity in 2019
IoT Units/Capita
0.6
1.2
1.3
1.5
1.7
2.2
2.3
3.5
3.8
5.1
5.6
8.2
8.5
IN
PH
VT
ID
HK
TH
MY
PRC
TW
SG
NZ
SK
AU

How is IoT works



Smart systems and IoT are driven by combination of three things



Sensors & Actuators

Connectivity

People & Processes

Sensors & Actuators

Sensors for collecting the information:

- Humidity sensor
- Level/tilt sensor
- Pressure sensor
- Temperature sensor
- Motion Sensors
- Optical Sensors
- Acceleration sensors
- Load sensors
- Vibration sensors
- Chemical sensors
- Flow sensors
- Proximity Sensors

Actuators:

- Light emitting Diodes (LED)
- Relays
- Motors
- Linear actuators
- Lasers
- Solenoids
- Speakers
- LCD or Plasma displays

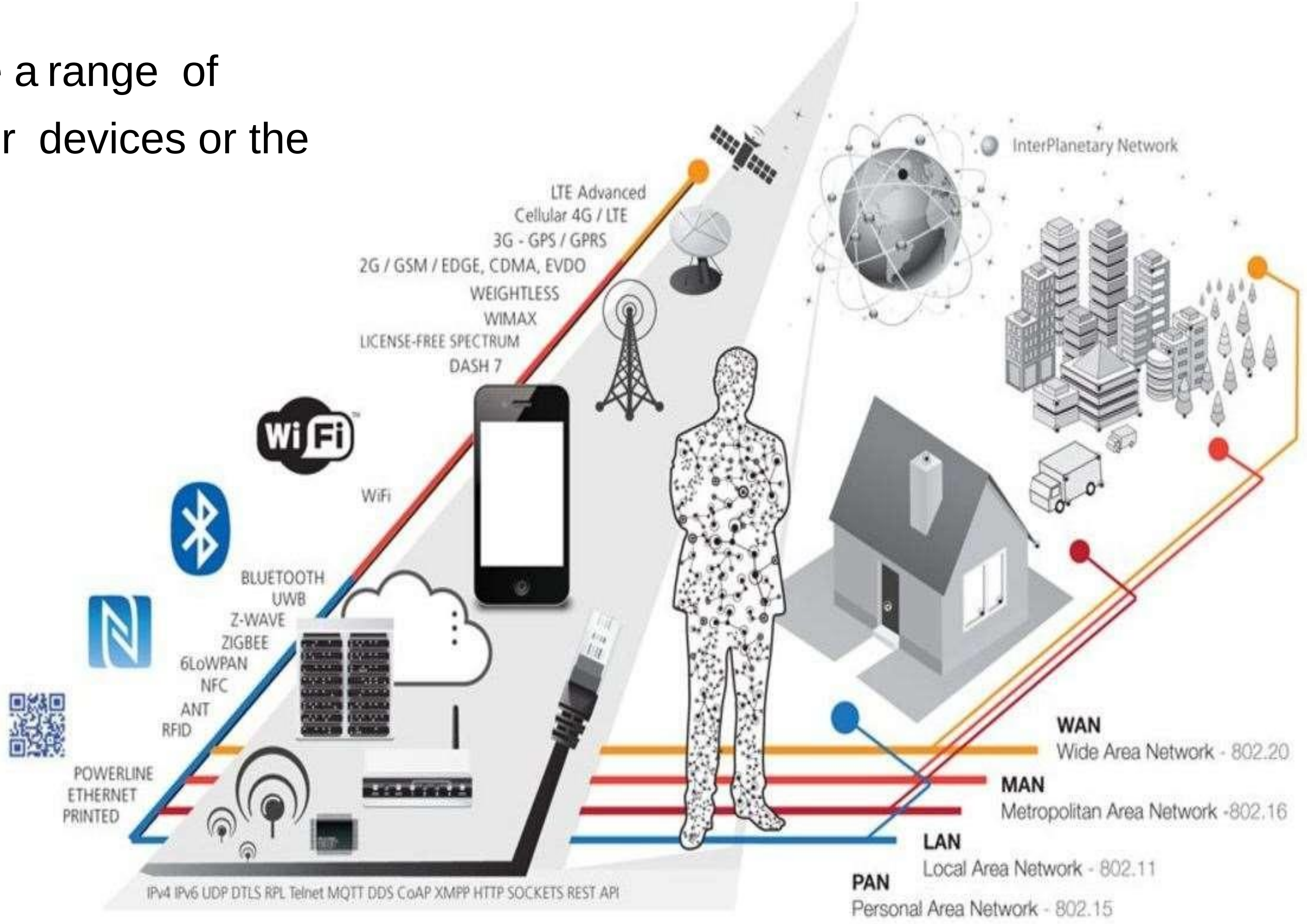
Connectivity

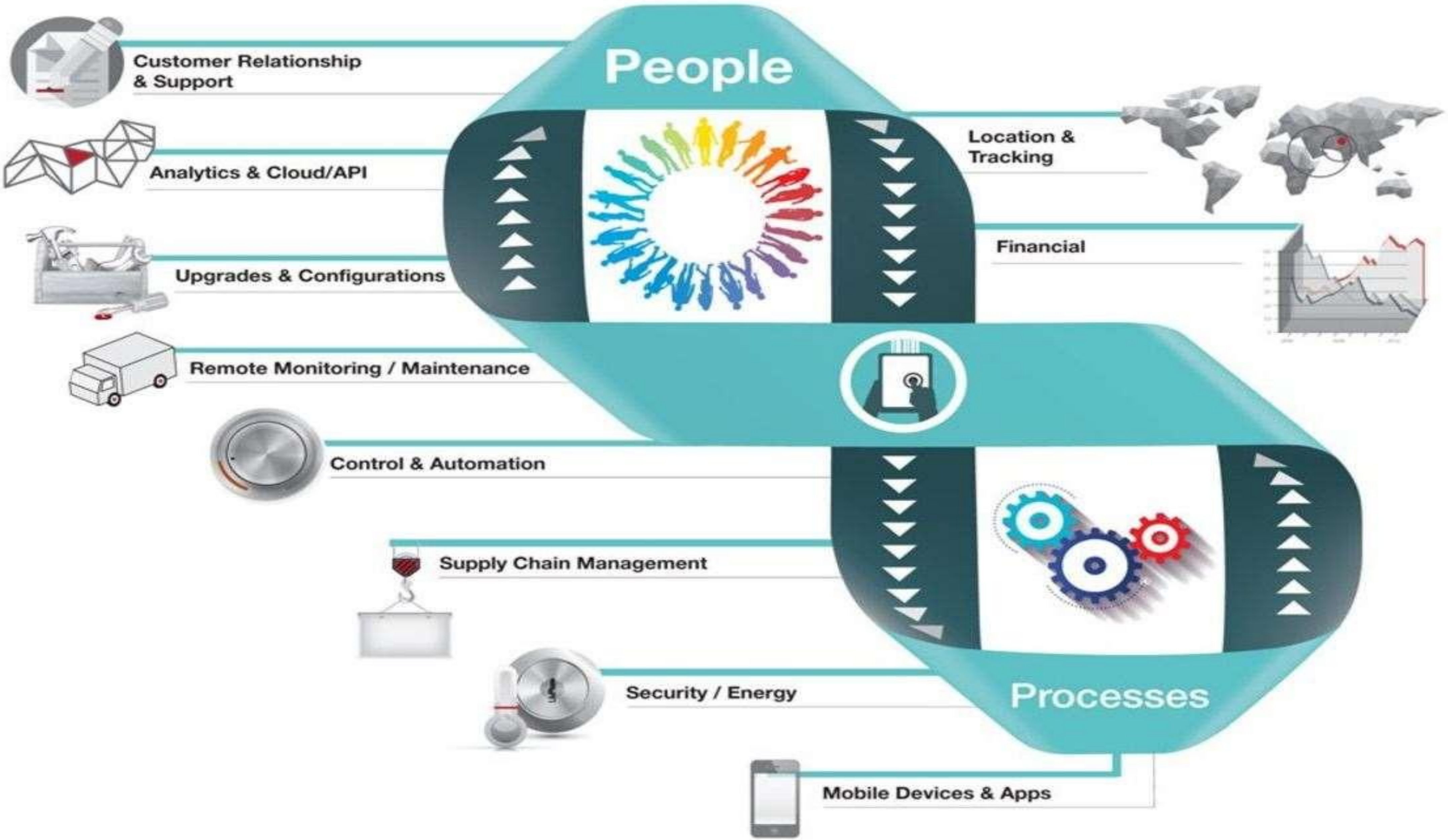
❖ The embedded systems can use a range of connectivity to connect with other devices or the internet.

❖ Some examples are as below:

- WiFi
- Bluetooth
- RFID
- ZIGBEE
- NFC

- Ethernet
- LTE
- 3G
- GSM
- CDMA



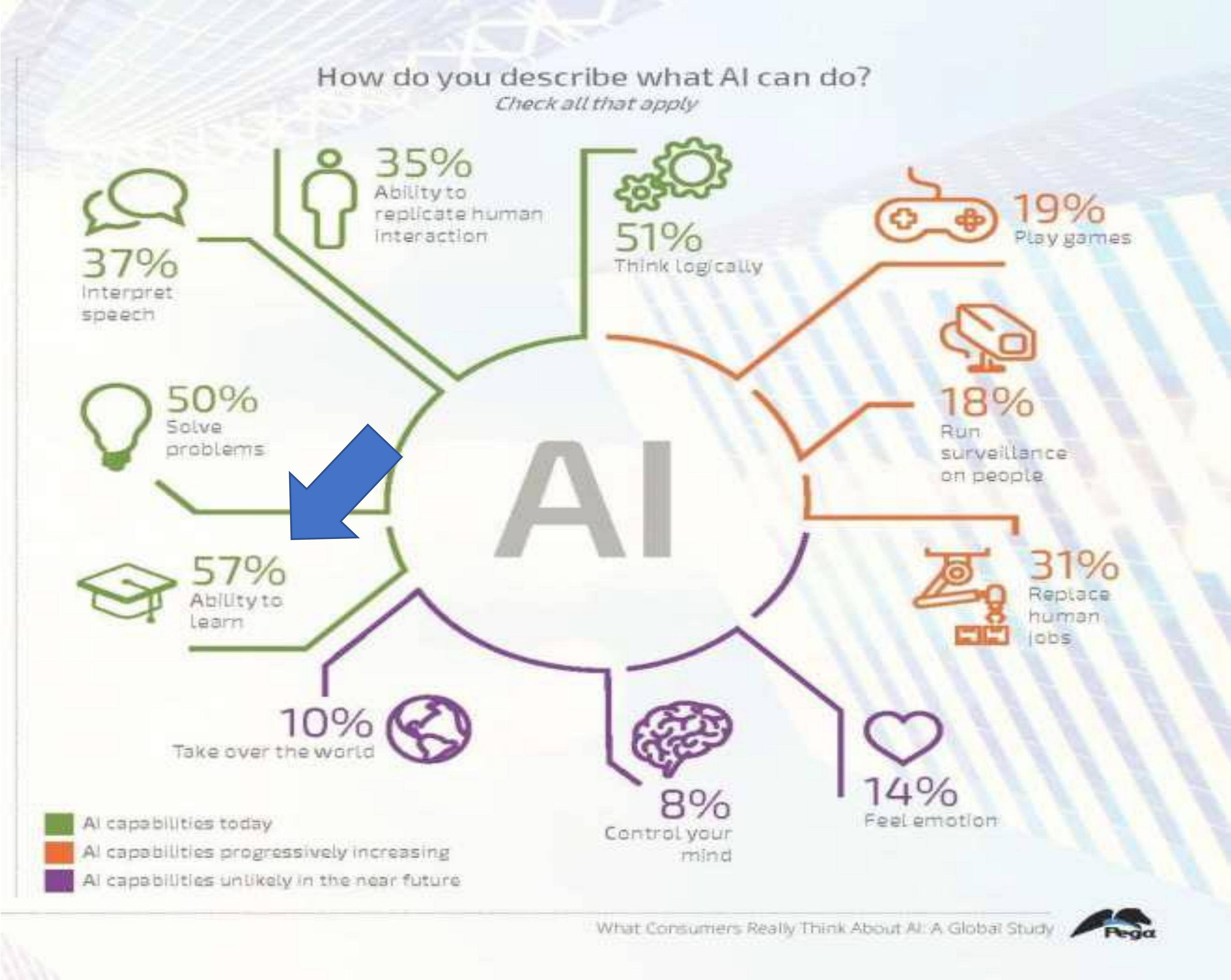

People
Processes
Customer Relationship & Support
Analytics & Cloud/API
Upgrades & Configurations
Remote Monitoring / Maintenance
Control & Automation
Supply Chain Management
Security / Energy
Mobile Devices & Apps
Location & Tracking
Financial

- Things get interesting when these connected devices and services start creating **COMPOUND APPLICATIONS** with in their own verticals and across industries

Introduction of AI

Artificial Intelligence

- 3-What is Artificial Intelligence Exactly?
- https://www.youtube.com/watch?v=kWmX3pd1f10
- ColdFusion, Published on Jul 20, 2016


How do you describe what AI can do?
Check all that apply
35% Ability to replicate human interaction
37% Interpret speech
51% Think logically
19% Play games
50% Solve problems
AI
18% Run surveillance on people
57% Ability to learn
31% Replace human jobs
10% Take over the world
8% Control your mind
14% Feel emotion
AI capabilities today
AI capabilities progressively increasing
AI capabilities unlikely in the near future
What Consumers Really Think About AI: A Global Study

Introduction of AI

- **AI** can be used to transform IoT data into useful information for improving decision making processes, thus creating a foundation for newer technology such as **IoT Data as a Service** (IoTDaaS) [1]
- **AI**, on the other hand, is the engine or the "brain" that will enable analytics and decision making from the data collected by IoT
- In other words, IoT collects the data and AI processes this data in order to make sense of it

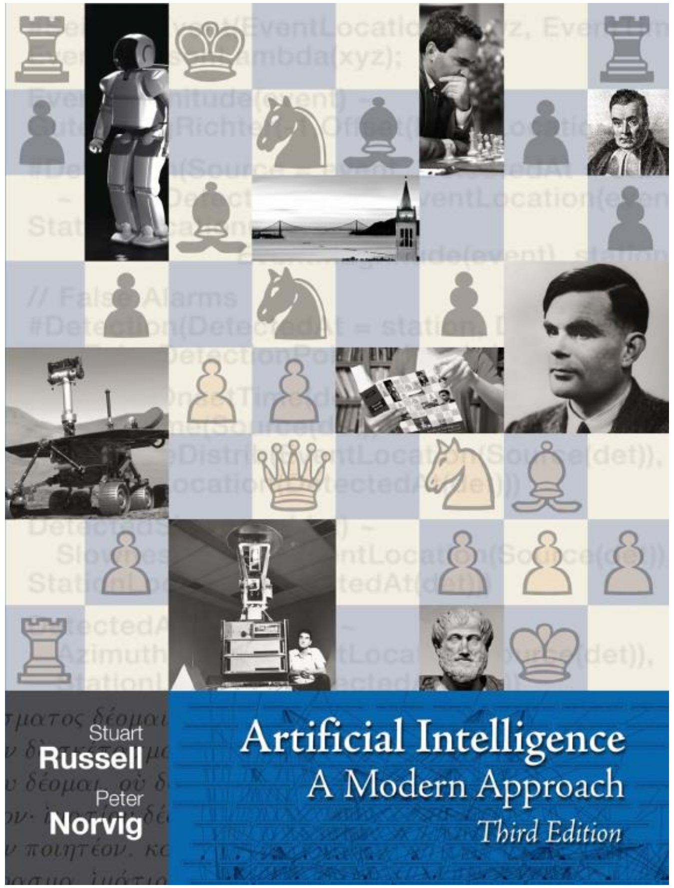
➢ Learning, Pattern recognition

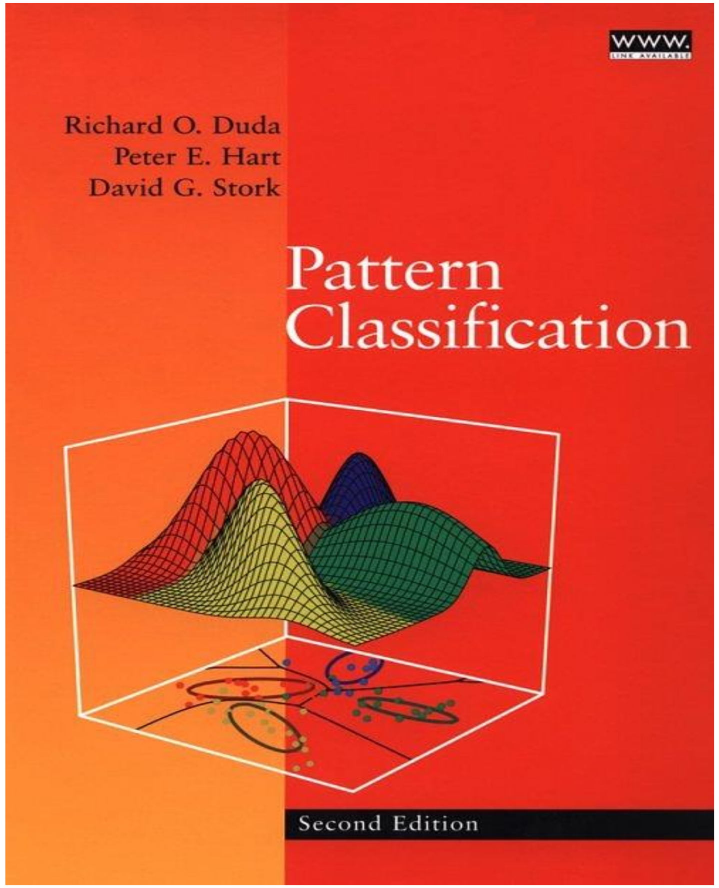
➢ Intelligent agents

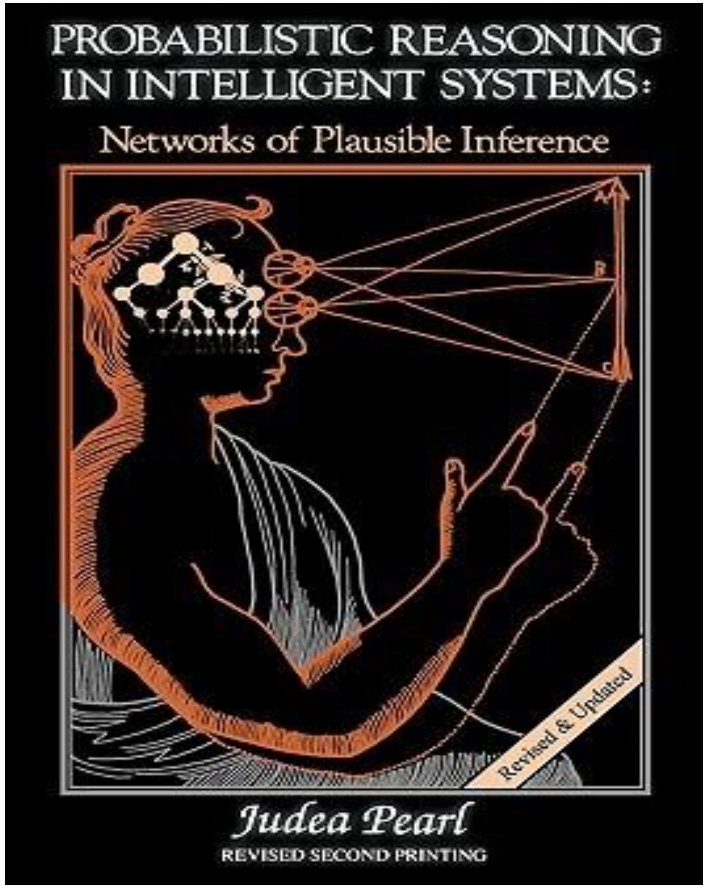
➢ Probabilistic reasoning and uncertainty

➢ Graphical models

Material used

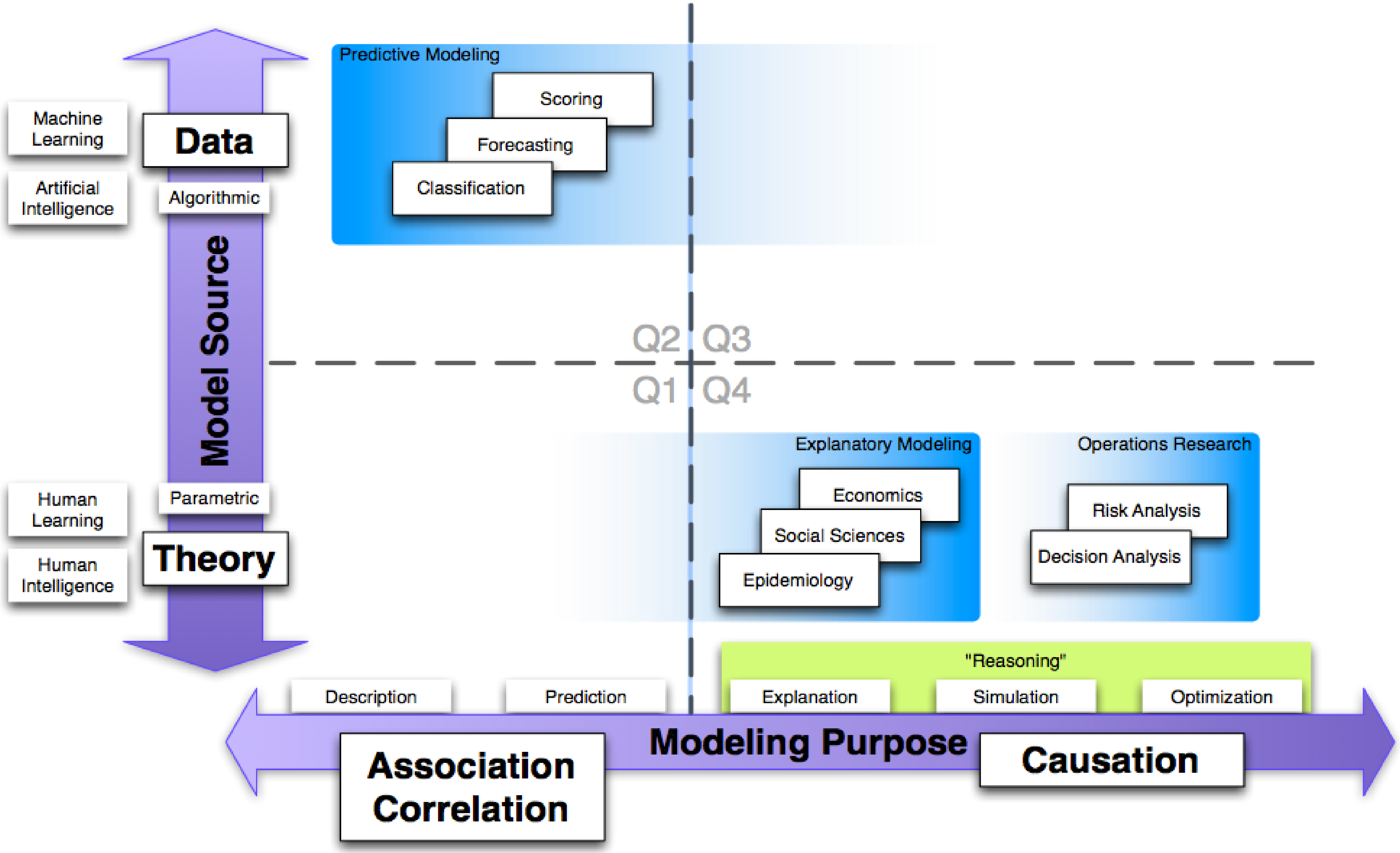






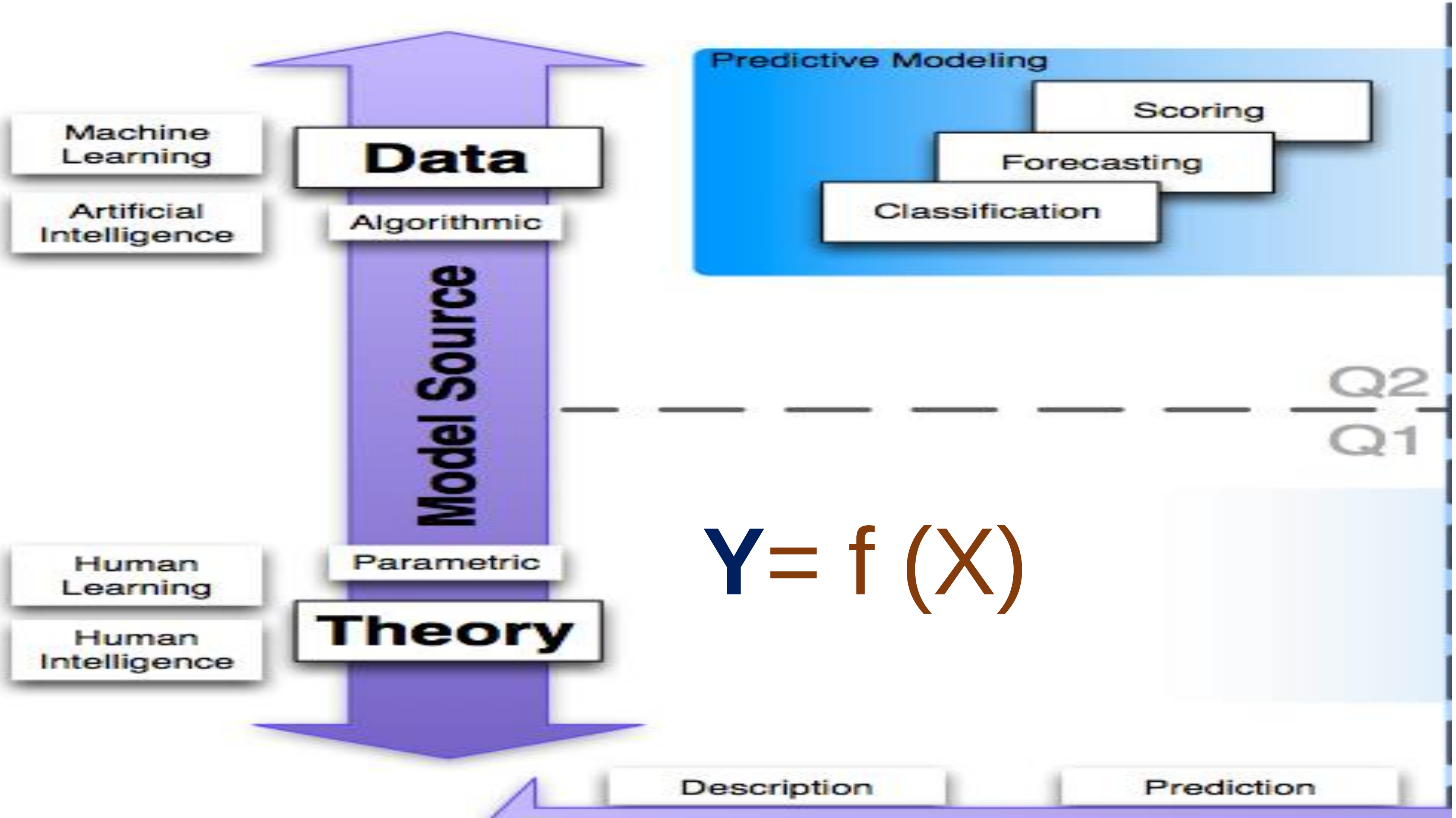
- UGent AI course: http://telin.ugent.be/~sanja/ArtificialIntelligence
- BaysiaLab white paper
- Wikipedia
- Google search

Map of Analytic Modeling



Breiman (2001) and Shmueli (2010)

Predictive modeling

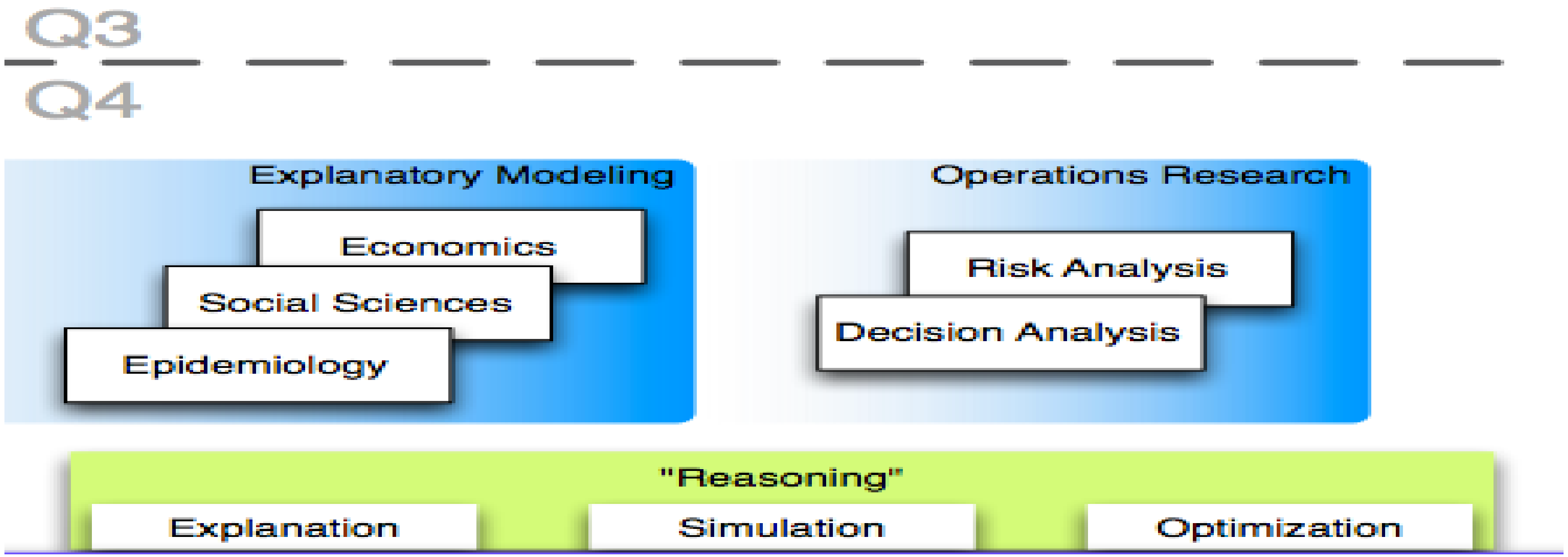


$$Y = f(X)$$

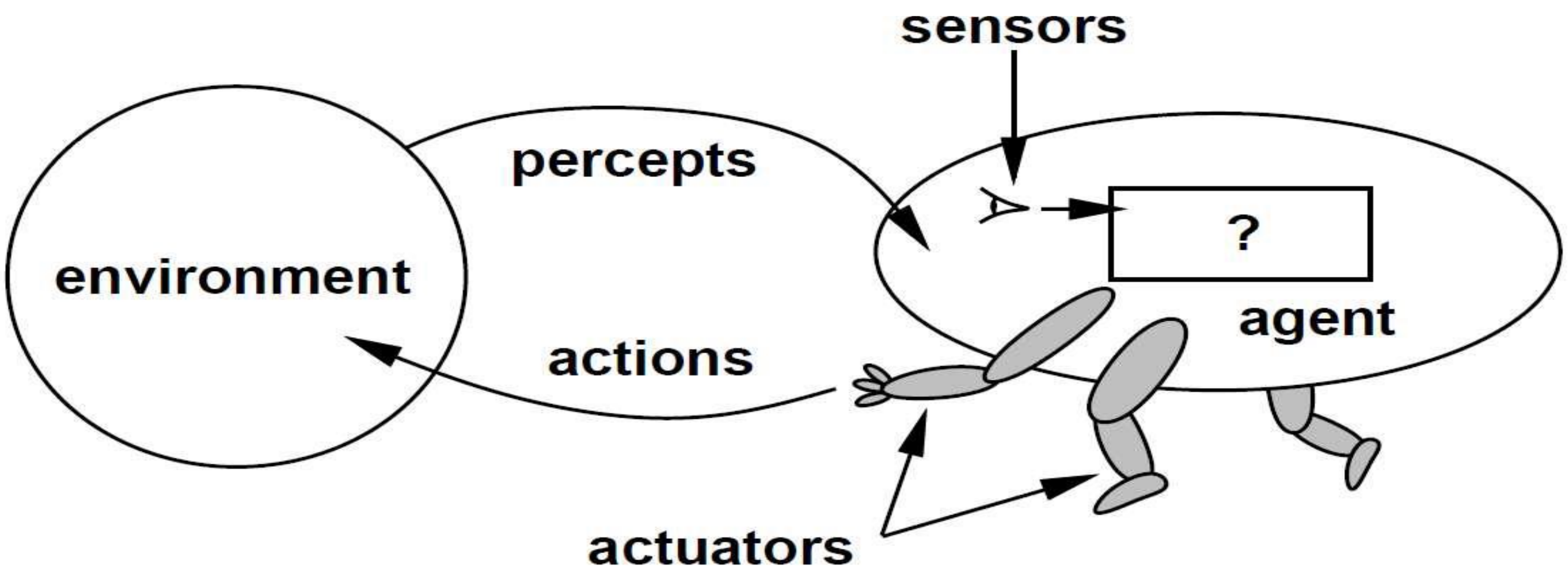
Explanatory modeling

Page 7

$$Y = f(X)$$



Intelligent agents



- **Agent**: an entity that perceives (feels) and acts (from latin *agere*, to do)
- **Rational (** reasonable**)** agent is one that acts so as to achieve

Rationality (reason)

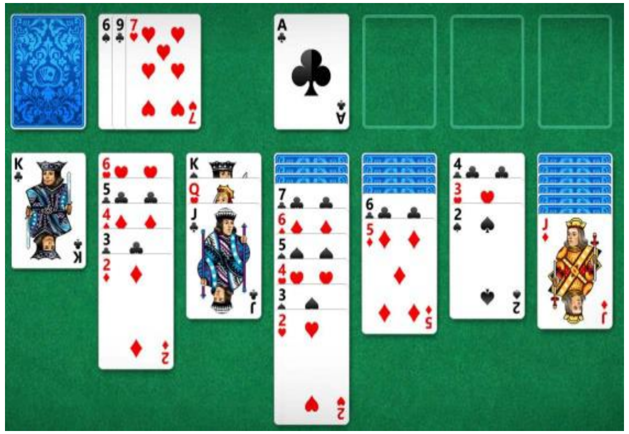
- A rational agent is one that does the right thing
- How do we know whether it is the right thing?
  - By considering the **consequences** of the agent behavior
- A sequence of states (through which the environment goes) is evaluated by a **performance measure**

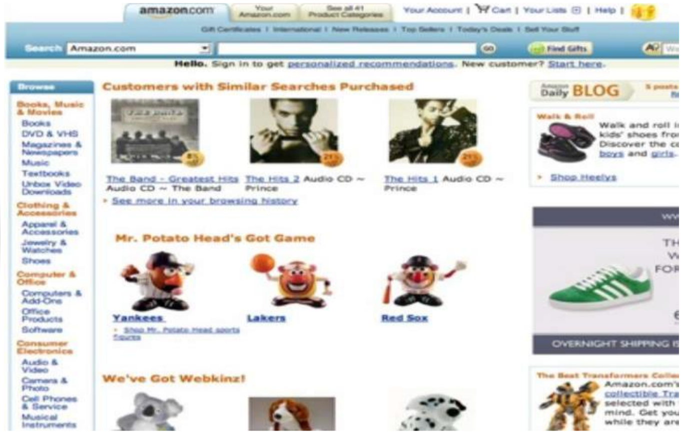
Specifying the task environment

- To design a rational agent, we must specify the task environment
- Consider the task of designing an automated taxi:
  - **Performance measure**: safety, destination, profits, legality, comfort
  - **Environment**: streets/freeways, traffic, pedestrians, weather
  - **Actuators**: steering, accelerator, brake, horn, speaker/display
  - **Sensors**: video, accelerometers, gauges, engine sensors, keyboard, sensors

Environment types

	Solitaire	Backgammon	Internet shopping	Taxi
Observable??	Yes	Yes	No	No
Deterministic??	Yes	No	Partly	No
Episodic??	No	No	No	No
Static??	Yes	Semi	Semi	No
Discrete??	Yes	Yes	Yes	No
Single-agent??	Yes	No	Yes (except auctions)	No

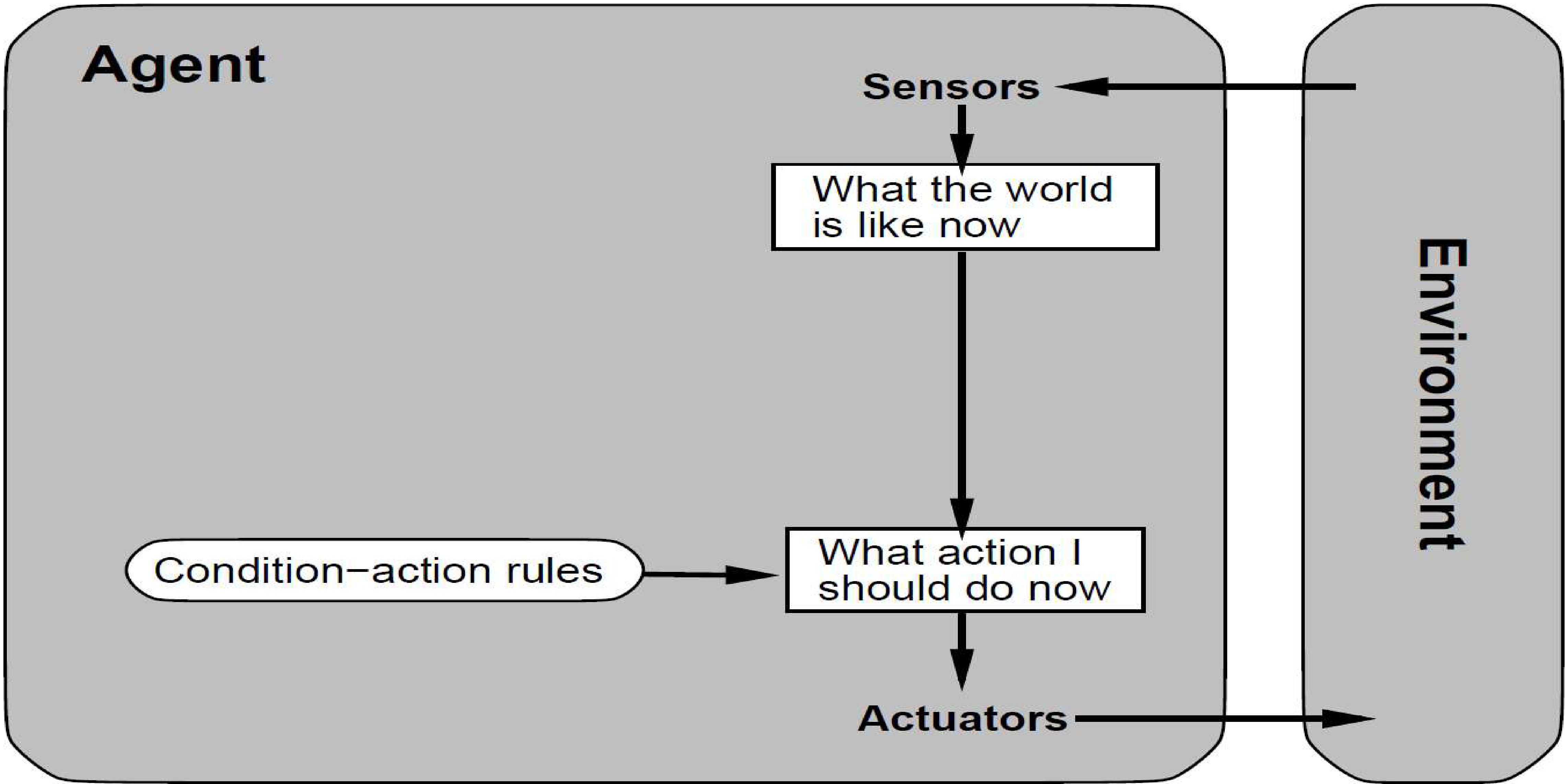




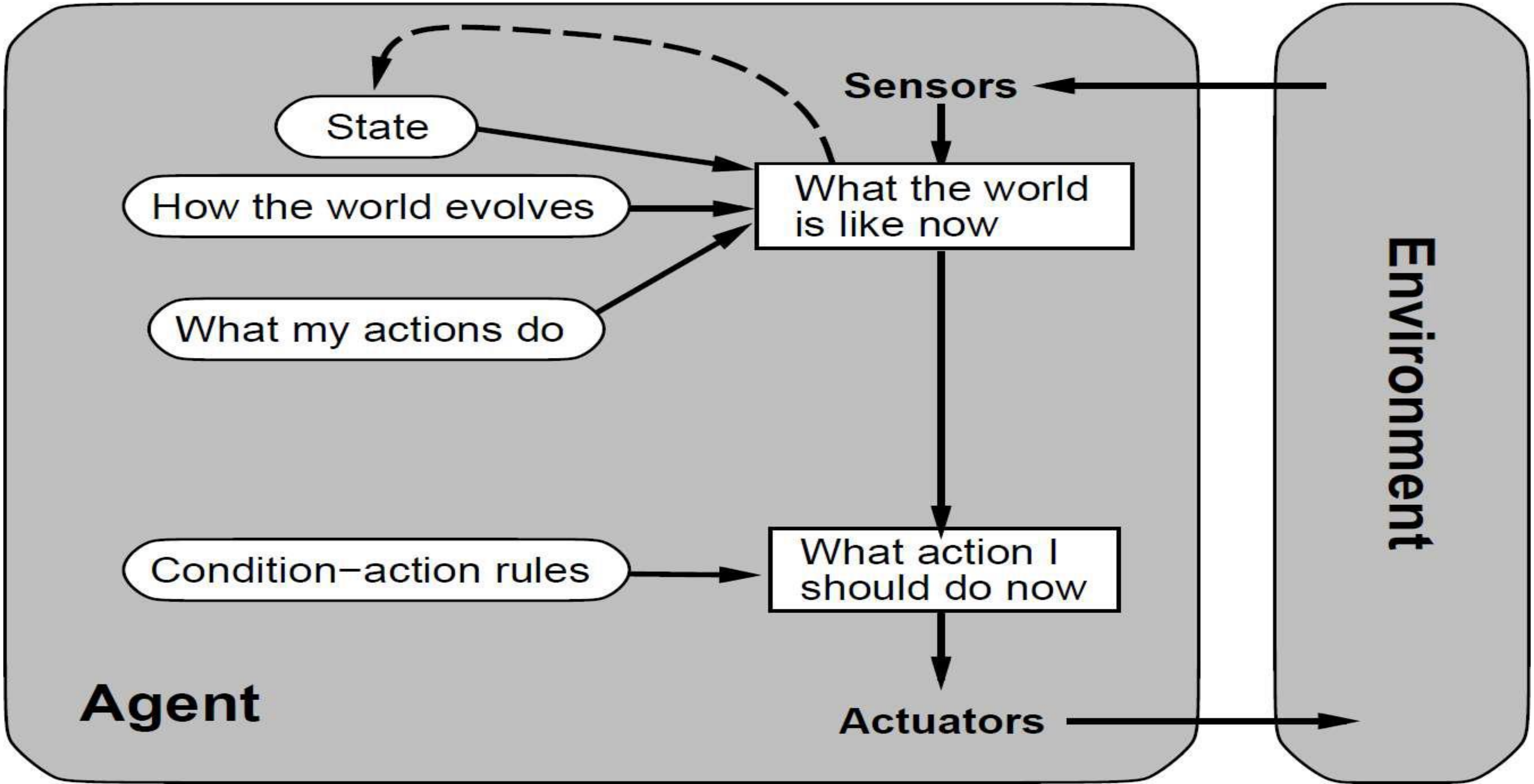
Agent types

- ❖ Four basic types in order of increasing generality:
  - simple reflex agents
  - reflex agents with state
  - goal---based agents
  - utility---based agents
- ❖ All these can be turned into learning agents

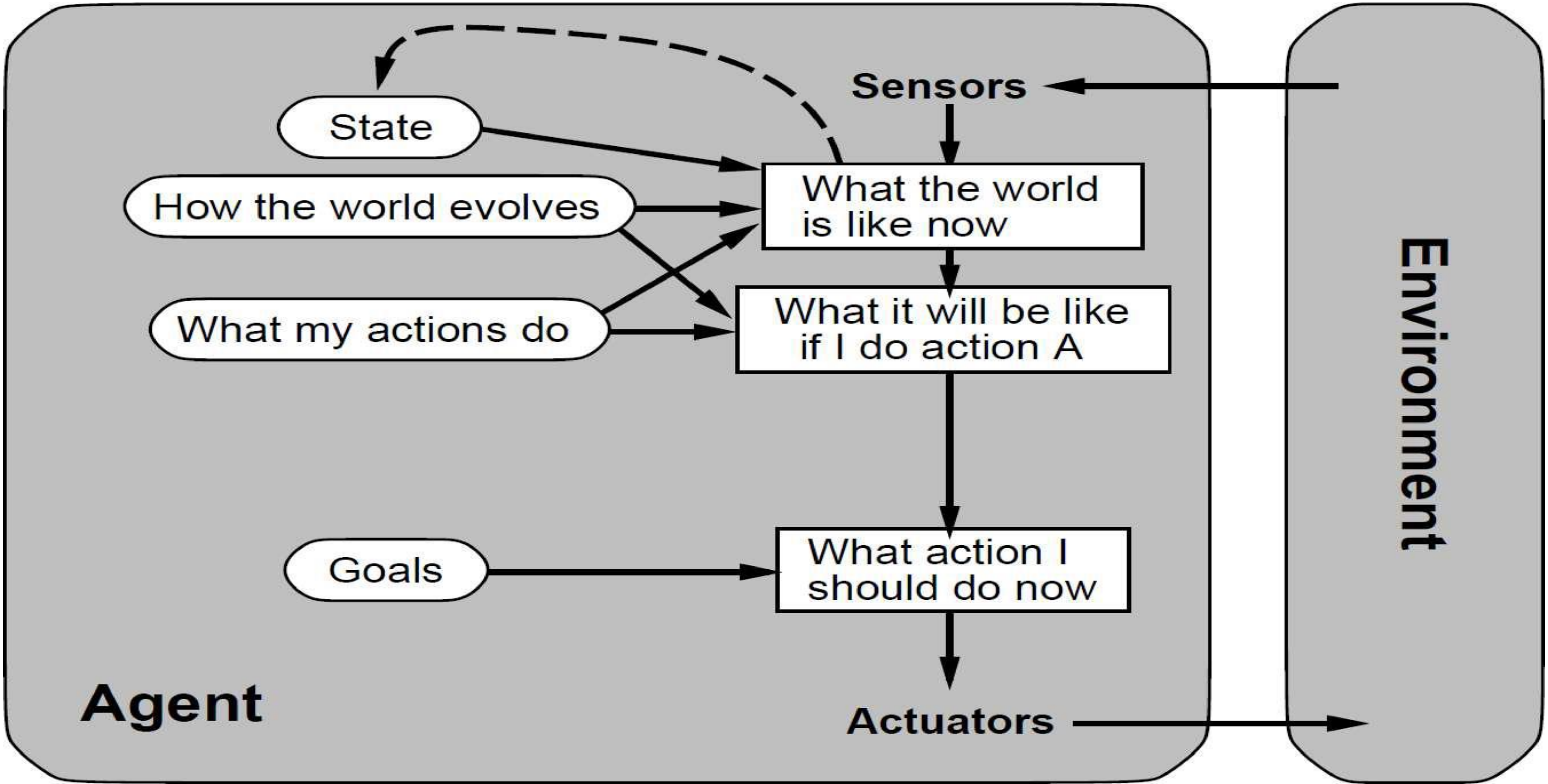
Simple reflex agents



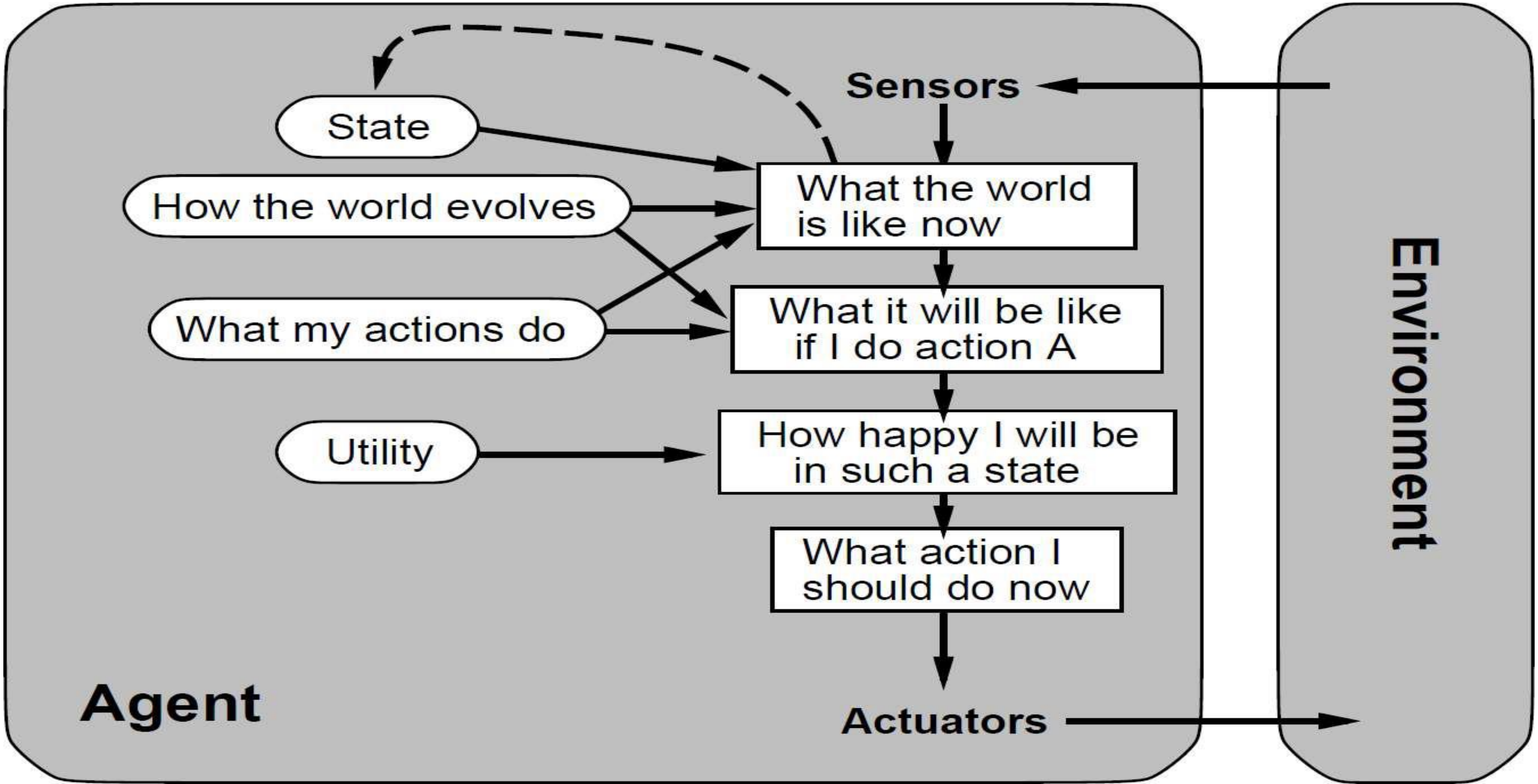
Reflex agents with state



Goal-based agents



Utility-based agents



Why learning?

- Why do we want an agent to learn? (Why Not program an improved design from the beginning)?

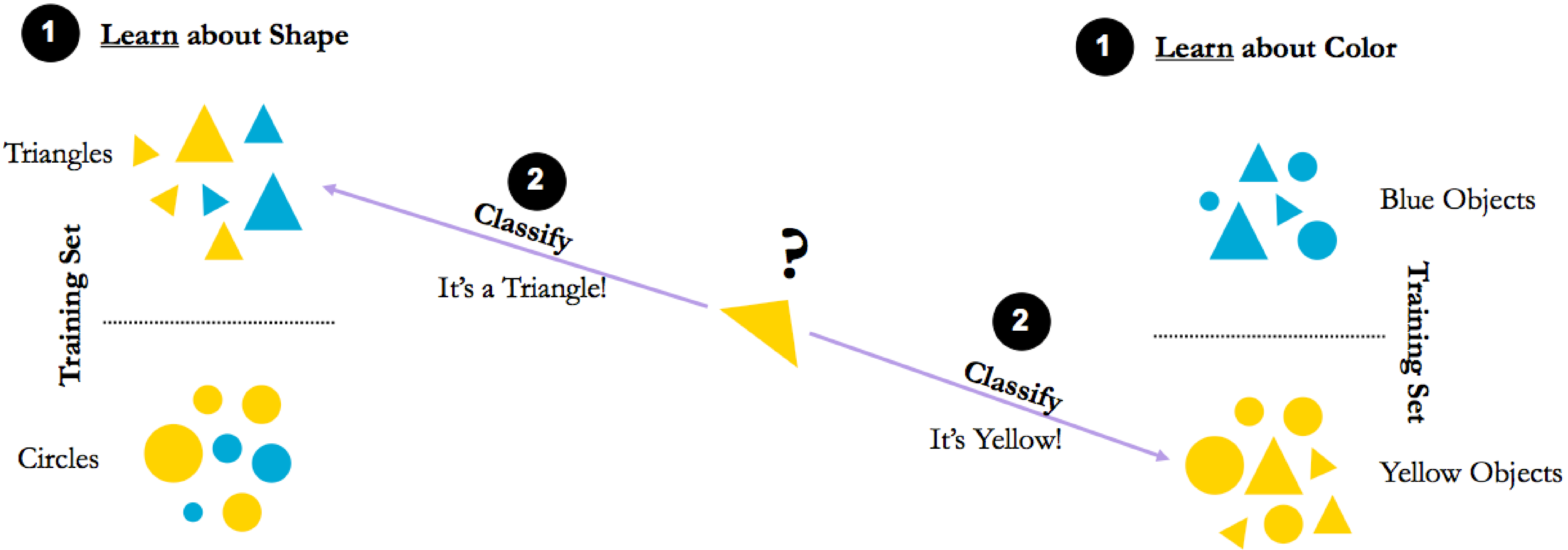
- Learning modifies the agent's decision mechanisms to improve performance

Machine Learning Approaches

- **Unsupervised learning**
  - Learning patterns without explicit feedback supplied
  - The system forms clusters or natural groupings of the input patterns (based on some similarity criteria) → Clustering
- **Reinforcement learning**
  - Learning from a series of reinforcements
  - Rewards and punishments
- **Supervised learning**
  - Learning a function that maps input to output based on available (observed) input-output pairs (Correct answers for each instance)
- **Semi-supervised learning**
  - A few labeled samples available and a large collection of unlabeled ones
  - Learn from geometry of unlabeled samples and use the labeled ones to improve the learning

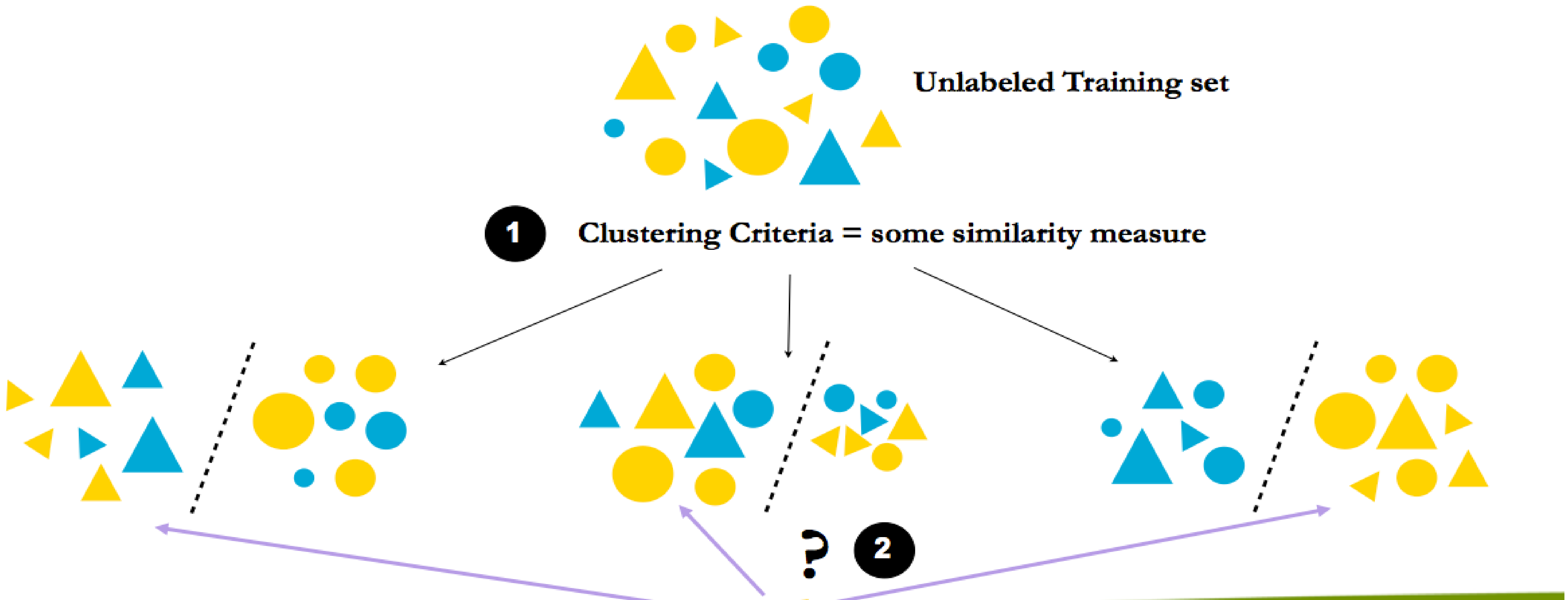
Supervised Learning

- labeled training sets, used to train a classifier



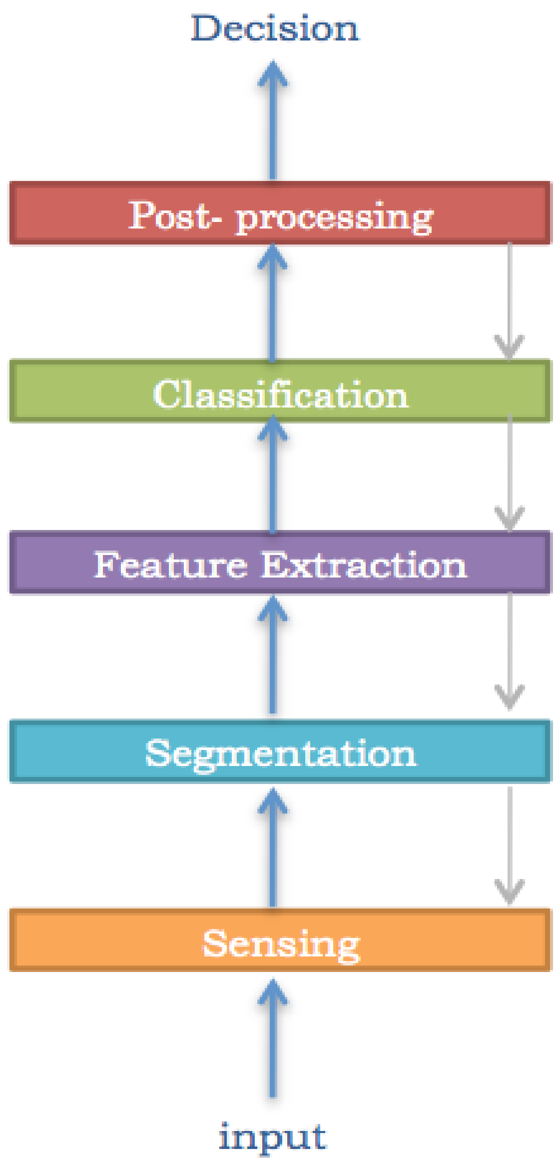
Unsupervised Learning

- ***No labeled training sets*** are provided
- System applies a specified clustering/grouping criteria to unlabeled dataset Clusters/groups together "most similar" objects (**according to given criteria**)

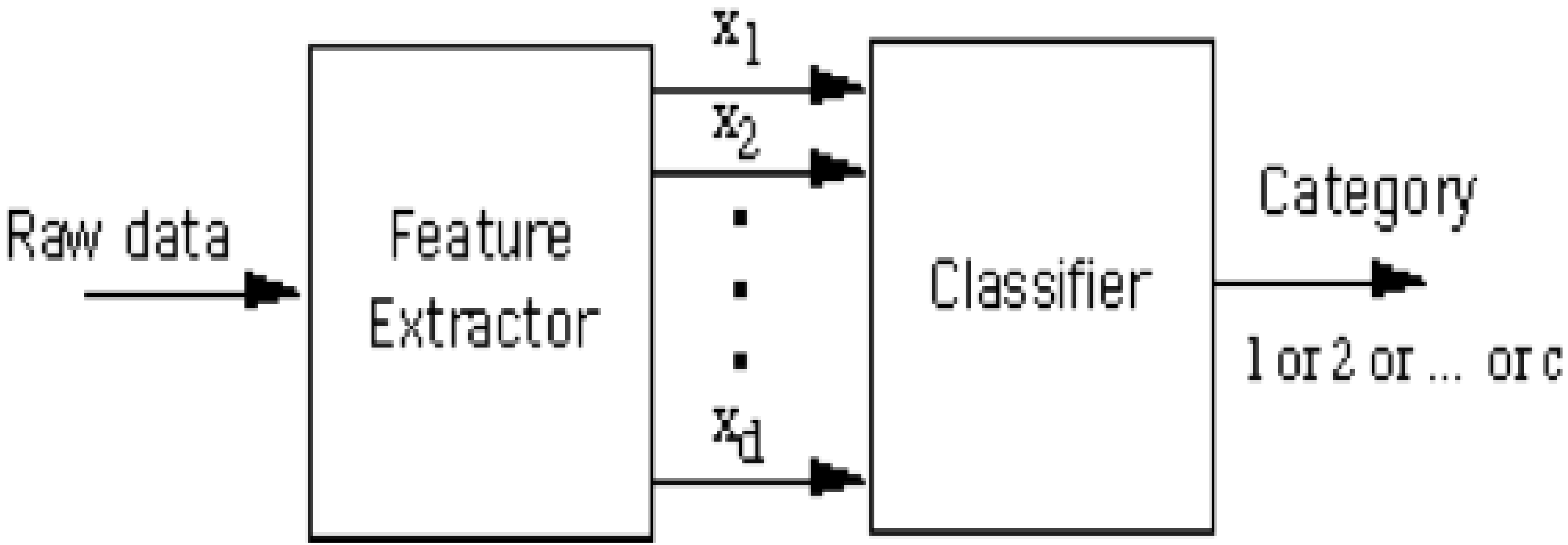


Pattern Recognition Process

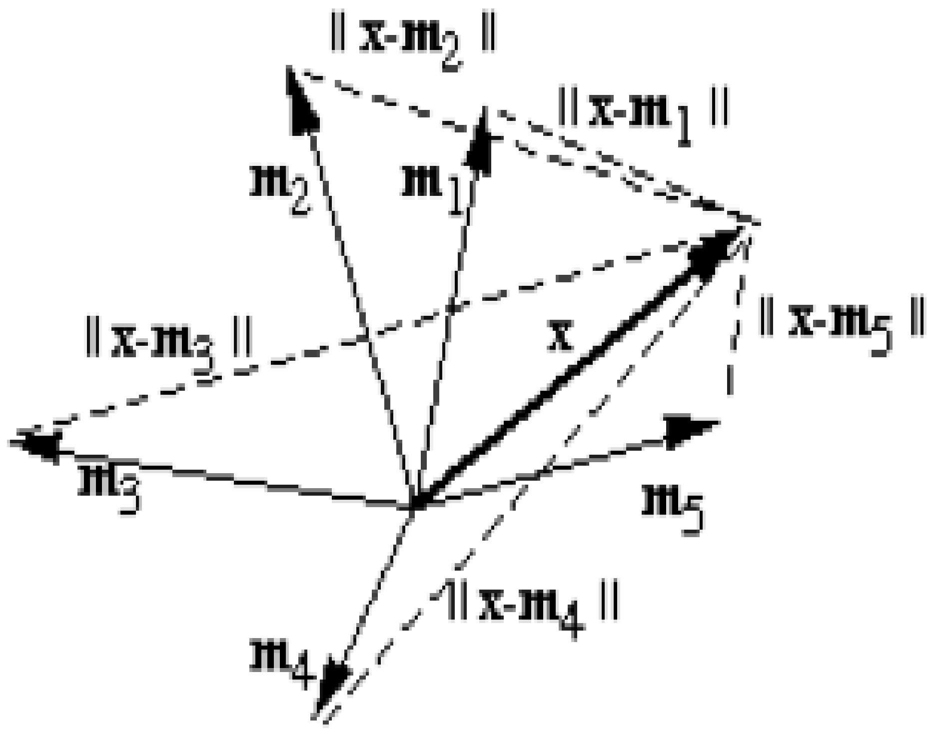
- **Data acquisition and sensing**
  – Measurements of physical variables.
  – Important issues: bandwidth, resolution , etc.
- **Pre-processing**
  – Removal of noise in data
  – Isolation of patterns of interest from the background
- **Feature extraction**
  – Finding a new representation in terms of features
- **Classification**
  – Using features and learned models to assign a pattern to a category
- **Post-processing**
  – Evaluation of confidence in decisions

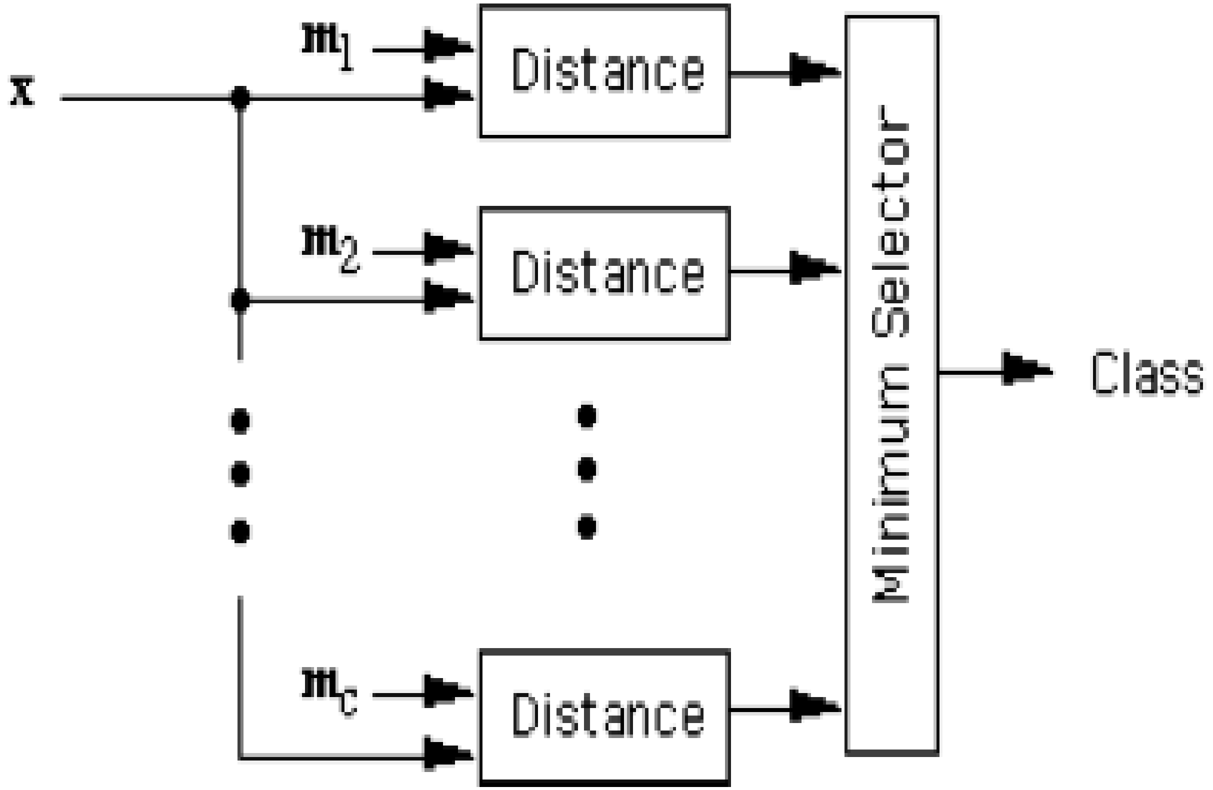


Classical model of Pattern Recognition

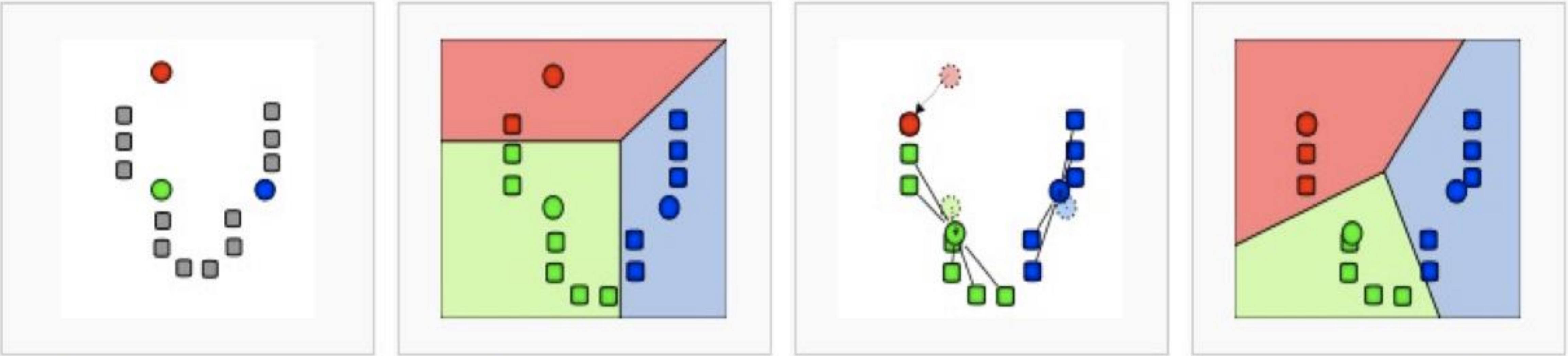


Example of Simple Classifier





Clustering: k-means



1) *k* initial "means" (in this case *k*=3) are randomly selected from the data set (shown in color).

2) *k* clusters are created by associating every observation with the nearest mean. The partitions here represent the Voronoi diagram generated by the means.

3) The centroid of each of the *k* clusters becomes the new means.

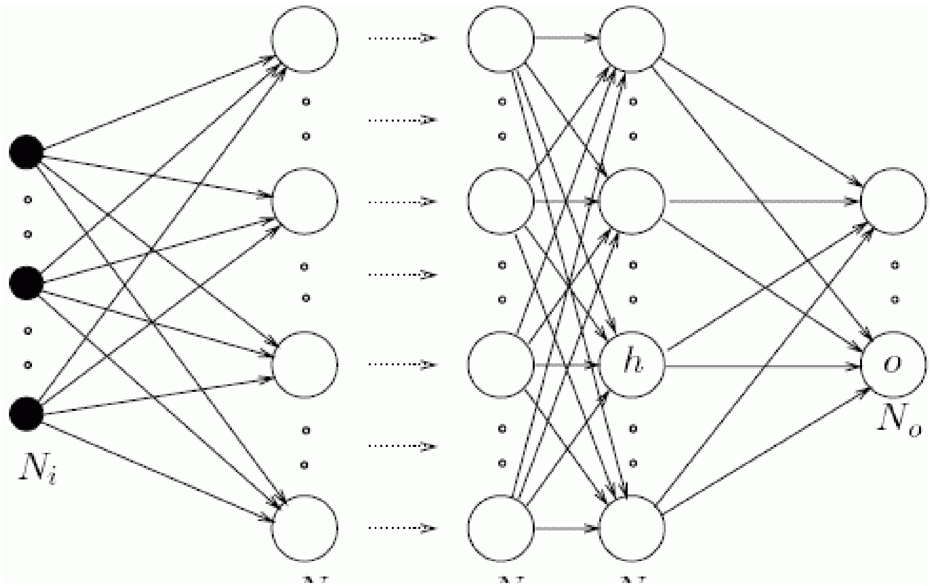
4) Steps 2 and 3 are repeated until convergence has been reached.

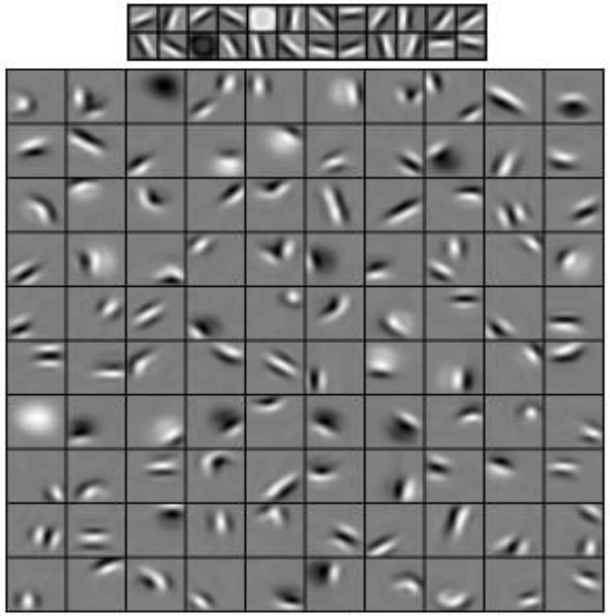
Deep Learning

- Choosing the correct feature representation of input data, is a way that people can bring prior knowledge of a domain to increase an algorithm's computational performance and accuracy
- To move towards general artificial intelligence, algorithms need to be less dependent on this feature engineering and better learn to identify the explanatory factors of input data on their own
- Deep learning tries to move in this direction by capturing a 'good' representation of input data by using compositions of non-linear transformations

Two types of models

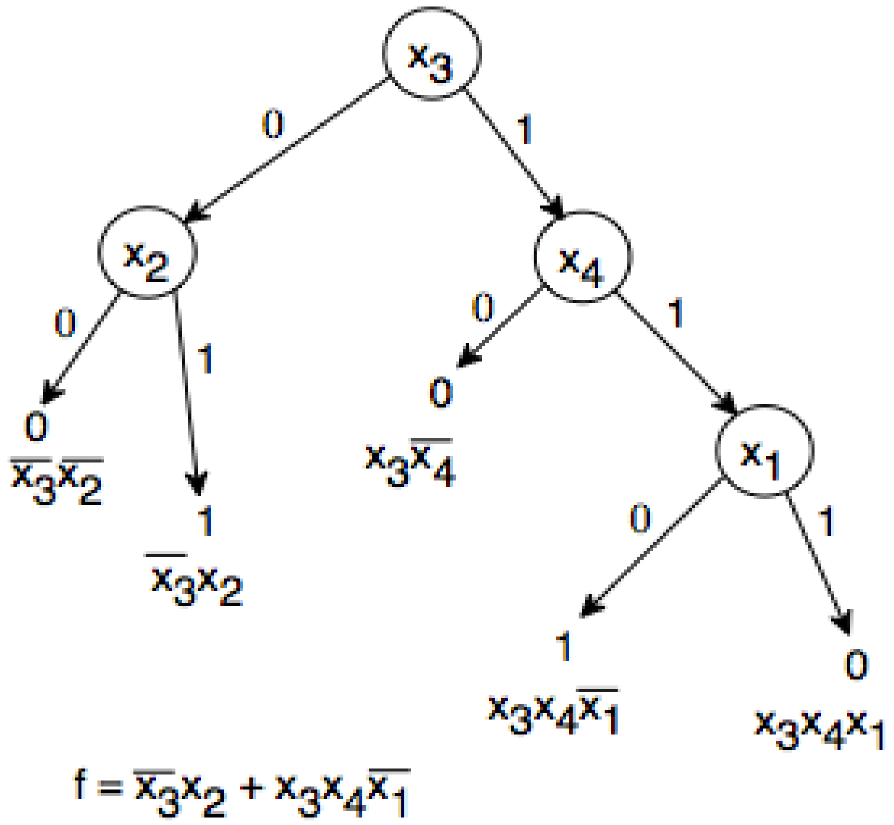
- **Probabilistic graphical models** have nodes in each layer that are considered as latent random variables
  - In this case, you care about the probability distribution of the input data x and the hidden latent random variables h that describe the input data in the joint distribution p(x,h). These latent random variables describe a distribution over the observed data
- **Direct encoding (neural network) models** have nodes in each layer that are considered as computational units
  - This means each node h performs some computation (normally nonlinear like a sigmoidal function) given its inputs from the previous layer





Decision trees

1. Learn rules from data
2. Apply each rule at each node
3. Classification is at the leaves of the tree



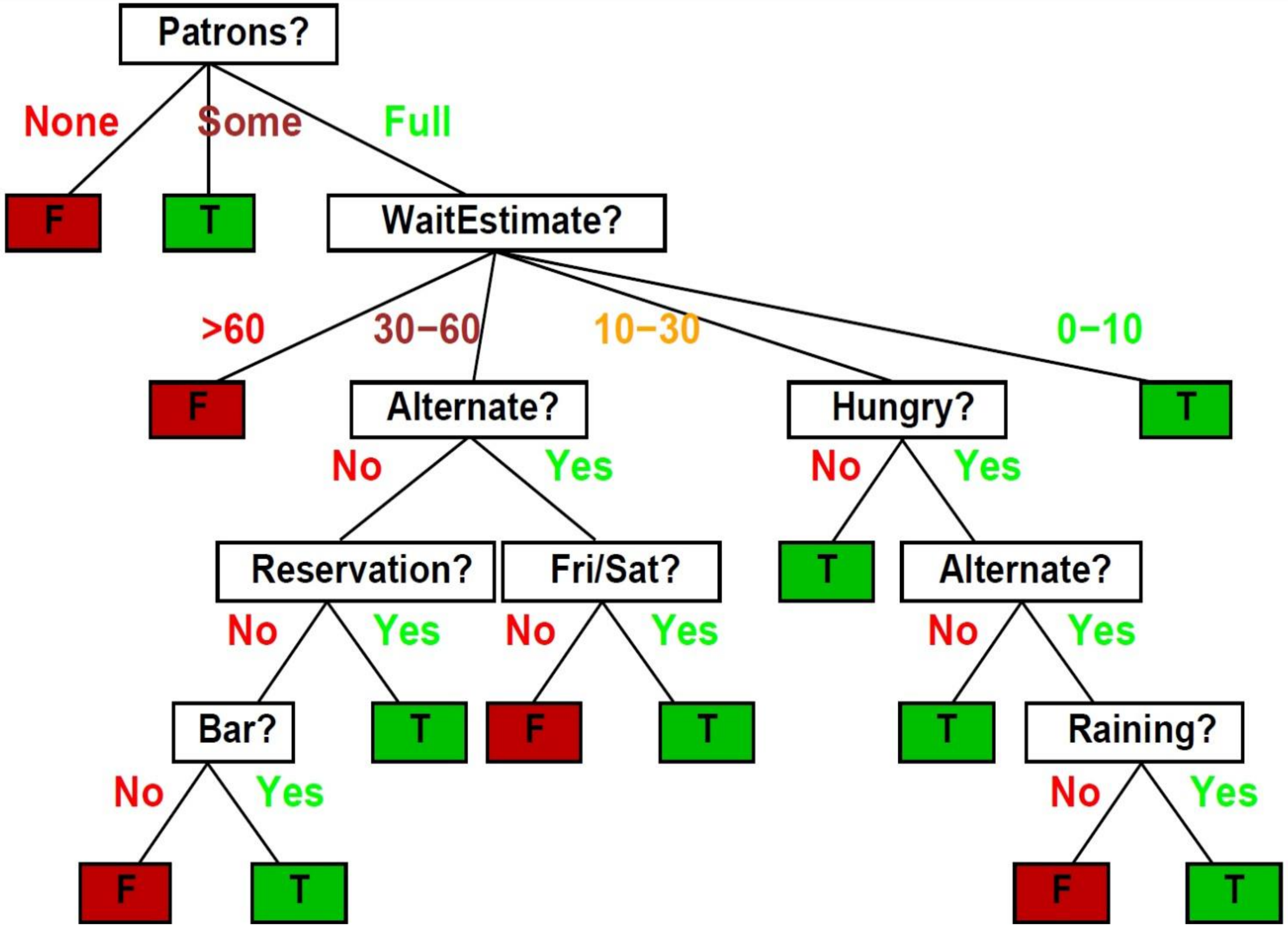
Decision Trees example

Example: Decision whether to wait for a table in a restaurant depending on the following attributes:

1. ***Alternate (Alt)***: Is there a suitable alternative restaurant nearby?
2. ***Bar***: Is there a comfortable bar area in the restaurant, where I can wait?
3. ***Fri/Sat (Fri)***: True on Fridays/Saturdays
4. ***Hungry (Hun)***: Are we hungry?
5. ***Patrons (Pat)***: How many people are in the restaurant (*None*, *Some or Full*)
6. ***Price***: The restaurant's price range (*$, $$, $$$*)
7. ***Raining (Rain)***: Is it raining outside?
8. ***Reservation (Res)***: Did we make a reservation?
9. ***Type***: the kind of restaurant (*French*, *Italian*, *Thai or burger*)
10. ***Wait Estimate (Est)***: the wait time estimated by the host (*0---10min*, *10---30*, *30---60*, or *>60*)

Decision tree

- ❖How many distinct decision trees we have with *n* Boolean attributes? = Number Of Boolean function = Number Of distinct Truth Tables With 2^n Rows = 2^n^n
- ❖**E.g.,** with 6 Boolean attributes 18,446,744,073,709,551,616



Introduction of AIoT

Where AI and IoT Meet: The Innodisk AIoT Solution

- 4-Where AI and IoT Meet: The Innodisk AIoT Solution

Introduction of AIoT

Part 1

- **The Artificial Intelligence of Things** (AIoT) is the combination of **Artificial Intelligence** (AI) technologies with the **Internet of Things** (IoT) infrastructure to achieve more efficient IoT operations, improve human-machine interactions and enhance data management and analytics [1]

- **AIoT** is transformational and mutually beneficial for both types of technology as AI adds value to IoT through machine learning capabilities and IoT adds value to AI through connectivity, signaling and data exchange [1]

Definition of AIoT

- The Artificial Intelligence of Things (AIoT) is the combination of artificial intelligence (AI) technologies with the Internet of Things (IoT) infrastructure to achieve more efficient IoT operations, improve human-machine interactions and enhance **data management** and **analytics**

Resource: Contributor(s): Posted by: Margaret Rouse, Gerry Christensen, https://internetofthingsagenda.techtarget.com/definition/Artificial-Intelligence-of-Things-AIoT

Definition of AIoT

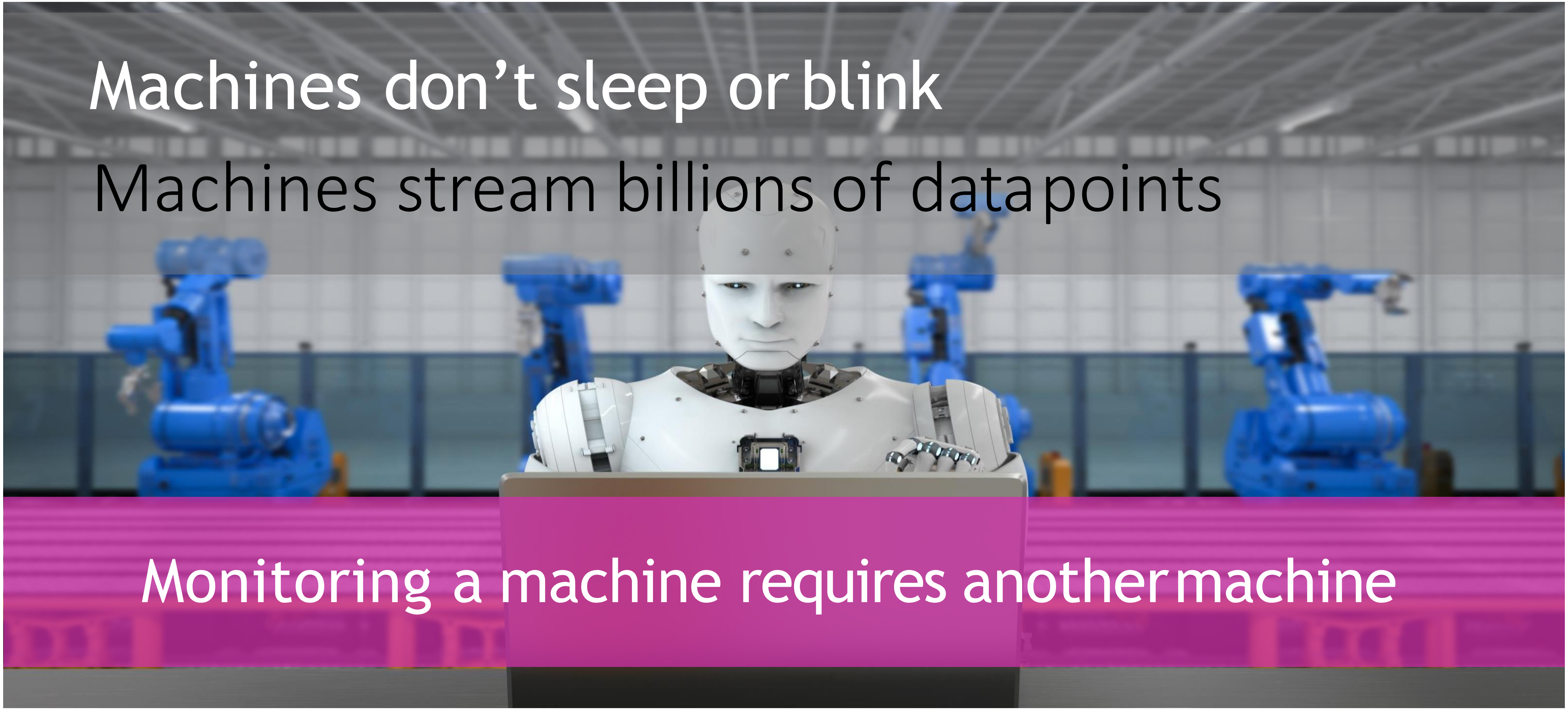
- AI can be used to transform IoT data into useful information for improved decision making processes, thus creating a foundation for newer technology such as IoT Data as a Service (IoTDaaS)

Resource: Contributor(s): Posted by: Margaret Rouse, Gerry Christensen, https://internetofthingsagenda.techtarget.com/definition/Artificial-Intelligence-of-Things-AIoT

AIoT: AI Meets IoT

- Machines monitoring machines
  - ✓When machines are in control of the machines
- Machines learning
  - ✓When machines learn from each other and us
- Machines collaborating
  - ✓When machines work together too solve problems
- Machines manufacturing machines for people
  - ✓When machines democratize the process of creation

Machines monitoring machines



Machines that look out for other machines

Machines must operate together in multi-vendor, low-trust ecosystems
Monitoring provides both system-wide state information and decision feedback loop

Monitoring goals

Complex event detection

Detecting events in complex systems involves reasoning over triggers from many independent sources, managing system state, and applying logic in real time. As event inputs grow in number and relationship complexity, logic moves towards ML and is no longer deterministic

Decision verification

Machine system are required to make millions of decisions every second with often incomplete information, all while predicting the behavior of machines around them. Learning systems require feedback on the efficiency of those decision to improve

Policing

Machine control spans multiple distributed systems with different goals, planning algorithms and trade off logic . Policing ensures that decisions with global impact are on the whole globally optimized or in accordance with governance algorithms. Important in training behavior

Machine Learning

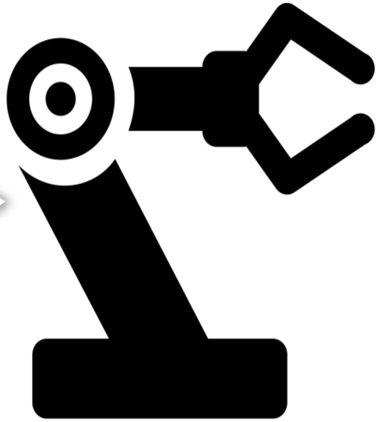
- Machine learning is when computers create models of system behavior based on data from historical or current systems
  - The denser (strong) the information in the data, the better the model
- Machine learns what we teach them

Machine learning on machine data is Hard

Learning is all about the data.
Machine data is a hot mess because the physical world is messy, dirty and often unpredictable

Devices must report data in simple formats to be flexible for function abstraction

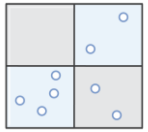
T_1 :measurement time
T_2 :server time
V :value (ex:5)
URL :source unique ID



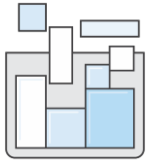
- Lack of labels, situational context & relationship: device data is simple. Unlike application data it doesn't carry information needed to interpret it. Context must be built elsewhere and addedto the raw data.

- Crappy data quality & integrity: many devices have limited local resources like memory, signal processing, connection management or cheap sensorquality.

- High volumes of data carrying sparse information: terabytes of streaming raw operations data may contain only a few kilobytes relevant to any one process or analysis.



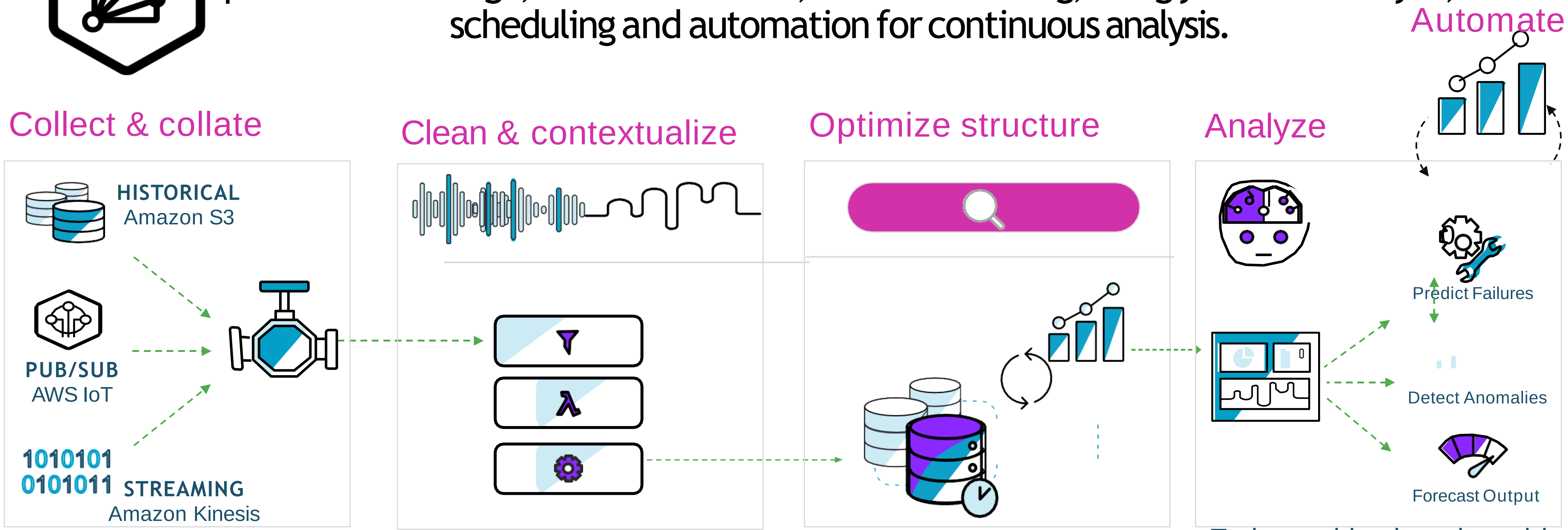
- Distinguishing deviation from variation: sources of variability abound in the physical world, especially in operations that involve us humans. Detecting meaningful deviation requires a broad analytical toolbox.



- High data dimensionality: data dimension refer to the number of independent parameters in an analysis.
- Techniques like ML are very compute expensive when
- crunching high dimensional analysis.

Machine learning on machine data with AWS IoT Analytics

AWS IoT Analytics brings together data preparation for machine data, optimized performant storage, data visualization, machine learning, bring your own analysis, scheduling and automation for continuous analysis.



Aggregate across multiple machine data sources, structure and collate data by time window

Separate signal from noise, clean, enrich, convert and prepare IoT data

Store and query processed data, analyze time series, archive & reuse raw data

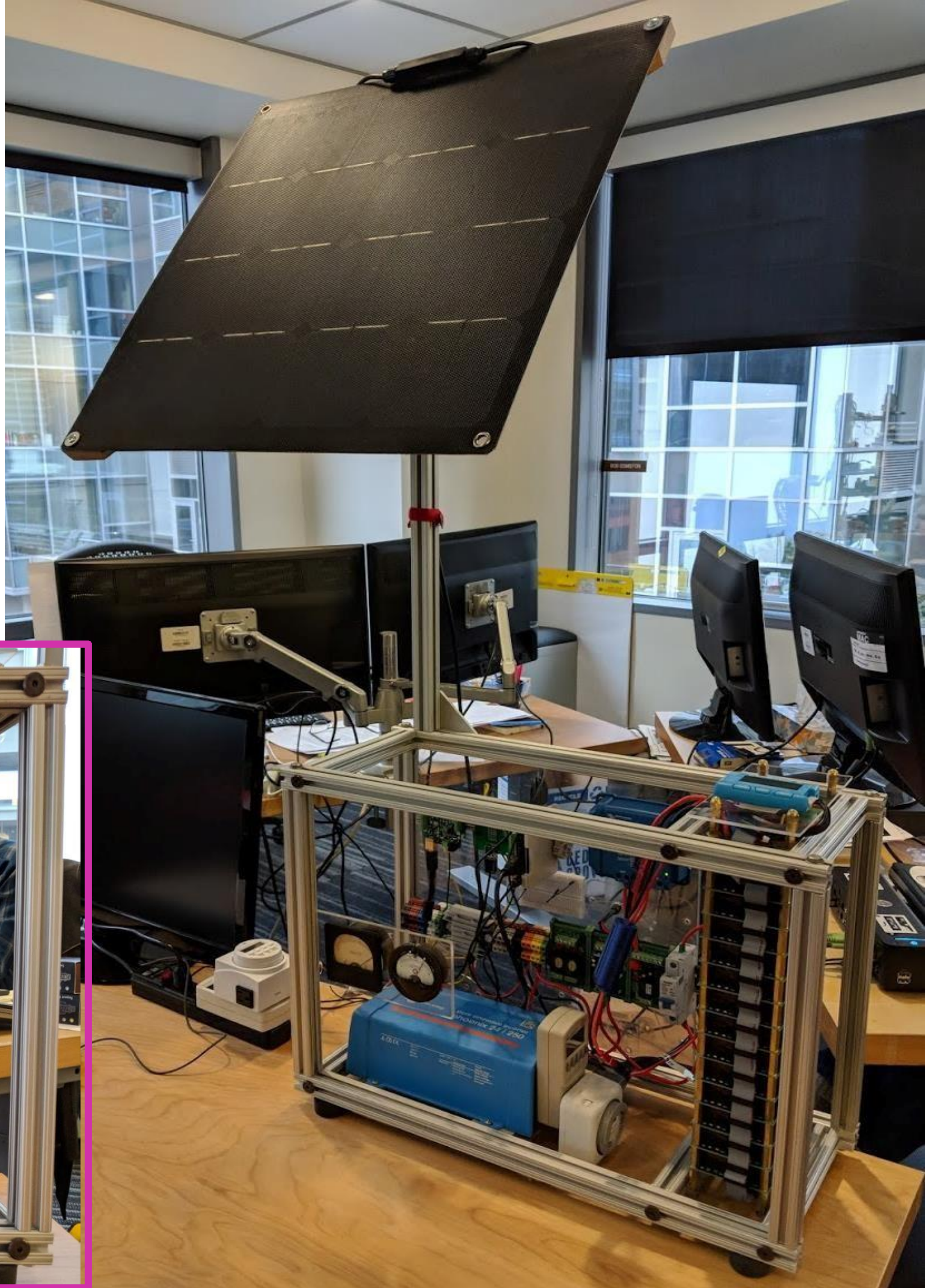
Train machine learning with Amazon Sagemaker, containerize custom analysis, explore results in Amazon QuickSight

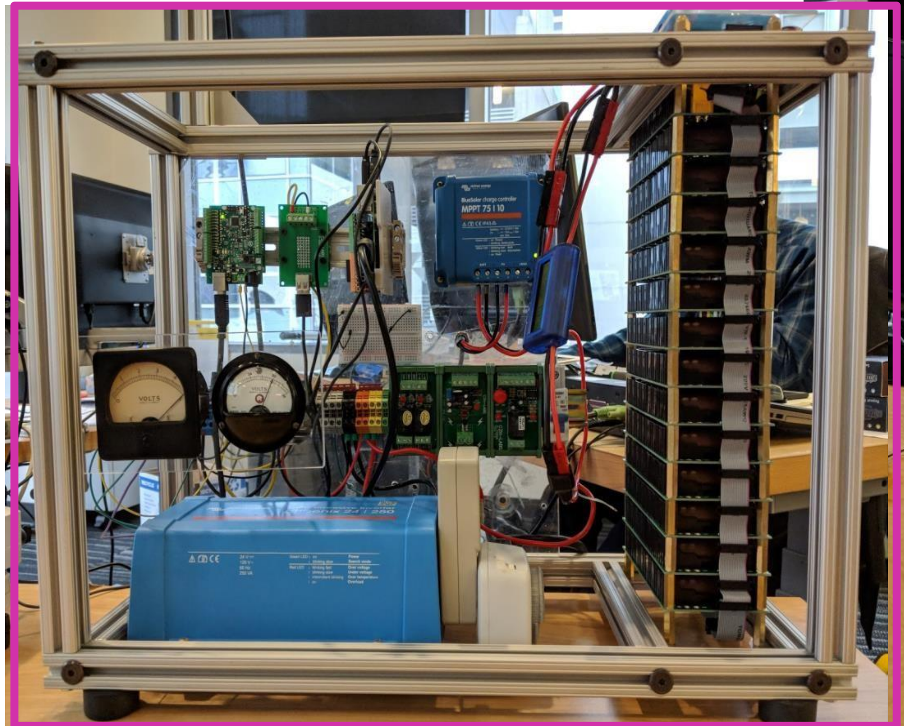

Machines are specialists
Completing complex tasks takes intelligent coordination
10%
60%
25%
40%
90%
50%
100%

Machine collaboration in power arbitrage

Autonomous power supply optimization

AWS IoT Analytics





Machines making machines

- Machines democratizing manufacturing for usally using AWS IoT

Applications of IoT and AIoT

Artificial Intelligence of Things (AIoT)

- MarketResearchDotComM, Published on Jun 28, 2019

  5-Artificial-Intelligence-of-things-aiot-market-by-technology-and-solutions-2019-2024

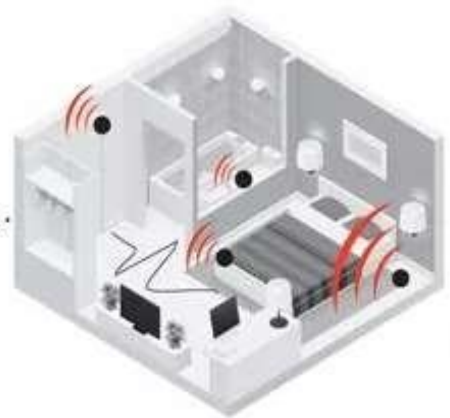
Applications of IoT

- 6-Internet of Things(IoT) Applications | IoT Tutorial for Beginners | IoT Training | Edureka
- edureka!, Published on Aug 24, 2018

Compound Applications Examples

HEALTHCARE + SMART HOME

Aging uncle Earl is still living isolated at his home and you are concerned about his safety.



Wireless sensors throughout his house help measure healthy activity levels, sleeping patterns and medication schedules.

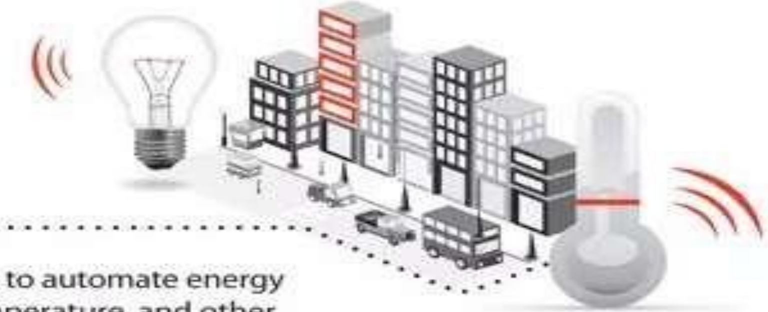
Alerts are automatically sent to health care services and authorized family members if any abnormal activity is detected.

40 million adults age 65 and over will be living alone in the U.S, Canada and Europe.

- U.S. Department of Health and Human Services: Administration for Community Living (ACL)

SMART BUILDINGS + MOBILITY

Anna is being pressured to reduce her company's expenses for their new corporate office.



After speaking with experts she decides to install sensors to automate energy usage according to building occupancy, people flow, temperature, and other ambient conditions -- improving the building's overall efficiency.

Energy used by commercial and industrial buildings in the US creates nearly 50% of our national emissions of greenhouse gases.

- United States Environmental Protection Agency

REAL-TIME SERVICE NETWORKS

- Appliance Monitoring
- Predictive Maintenance
- Service Technician / CRM
- Waste Management / Recycling

R Hotel Denver,
Industrial Washer #GHS40-2608

Location: *ID: FC-RM #00243*
Manufacturer: *Appliance Park Louisville, KY ID: #45205343*
Materials: *FC / SUS*
Sensor: *Vibration*
Connectivity: *Wireless LAN*

Connor, the Lead Maintenance Manager at the R Hotel in Denver, receives a sensor notification that the pump body O-ring #6 on washing machine #230243 is starting to fail in the housekeeping laundry room.

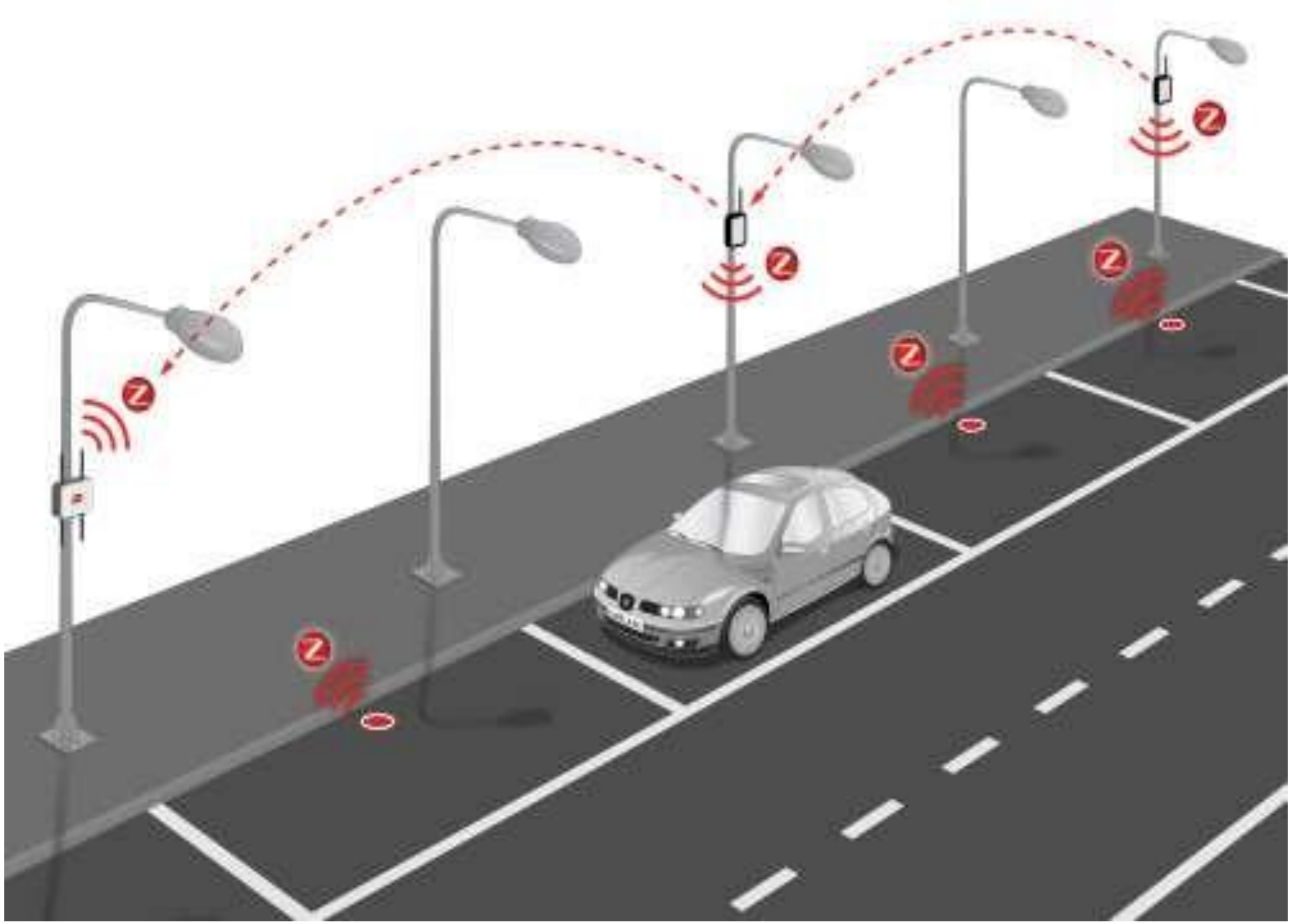
On his mobile, Connor prompts the machine to order a new part. This action triggers a bidding opportunity for local service technicians within the product's authorized maintenance network.

The request lays out:
- *Pricing parameters*
- *Timing requirements*
- *Machine history*
- *Part specs*
- *Predictive sensor measurements & alerts*

Tom from IA Appliances bids on the service request and receives a notification a few moments later that his bid was accepted.

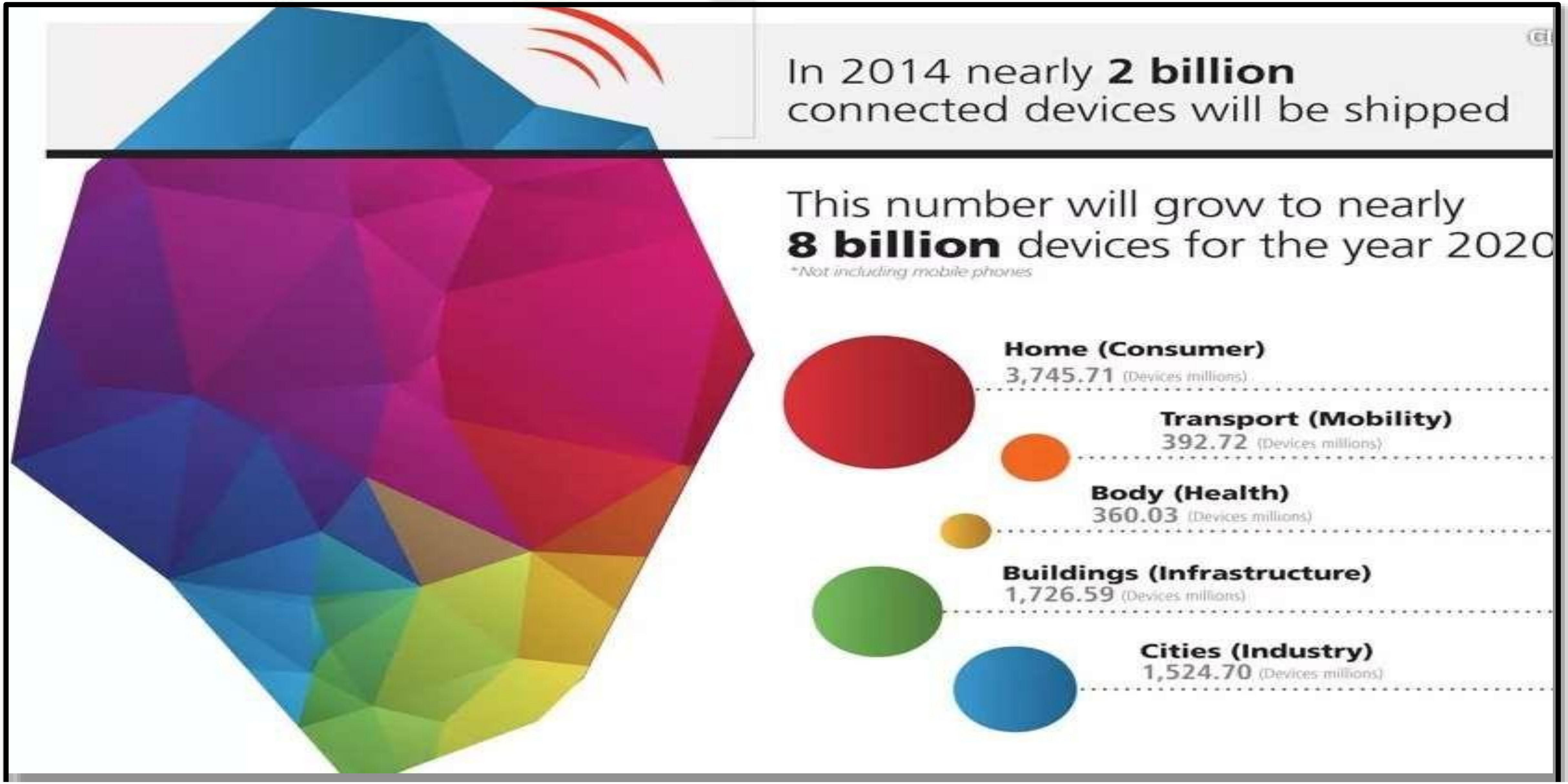
Within 1.5 hours, a service technician from IA Appliances is on site (Using a temporary facility access code for the wireless door lock) to replace the water pump. Connor sends a brief note on the service quality and IA Appliances releases a bid request for the part's raw materials to local recycling centers.

Connect with things



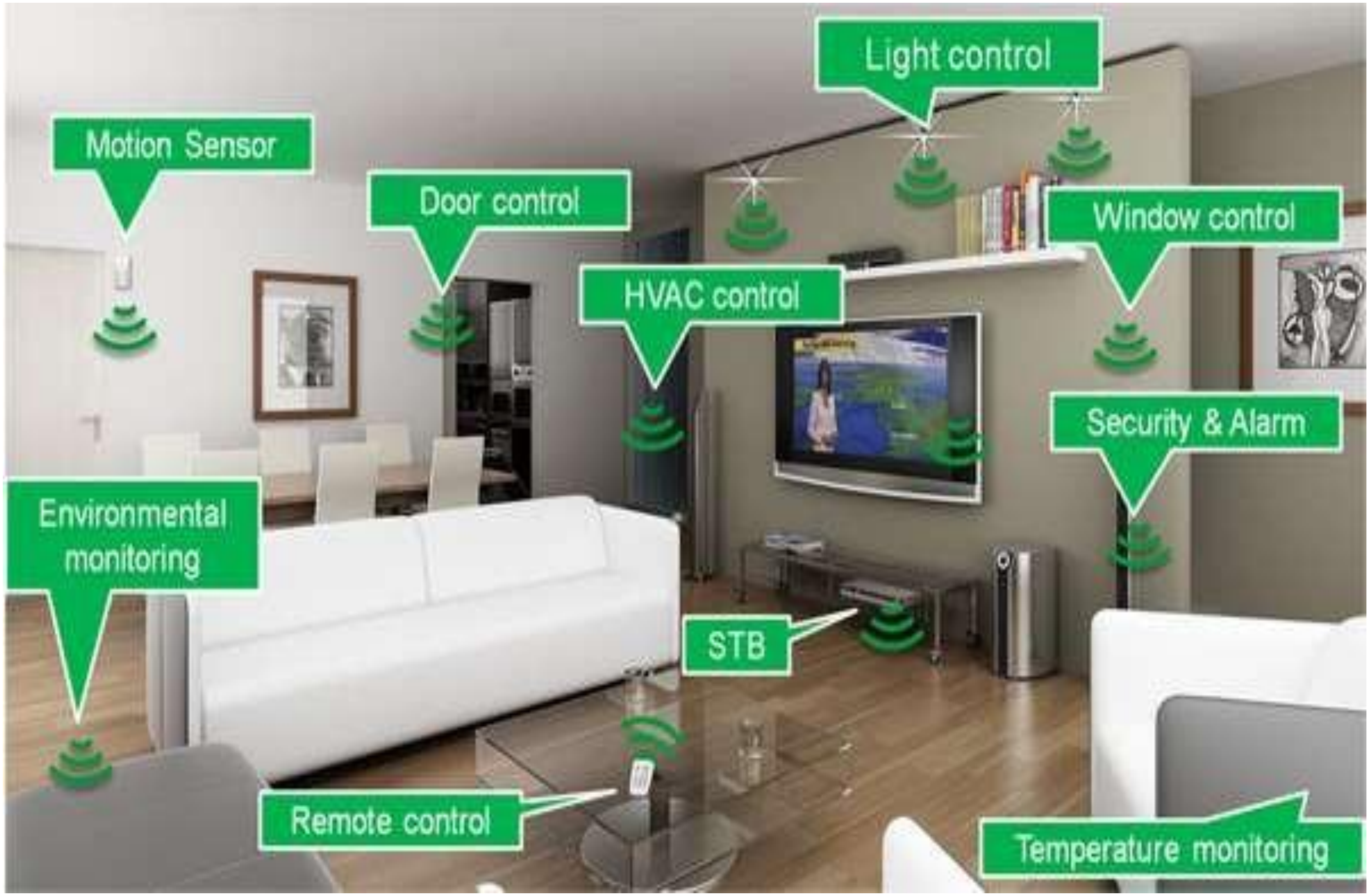
- Connect with things
- *Search for things*
- *Manage Things (manage facilities)*

How large is IoT market – connected devices

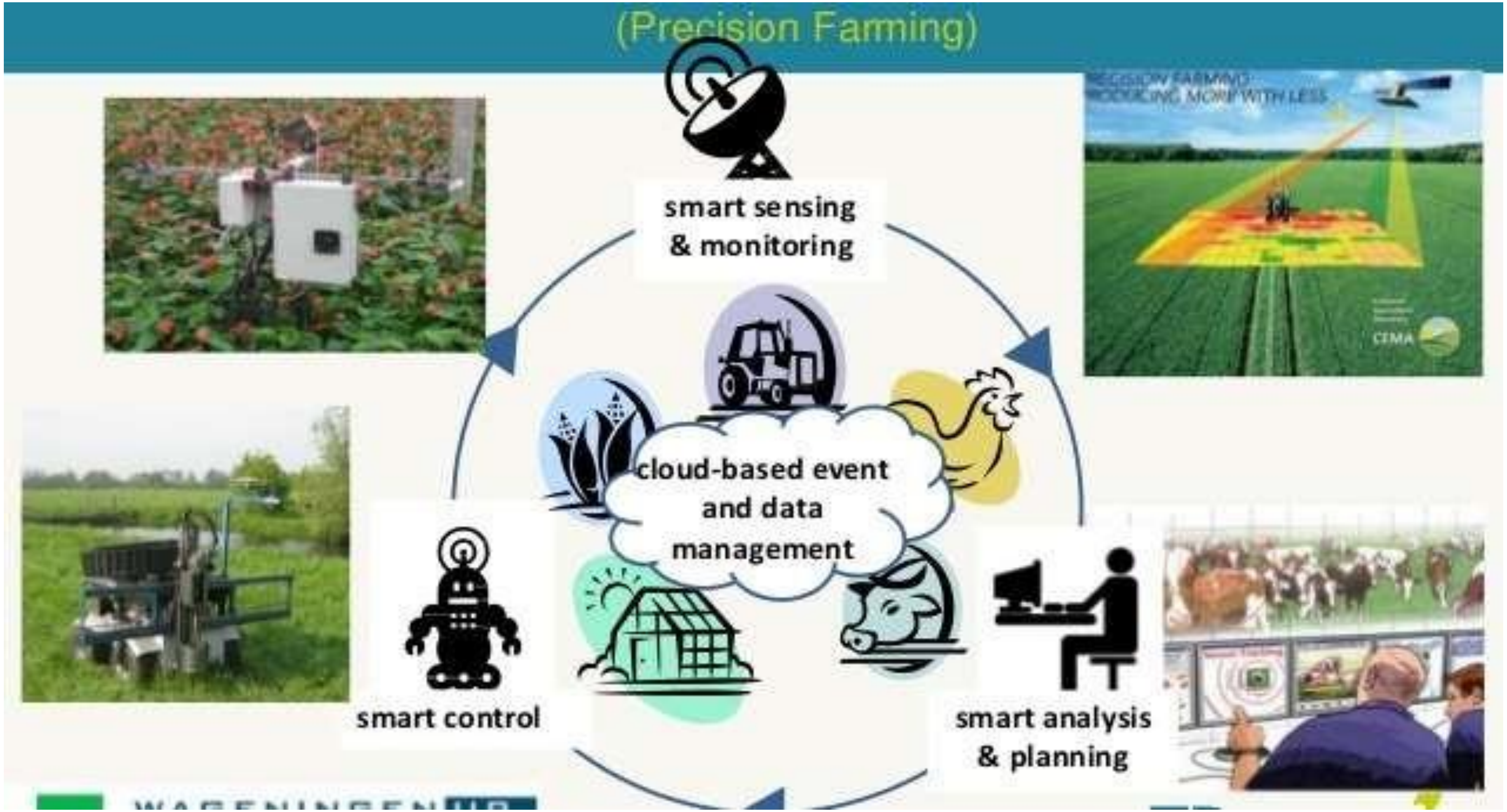


Home automation

- ✓ Home & family
- ✓ Door & locks
- ✓ Light & Switches
- ✓ Damage & Danger
- ✓ Motions & cameras
- ✓ Comfort
- ✓ A.C temperature



Smart Agriculture



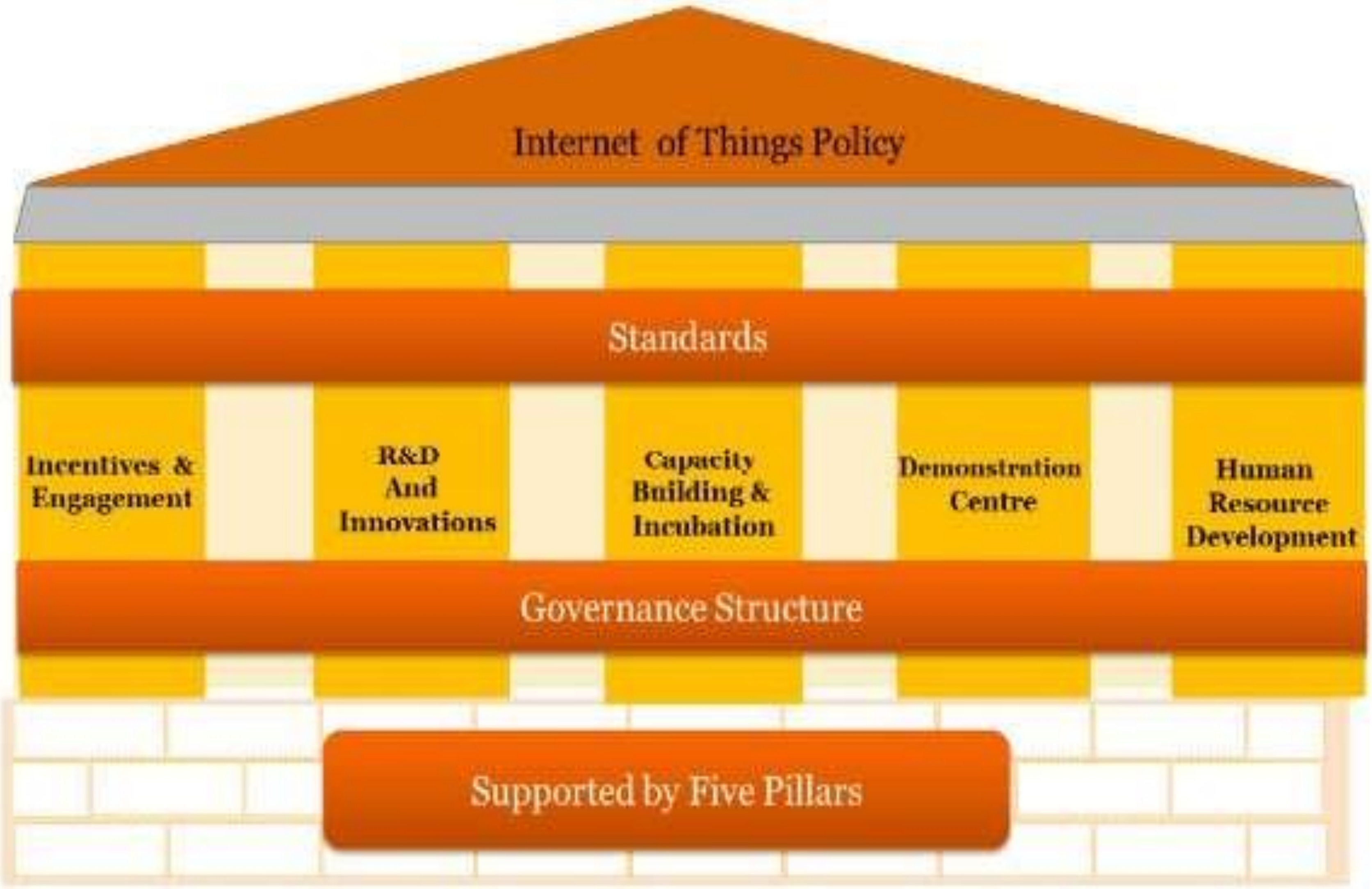
TAAS – Things as a Service

- Things when **you** need it, as long as you need it
- Cost when **you** use it, as long as you use it

Smart cities

- Rupees. 7,060 crores (1 crore=ten million) kept for 100 Smart cities to undertake
  - Smart parking
  - Intelligent transport system
  - Tele-care
  - Smart grids
  - Smart urban lighting
  - Waste management
  - Smart city maintenance
  - Digital-Signage

Pillars (cylinder) of IoT



http://deity.gov.in/content/internet-things

Artificial Intelligence of Things (AIoT) Applications

https://www.youtube.com/watch?v=Cx5aNwnZYDc

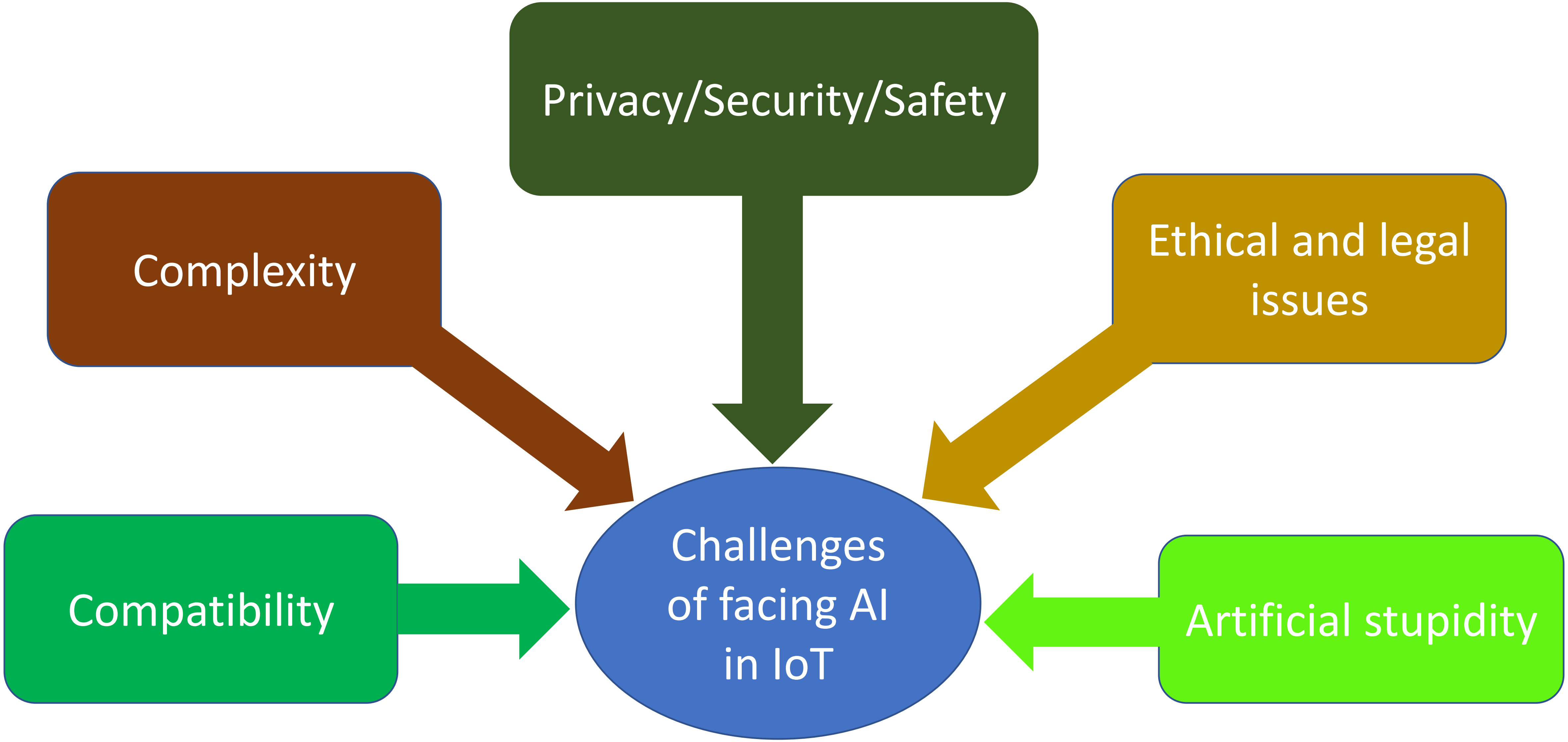
Geospatial World, Published on Dec 12, 2017

1-AIoT--How will Artificial Intelligence and Internet of Things change the world

AI in IoT Applications [3]

- Visual big data, for example – will allow computers to gain a deeper understanding of images on the screen, with new AI applications that understand the context of images
- Cognitive systems will create new recipes that appeal to the user's sense of taste, creating optimized menus for each individual, and automatically adapting to local ingredients
- Newer sensors will allow computers to "hear" gathering sonic information about the user's environment
- Connected and Remote Operations- With smart and connected warehouse operations, workers no longer have to roam the warehouse picking goods off the shelves to fulfill an order

Challenges facing AI in IoT



Challenges facing AI in IoT [6]

- **Compatibility:** IoT is a collection of many parts and systems they are fundamentally different in time and space
- **Complexity:** IoT is a complicated system with many moving parts and non – stop stream of data making it a very complicated ecosystem
- **Privacy/Security/Safety (PSS):** PSS is always an issue with every new technology or concept, how far IA can help without compromising PSS? One of the new solutions for such problem is using Blockchain technology
- **Ethical and legal Issues:** It's a new world for many companies with no precedents, untested territory with new laws and cases emerging rapidly
- **Artificial Stupidity:** Back to the very simple concept of GIGO (Garbage In Garbage Out), AI still needs "training" to understand human reactions/emotions so the decisions will make sense

Thank you for your listing.

- **Q & A**

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