Smart Product design

Notes compiled

Smart Product Design-2025

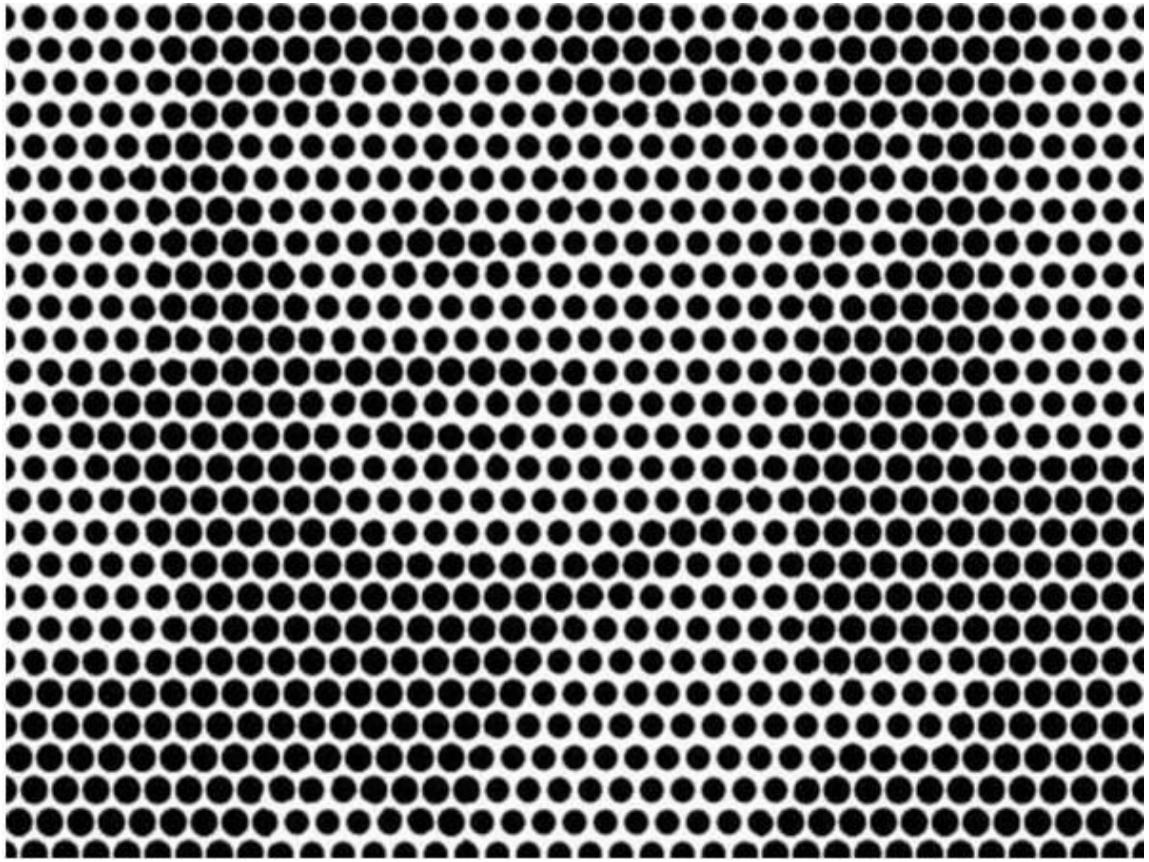
DS2001
Jan – May 2025

Dr. Monisha Mohan
Dr. Arunachalam

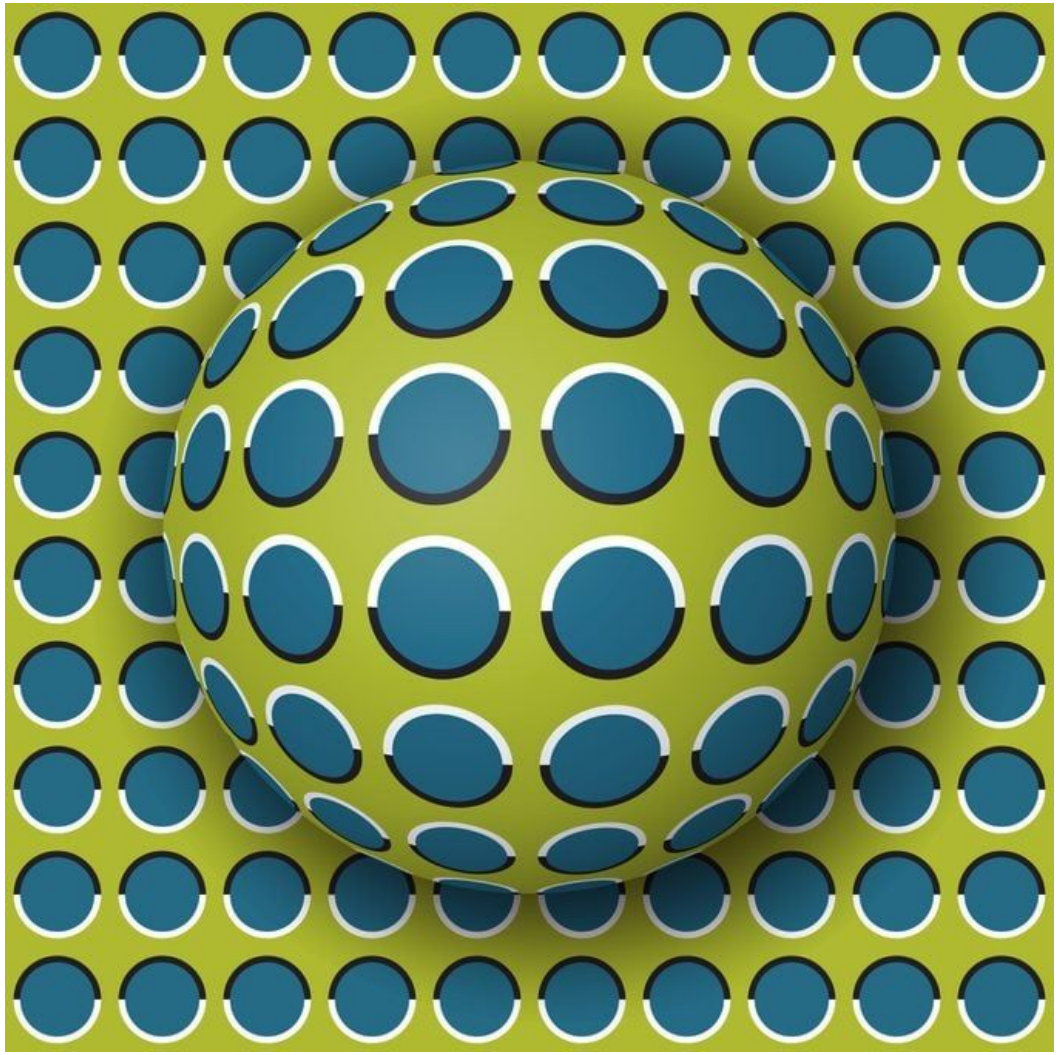
Marks allocation

Assignments	Project/EHIPASSIKO Presentation	End semester
25	25	50

Smart



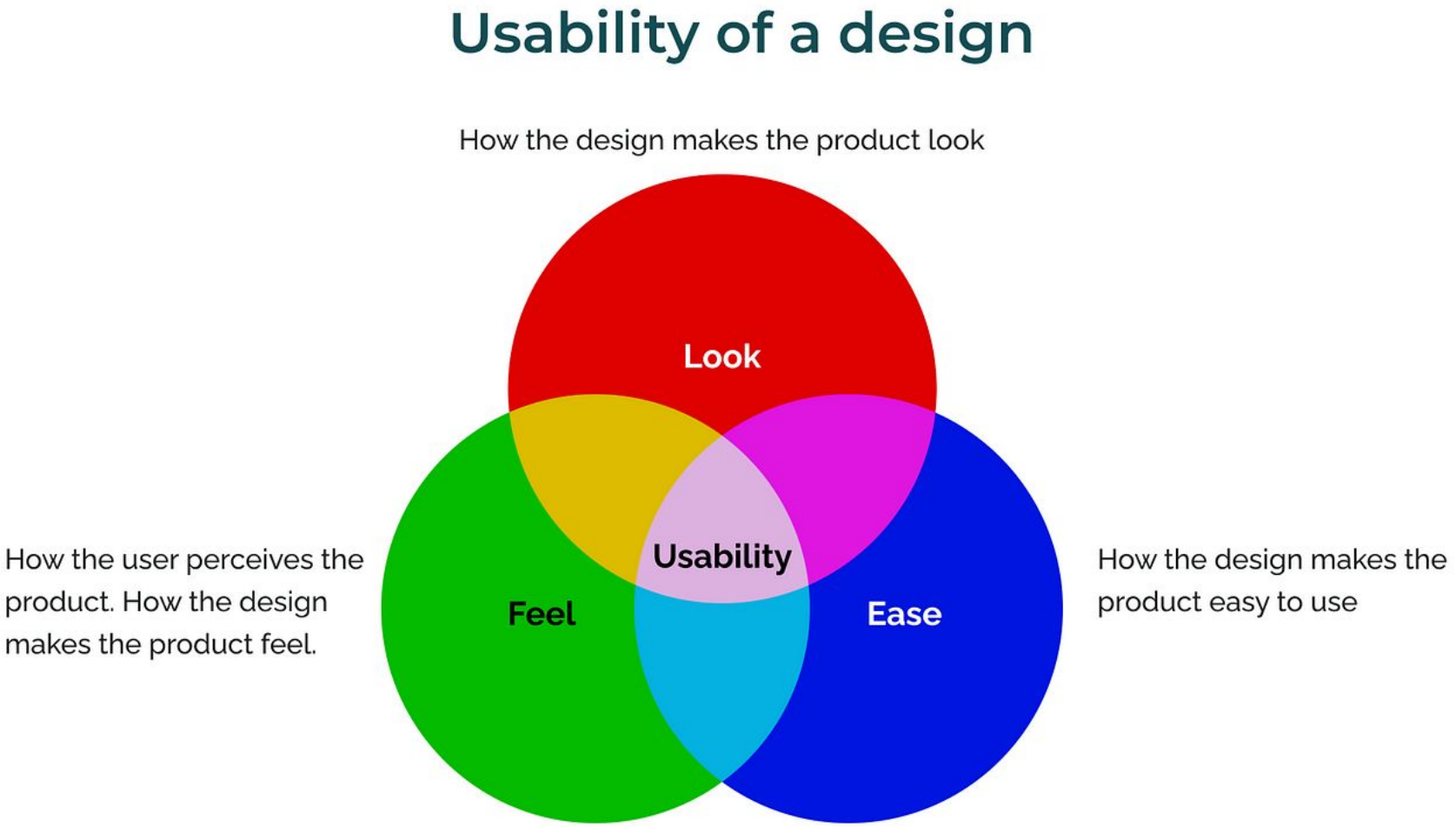
Smart



What is Smart Product Design?

Smart product design integrates **technology and intelligent features** into products to enhance

- ***Usability***
- ***Functionality***
- ***Efficiency***



What is Smart Product Design?

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- ***Usability***
- ***Functionality***
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Smart water

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Dyson vaccum cleaner – Time, User and Energy Efficient

Task - 1

(20 mins)

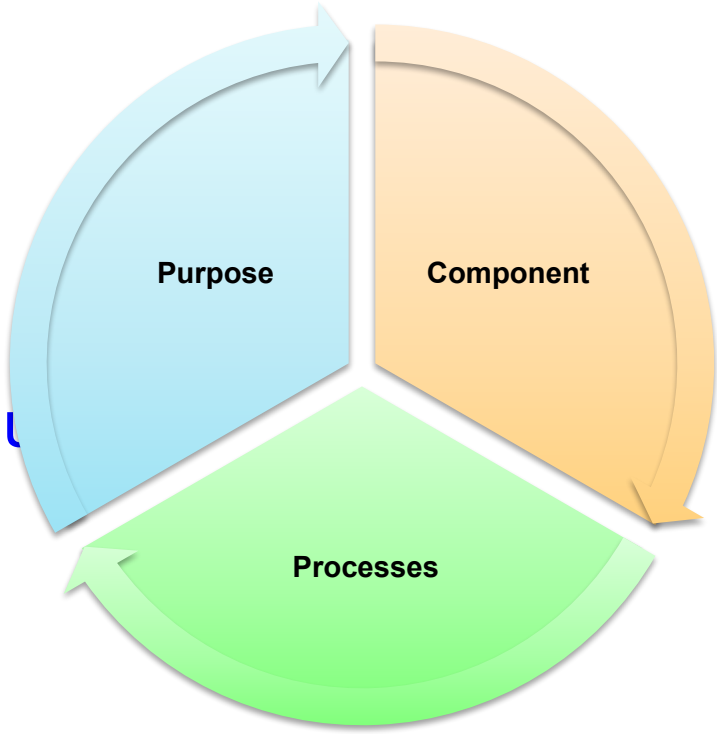
Know and write about the 4 smart systems you know about

PCP Framework

Purpose, Components, and Processes, used in systems thinking and product development to analyze and design systems or solutions effectively

Purpose

- What problem does the product solve?
- What value does it provide to users?



Components

- What are the essential components of the produ
- How do these components work together?

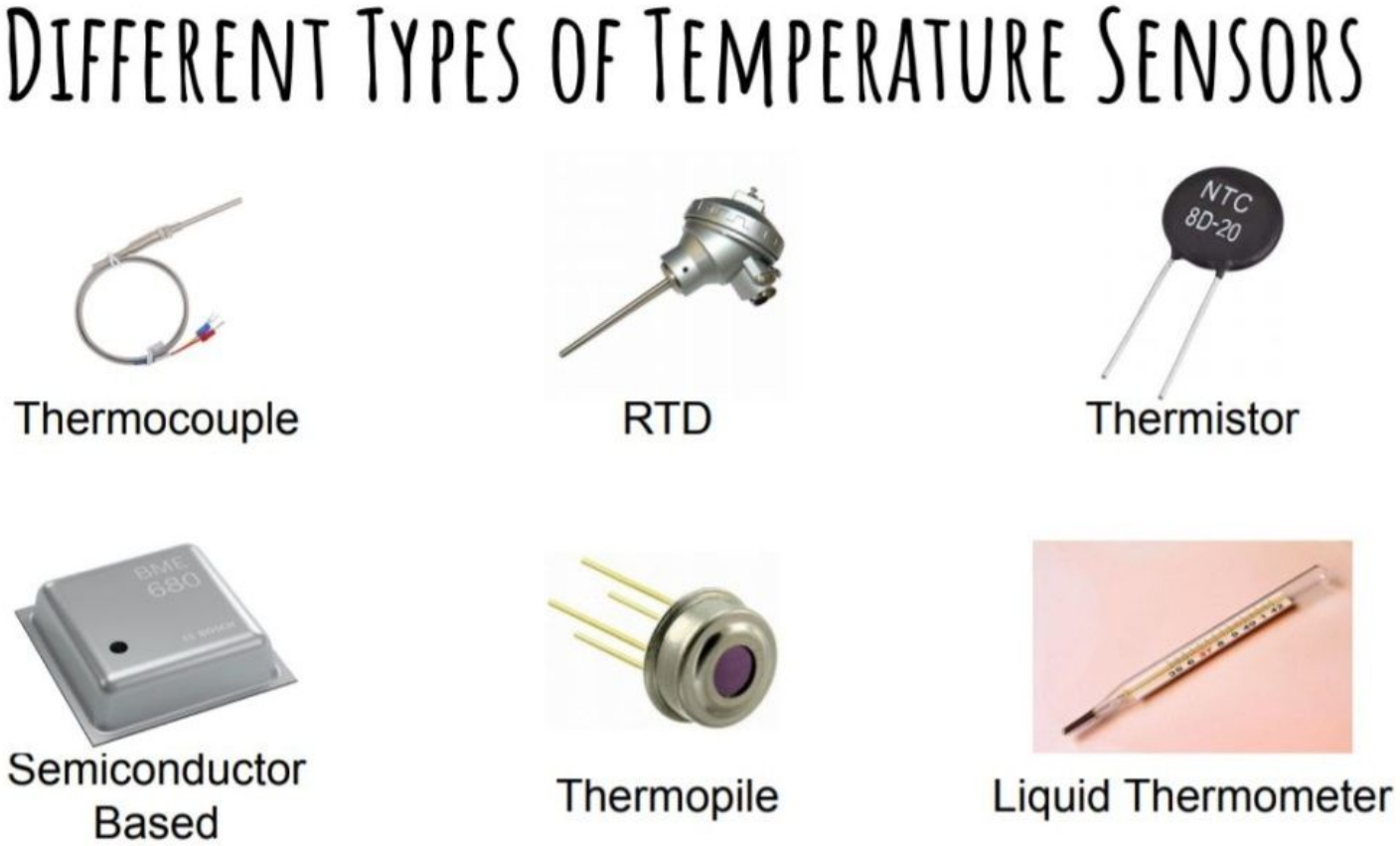
Processes

- How is the product designed, manufactured, and delivered?
- What steps do users follow to interact with the product?

Key Components of Smart Products

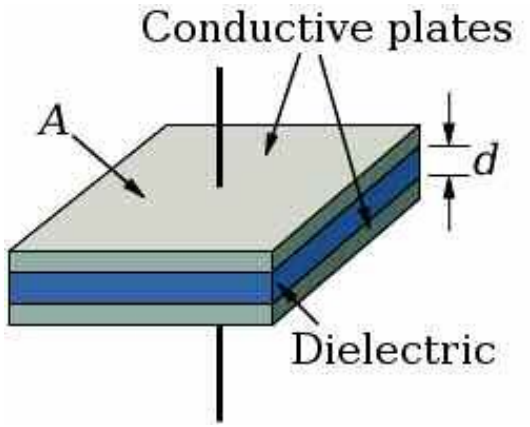
- **Sensors**: Devices to collect real-world data

Temperature Sensors: Measure ambient or surface temperature.

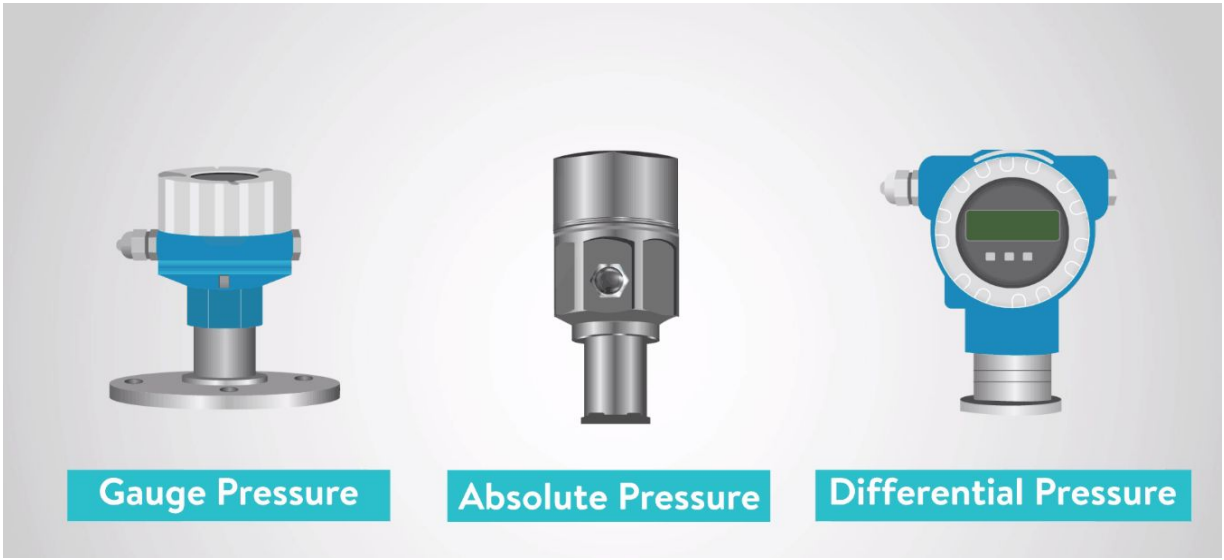


Key Components of Smart Products

- **Sensors**: Devices to collect real-world data
  - **Humidity Sensors:** Detect moisture levels in the air
  - **Pressure Sensors:** Measure gas or liquid pressure

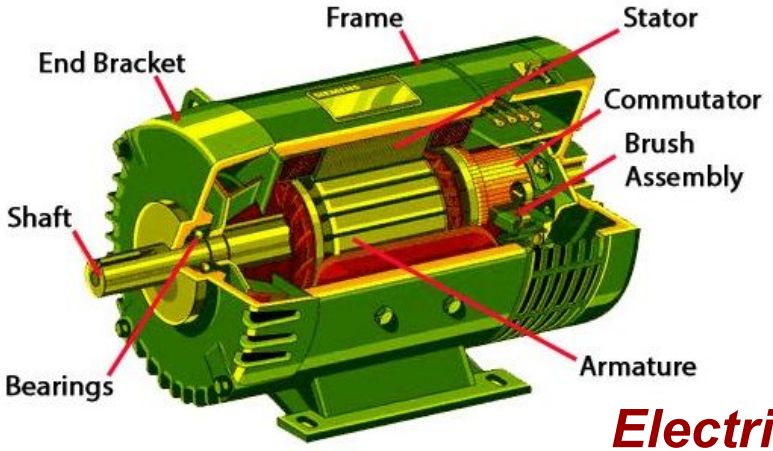


Capacitive Humidity Sensor



Key Components of Smart Products

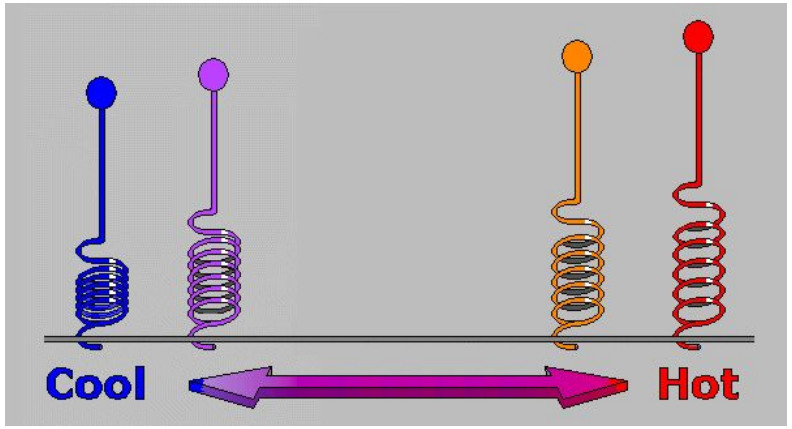
- **Actuators**: Convert a signal into mechanical movement.



Electric Motors

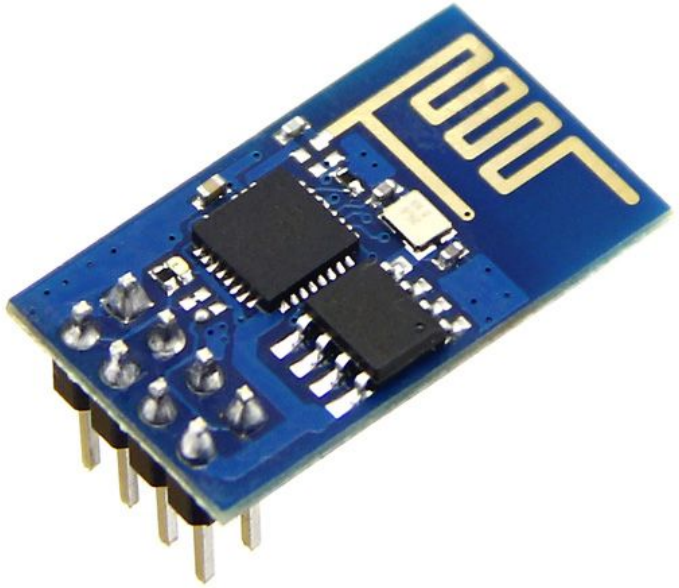
Solenoids

Shape Memory Alloys (SMAs)



Key Components of Smart Products

- **Connectivity:** Allows communication between devices

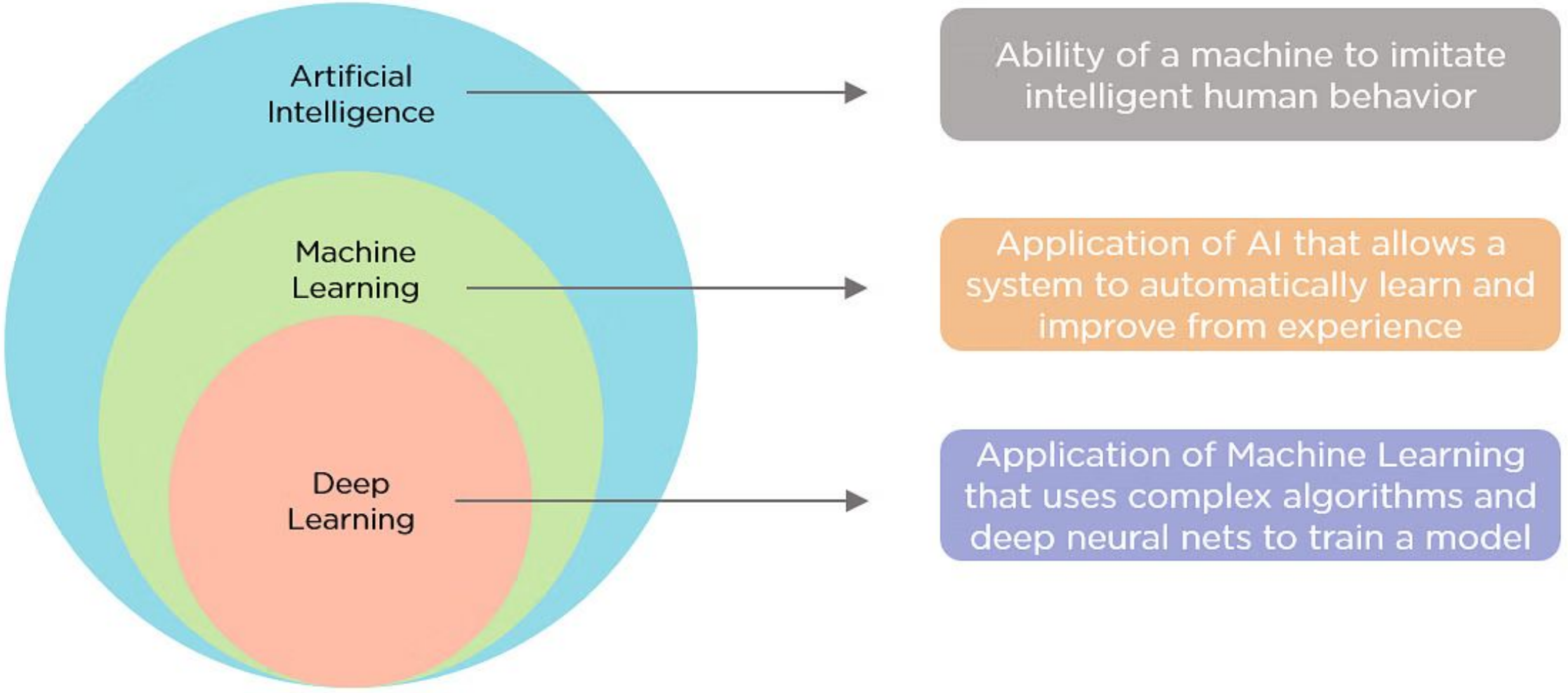


ESP8266 WiFi Module

Bluetooth Module

Key Components of Smart Products

- **Intelligence:** Software and algorithms that process data to make decisions



Key Components of Smart Products

- **User Interface (UI):** The way users interact with the product

Touchscreens

Swipe, tap, and multi-touch gestures to navigate apps
‘‘ings.

Smartphones and Tablets

Self-service kiosks

Nest thermostat for adjusting temperature

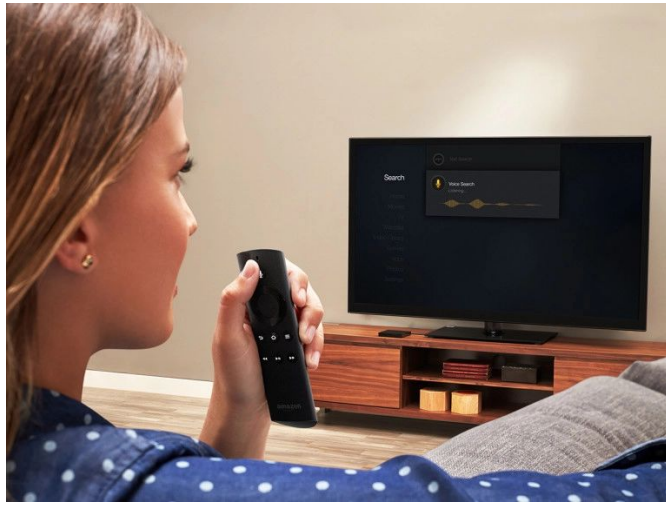
Key Components of Smart Products

- **User Interface (UI):** The way users interact with the product

Voice commands

Use hand, body, or facial gestures to interact with devices, systems, or applications

Smart Speakers
Alexa



Smart
TVs

Wearabl
es

Key Components of Smart Products

- **User Interface (UI):** The way users interact with the product

Gesture-Based UIs

Use hand, body, or facial gestures to interact with devices, systems, or applications

Smart TV

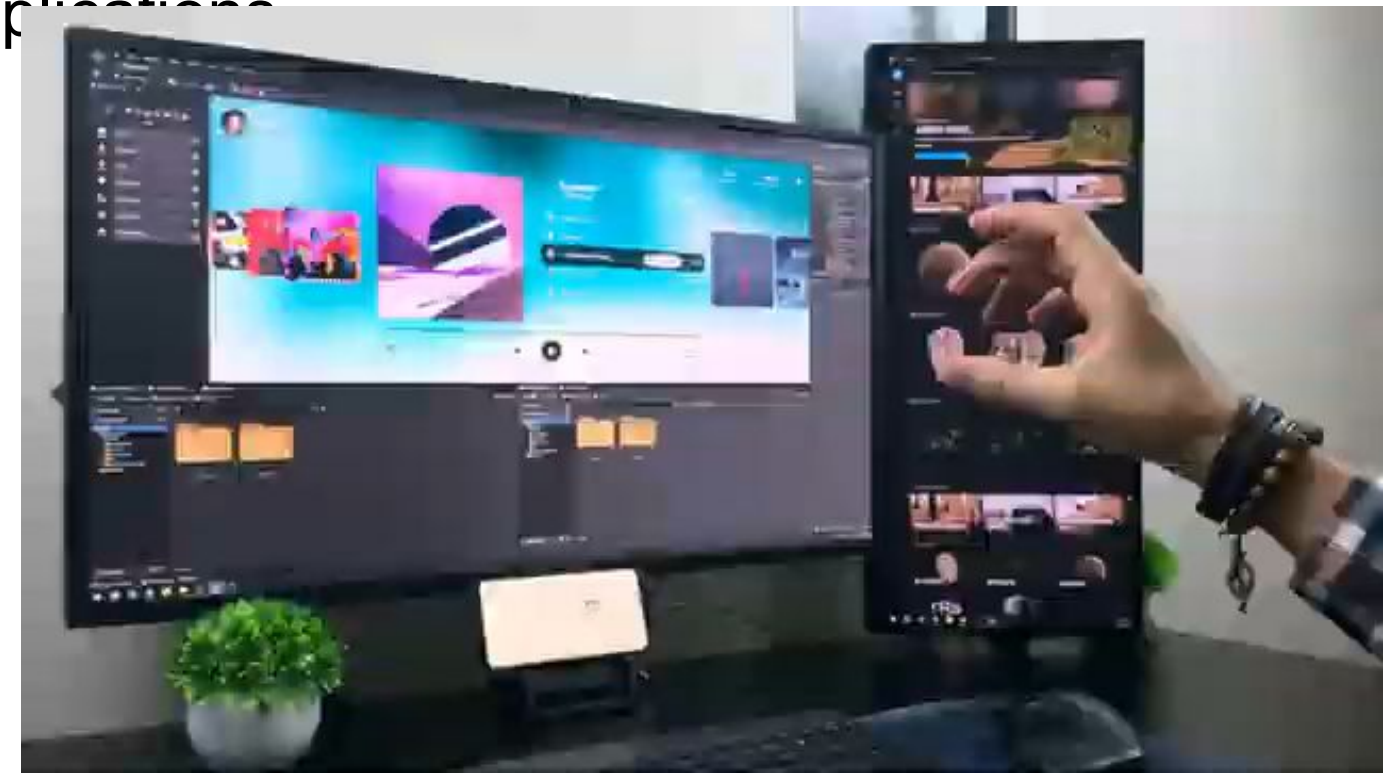
Augmented Reality Devices

Key Components of Smart Products

- **User Interface (UI):** The way users interact with the product

Gesture-Based UIs

Use hand, body, or facial gestures to interact with devices, systems, or applications



Key Components of Smart Products

- **Sensors**: Devices to collect real-world data (e.g., temperature, motion, light).
- **Actuators**: Components that enable actions (e.g., motors, lights).
- **Connectivity**: Allows communication between devices (e.g., Wi-Fi, Bluetooth).
- **Intelligence**: Software and algorithms that process data to make decisions (e.g., AI, machine learning).
- **User Interface (UI)**: The way users interact with the product (e.g., touchscreens, voice commands)

TASK 2

(20 mins)

Understand one simple system in your surroundings (follow PCP)

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Definition of Intelligence

"The ability to use memory, knowledge, experience, understanding, reasoning, imagination and judgment in order to solve problems and adapt to new situations." AllWords Dictionary, 2006

"...ability to adapt effectively to the environment, either by making a change in oneself or by changing the environment or finding a new one ...intelligence is not a single mental process, but rather a combination of many mental processes directed toward effective adaptation to the environment." Encyclopedia Britannica, 2006

"the general mental ability involved in calculating, reasoning, perceiving relationships and analogies, learning quickly, storing and retrieving information, using language fluently, classifying, generalizing, and adjusting to new situations." Columbia Encyclopedia, sixth edition, 2006

"The ability to acquire and apply knowledge and skills." Compact Oxford English Dictionary, 2006

"...the ability to adapt to the environment." World Book Encyclopedia, 2006

"The ability to learn and understand or to deal with problems." Word Central Student Dictionary, 2006

Intelligence definition

"...the ability of a system to act appropriately in an uncertain environment, where appropriate action is that which increases the probability of success, and success is the achievement of behavioral subtotals that support the system's ultimate goal." J. S. Albus [1]

"Any system ...that generates adaptive behviour to meet goals in a range of environments can be said to be intelligent." D. Fogel [10]

- Is a property that an individual agent has as it interacts with its environment or environments.
- Is related to the agent's ability to succeed or profit with respect to some goal or objective.
- Depends on how able the agent is to adapt to different objectives and environments.

"Intelligence measures an agent's ability to achieve goals in a wide range of environments." S. Legg and M. Hutter [22]

Intelligence definition

Intelligence refers to the ability to sense, process, and act on information autonomously or semi-autonomously.

Intelligence in Smart products

- **Sensing:** Gathering real-time data using sensors (e.g., temperature, motion, or pressure sensors).
- **Processing:** Analyzing the data using onboard or cloud-based computational capabilities
- **Decision-Making:** Drawing insights or predictions from the data to make informed decisions.
- **Actuation:** Executing actions or recommendations based on those decisions, often in an adaptive or automated manner.
- **Connectivity:** Communicating with other devices, systems, or users through the Internet of Things (IoT).
- **Learning:** Improving performance over time by learning from user interactions and feedback.

Assignment 1

Intelligence in a Smart Air Purifier

1. Understand the system

2. Analyze which acts and processes you consider as intelligence and why

3. Put it down on paper

Assignment 1

Intelligence in a Smart Doorbell with Camera

1. Understand the system

2. Analyze which acts and processes you consider as intelligence and why

3. Put it down on paper

Assignment 1

Intelligence in a Robot Vacuum Cleaner

1. Understand the system

2. Analyze which acts and processes you consider as intelligence and why

3. Put it down on paper

Intelligence in a Smart Air Purifier

Inputs (Cause)

Sensor Readings: 120 µg/m³ (poor air quality).

External Data: Weather app forecasts high pollution levels

Suitable Decision

Air quality > 100 µg/m³: Operate at high speed temporarily, then reduce to medium speed once levels drop below a threshold.

Feedback: Notify the user about the operation via a smartphone app and suggest keeping doors closed for better efficiency.

Outcome

Improved air quality with minimal energy

User satisfaction

Intelligence in a Smart Doorbell with Camera

Inputs (Cause)

Motion Detection: Sensors identify movement

A person, object (package), Environmental factors (leaves).

Suitable Decision

Visitor Detected Notify the user with a live feed and allow interaction through two-way audio

Package Delivered Notify the user and offer an option to save the video or share instructions with the delivery person.

Suspicious Behavior Notify the user and activate deterrent features like lights or alarms.

Outcome

Enhanced Security: Prevents theft or unauthorized access

User Convenience: Provides real-time updates and remote control

Optimized Experience: Reduces false alarms through adaptive learning

Intelligence in a Robot Vacuum Cleaner

Inputs (Cause)

Obstacle Detection: Sensors (e.g., infrared, ultrasonic) detect a physical obstruction.

Surface Analysis: The system identifies whether the area has been cleaned sufficiently.

Suitable Decision

Temporary Obstacle (e.g., a toy): Navigate around the obstacle and continue cleaning.

Large Obstacle (chair blocking a hallway): Attempt to navigate around it. If the area remains inaccessible, notify the user.

Pet in the Cleaning Area: Wait briefly and retry cleaning the area later.

Outcome

Efficiency: The robot ensures most of the space is cleaned without interruptions.

User Convenience: Reduces the need for manual intervention

TASK 2

A “**context**” driven “**creative process”** of developing the **objects/systems/products**::

“Context” (conditions/constraints) – User centric/ human centric / environment centric”

Design & Document the **15** features / functionalities you can define in the “system of your project” using the definition of intelligence.

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Classification of intelligent Products

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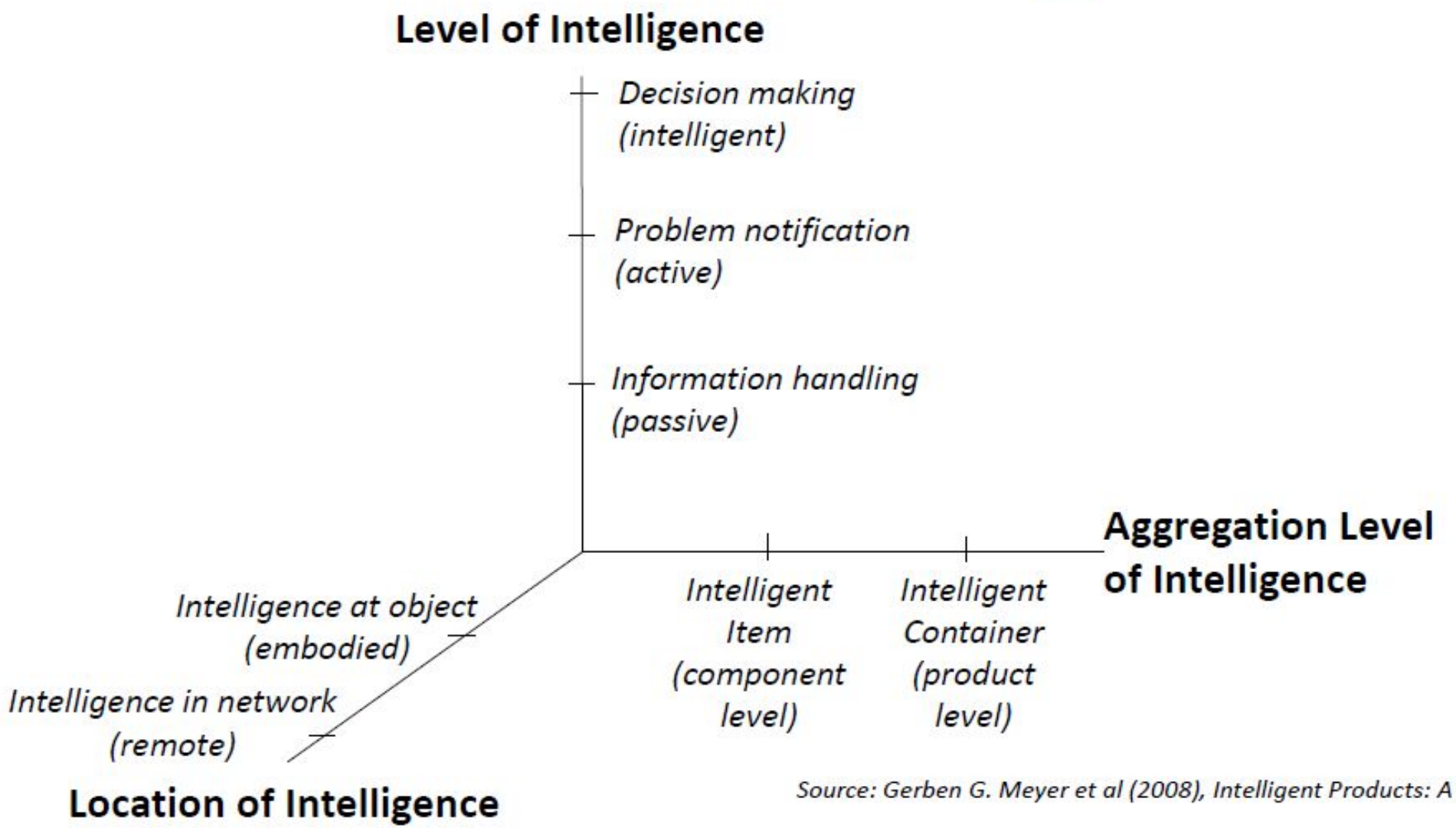
Classification of intelligent Products



Source: Gerben G. Meyer et al (2008), Intelligent Products: A survey

Classification of intelligent Products

Classification of Intelligent products based on their level of intelligence

- **Information Handling Products**
- **Problem Notification Products**
- **Decision-Making Products**

Classification of Intelligent products based on their aggregation level

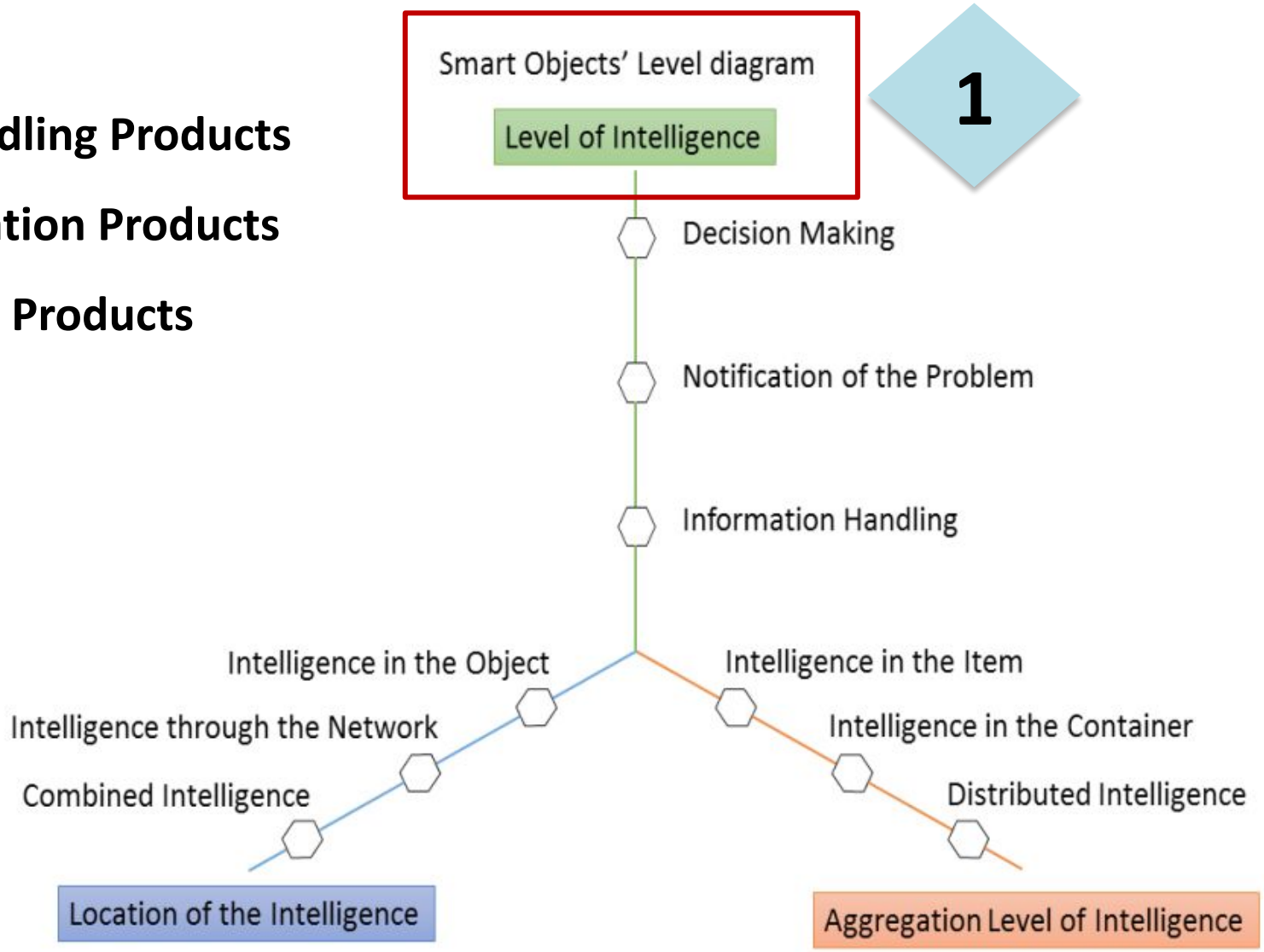
- **Intelligent Item (Component Level)**
- **Intelligent Container (Product/System Level)**

Classification of Intelligent products based on location of intelligence

- **Intelligence in Object (Embodied Intelligence)**
- **Intelligence in Network (Remote Intelligence)**

Classification of Intelligent products based on their level of intelligence

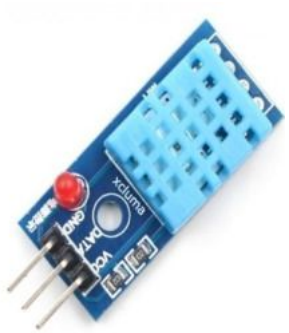
- **Information Handling Products**
- **Problem Notification Products**
- **Decision-Making Products**



Classification of Intelligent products based on their level of intelligence

Information Handling Products (Basic Intelligence)

- **Characteristics**
  - **Collect and present information**
  - **Do not interpret or make decisions**
  - **Require human intervention for further action.**



Temperature sensors

Motion Detection Sensor

Classification of Intelligent products based on their level of intelligence

Problem Notification Products (Intermediate Intelligence)

- **Characteristics**
  - **Detect anomalies and potential issues.**
  - **Provide alerts or notifications.**
  - **Require user intervention for resolution.**

Smoke detectors

Classification of Intelligent products based on their level of intelligence

Problem Notification Products (Intermediate Intelligence)

- **Characteristics**
  - **Detect anomalies and potential issues.**
  - **Provide alerts or notifications.**
  - **Require user intervention for resolution.**

Gas leak sensors

Classification of Intelligent products based on their level of intelligence

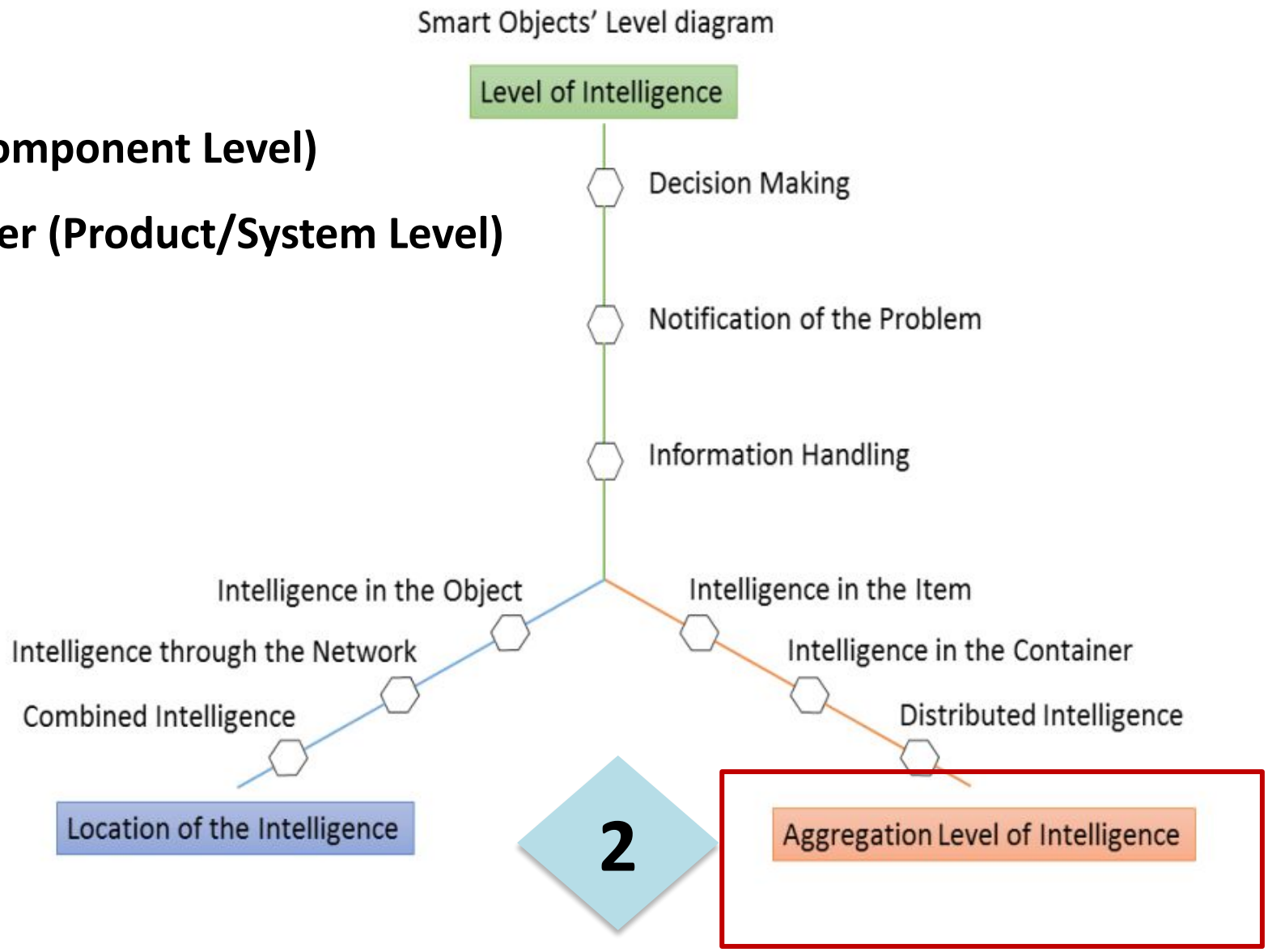
Decision-Making Products (Advanced Intelligence)

- **Characteristics**
  - **Process data and make independent decisions.**
  - **Use AI and machine learning algorithms.**
  - **Reduce human involvement in routine tasks.**

Autonomous Vehicles: Self-driving cars

Classification of Intelligent products based on their aggregation level

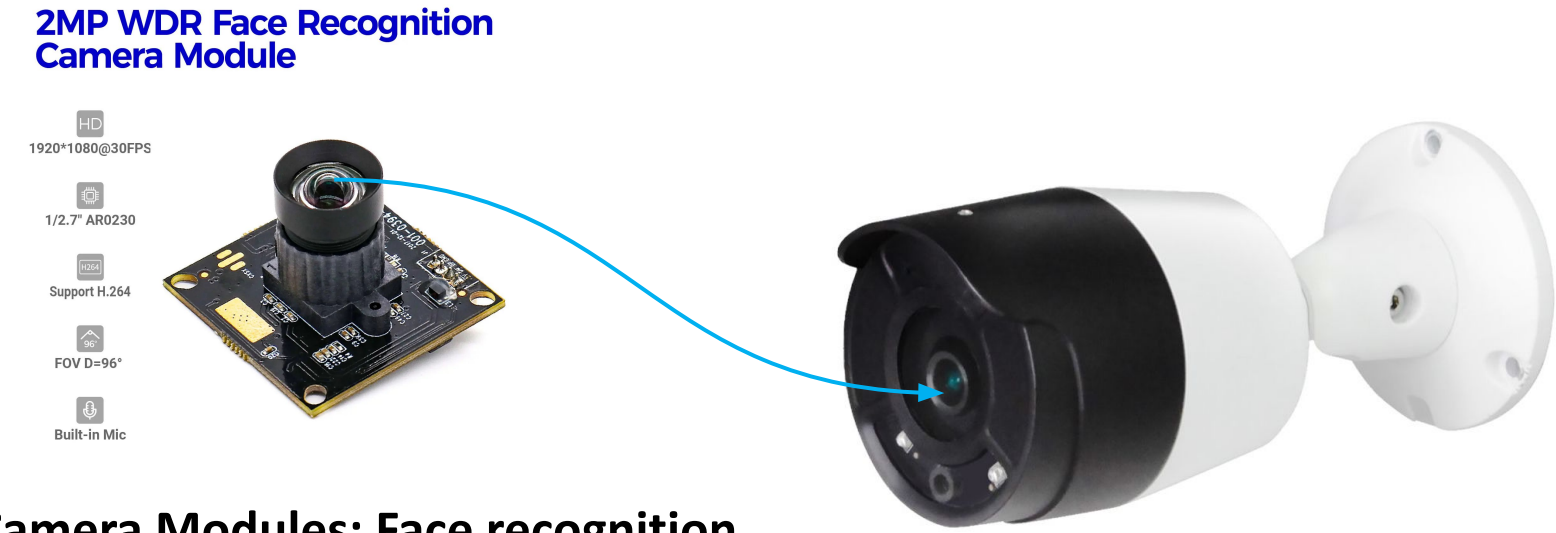
- **Intelligent Item (Component Level)**
- **Intelligent Container (Product/System Level)**



Intelligent Item (Component Level)

Characteristics

- intelligence is embedded within individual components.
- The component can collect data, process information, or respond to specific inputs.
- Used to enhance the functionality of a larger system.



AI-Enabled Camera Modules: Face recognition cameras in security systems

Intelligent Container (Product/System Level)

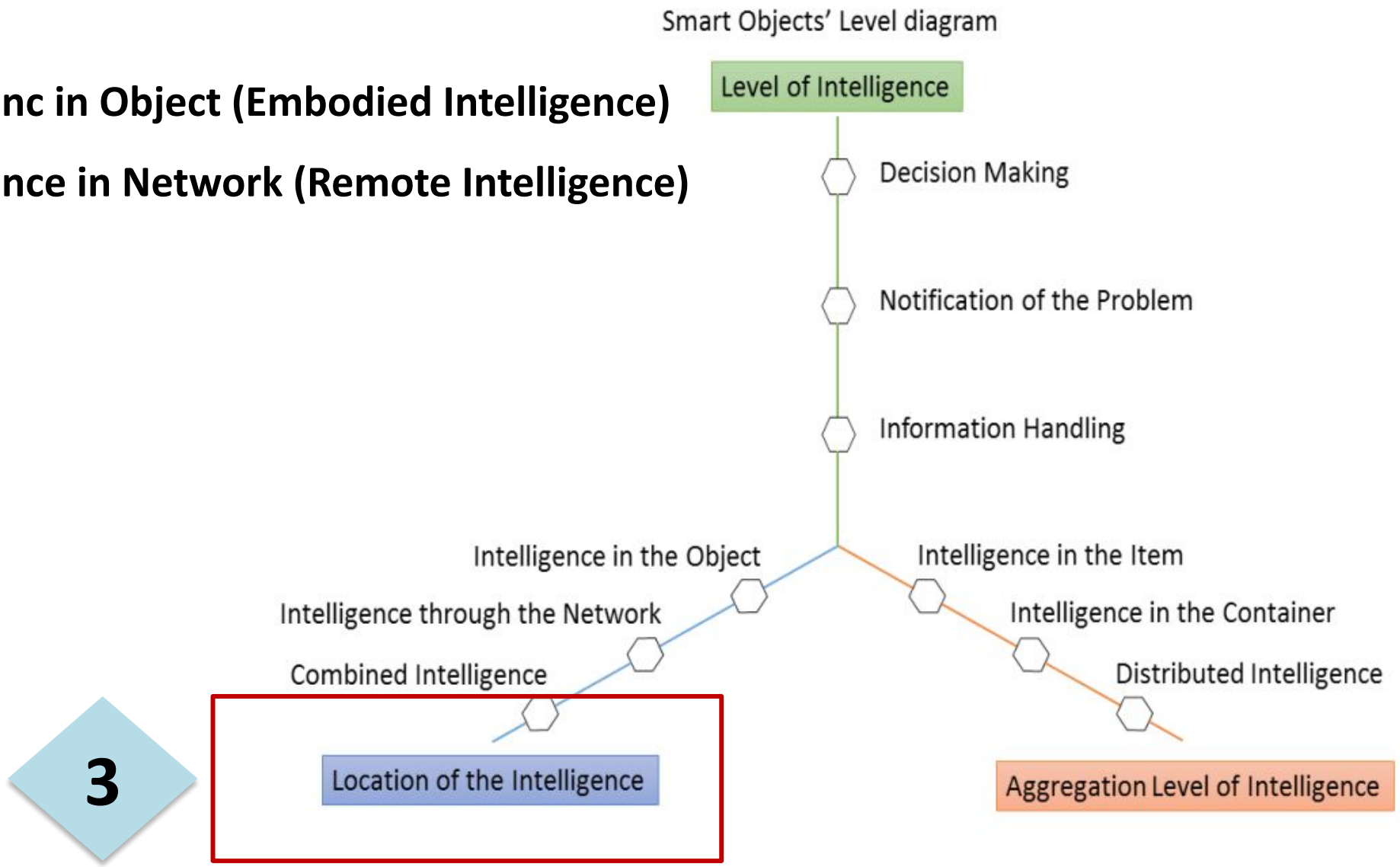
Characteristics

- **Intelligence is distributed across multiple components and integrated into a single product.**
- **The product/system operates autonomously or with minimal human intervention.**

Smart Home Automation: IoT-enabled thermostats, lighting, security, and entertainment systems working together

Classification of Intelligent products based on location of intelligence

- **Intelligenc in Object (Embodied Intelligence)**
- **Intelligence in Network (Remote Intelligence)**



Intelligence in Object (Embodied Intelligence)

Characteristics

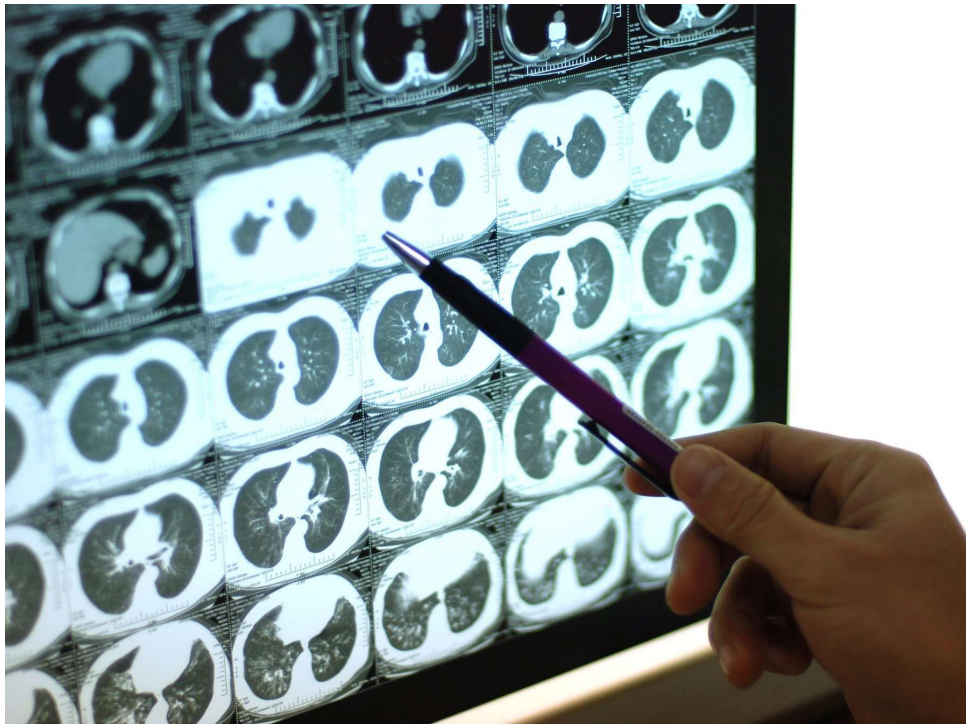
- Processing and decision-making happen locally within the device.
- The product does not require constant network connectivity.
- Fast response times with lower dependency on external systems.

Smart Wearables (Fitness trackers processing health data locally)

Intelligence in Network (Remote Intelligence)

Characteristics

- Intelligence is distributed across a network, data is processed and decisions taken remotely.
- The product relies on an external system (cloud, or central server).
- Allows remote monitoring, updates, and data synchronization.



Cloud-based AI system for analyzing medical imaging (X-rays, MRIs, CT scans) to assist radiologists

Classification of intelligent Products

Activity

Classify the 15 features of the intelligence you defined for your system /project as per different levels of intelligence. Tweak or modify the features if needed

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Features of intelligent Products

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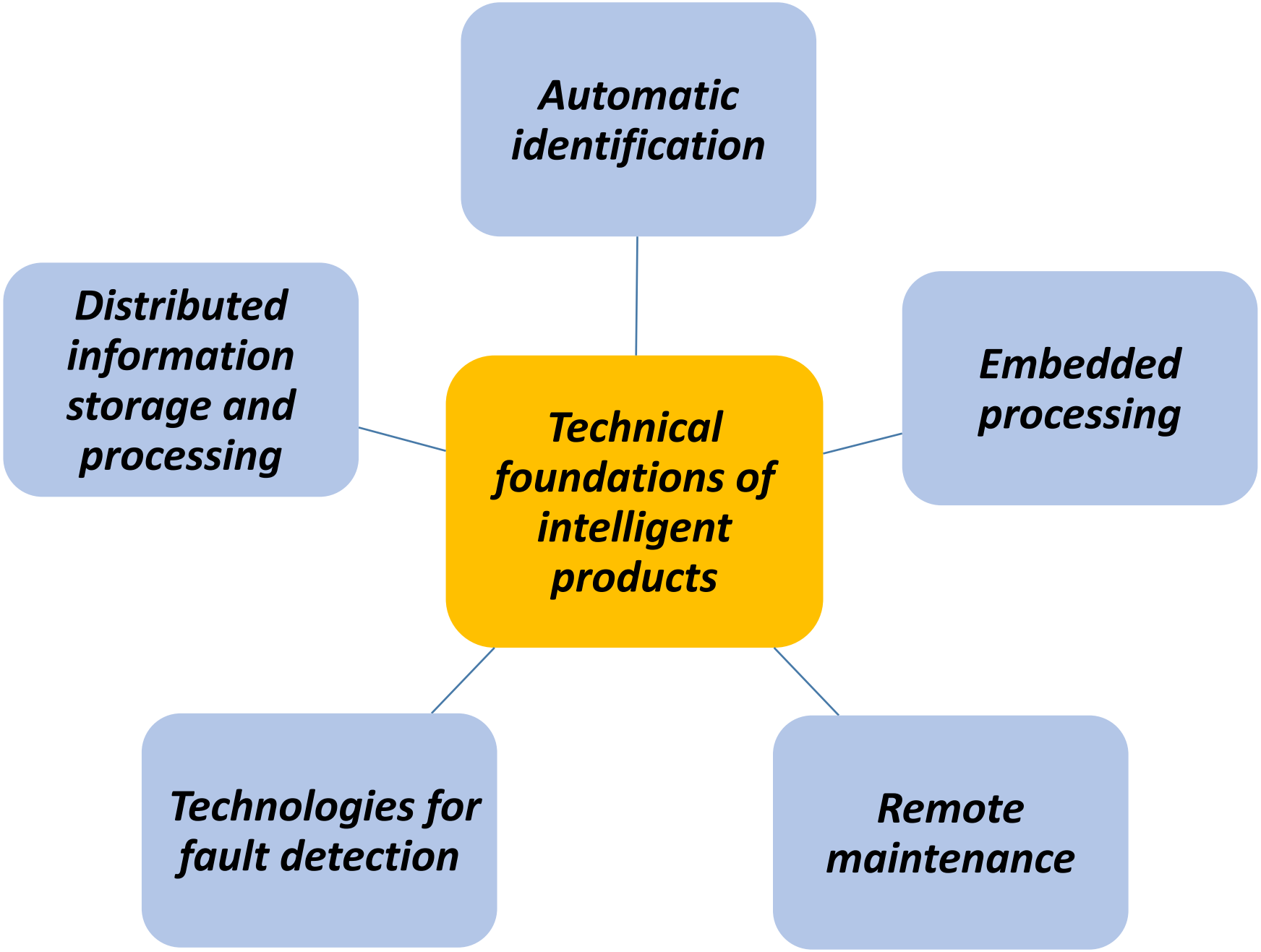
Automatic identification
Distributed information storage and processing
Technical foundations of intelligent products
Embedded processing
Technologies for fault detection
Remote maintenance

Automatic identification

- Enable intelligent products to recognize, track, and authenticate objects or users without manual input

- Examples
  - ***Radio Frequency Identification (RFID)***
  - *Barcode and QR Code Scanning*
  - *Biometric Identification*
  - *Computer Vision-Based Recognition*

RFID-based Smart Desk

Automatic identification

- Enable intelligent products to recognize, track, and authenticate objects or users without manual input

- Examples
  - *Radio Frequency Identification (RFID)*
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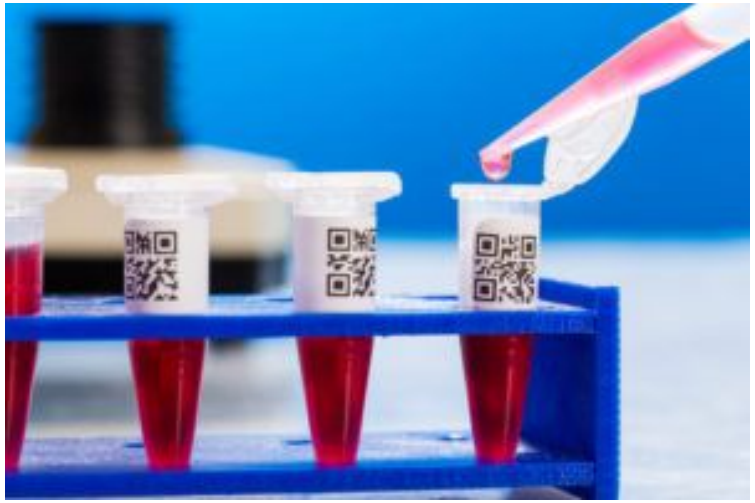

***QR-coded labels for* Blood & Sample Tracking**

Automatic identification

- Enable intelligent products to recognize, track, and authenticate objects or users without manual input

- Examples
  - *Radio Frequency Identification (RFID)*
  - *Barcode and QR Code Scanning*
  - ***Biometric Identification***
  - *Computer Vision-Based Recognition*

Wearable Biometric Devices: Smartwatches use fingerprint

Automatic identification

- Enable intelligent products to recognize, track, and authenticate objects or users without manual input

- Examples
  - *Radio Frequency Identification (RFID)*
  - *Barcode and QR Code Scanning*
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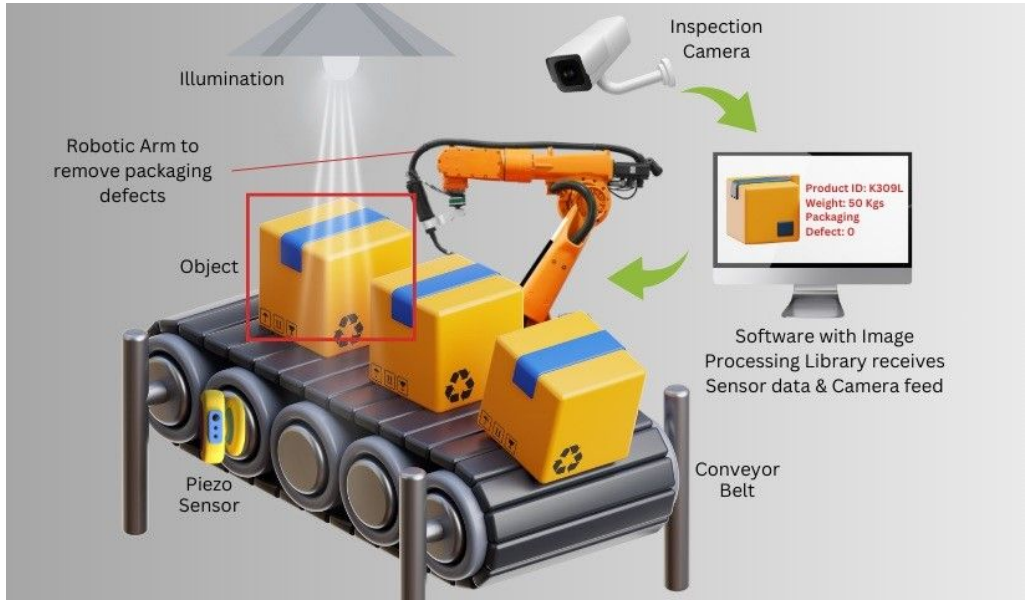
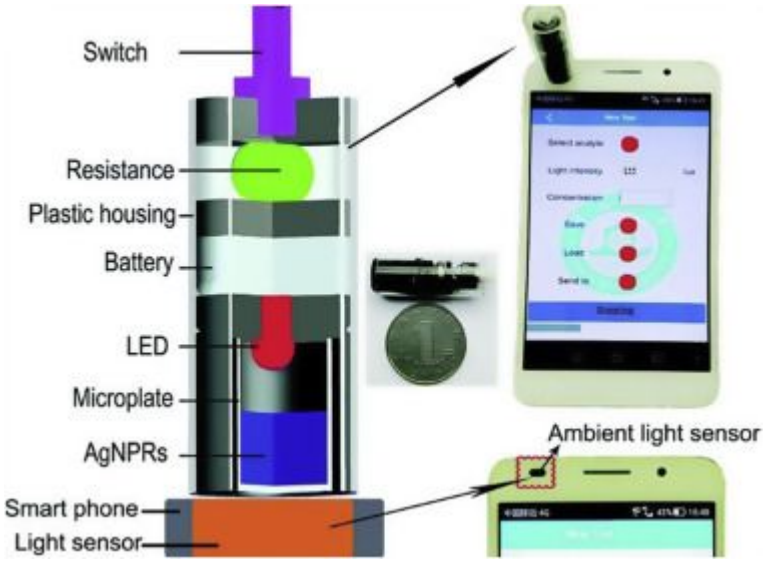


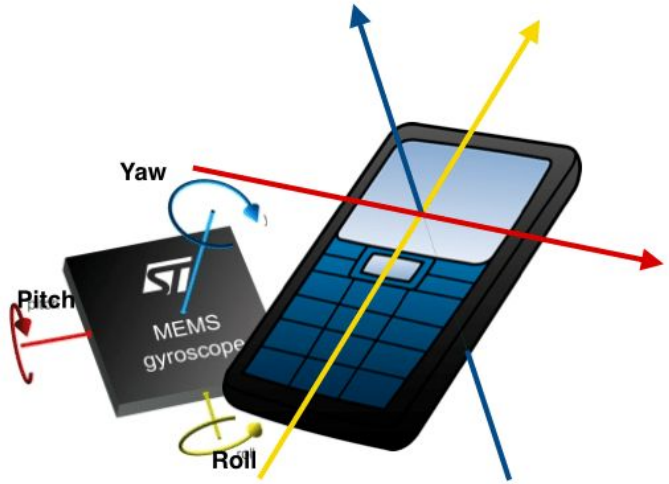
Automated Quality Control: AI-powered cameras inspect products for defects during manufacturing

Embedded processing

- Embedded processing integrates processors and sensors to enable real-time data collection, analysis, and decision-making without external computing resources.



Embedded optical sensors for smartphone auto-brightness



MEMS Accelerometer & Gyroscope (IMU - Inertial Measurement Unit) -Smartphones for screen orientation

Distributed information storage and processing

- Storing and processing data across multiple locations or systems, which are often interconnected over a network

- *Distributed File Systems (DFS)*
- *Cloud Storage*
- *Parallel Computing*
- *Cluster Computing*

Security cameras and sensors store footage both locally (on-device or hub) and in the cloud.

Enables remote access and processing of security alerts

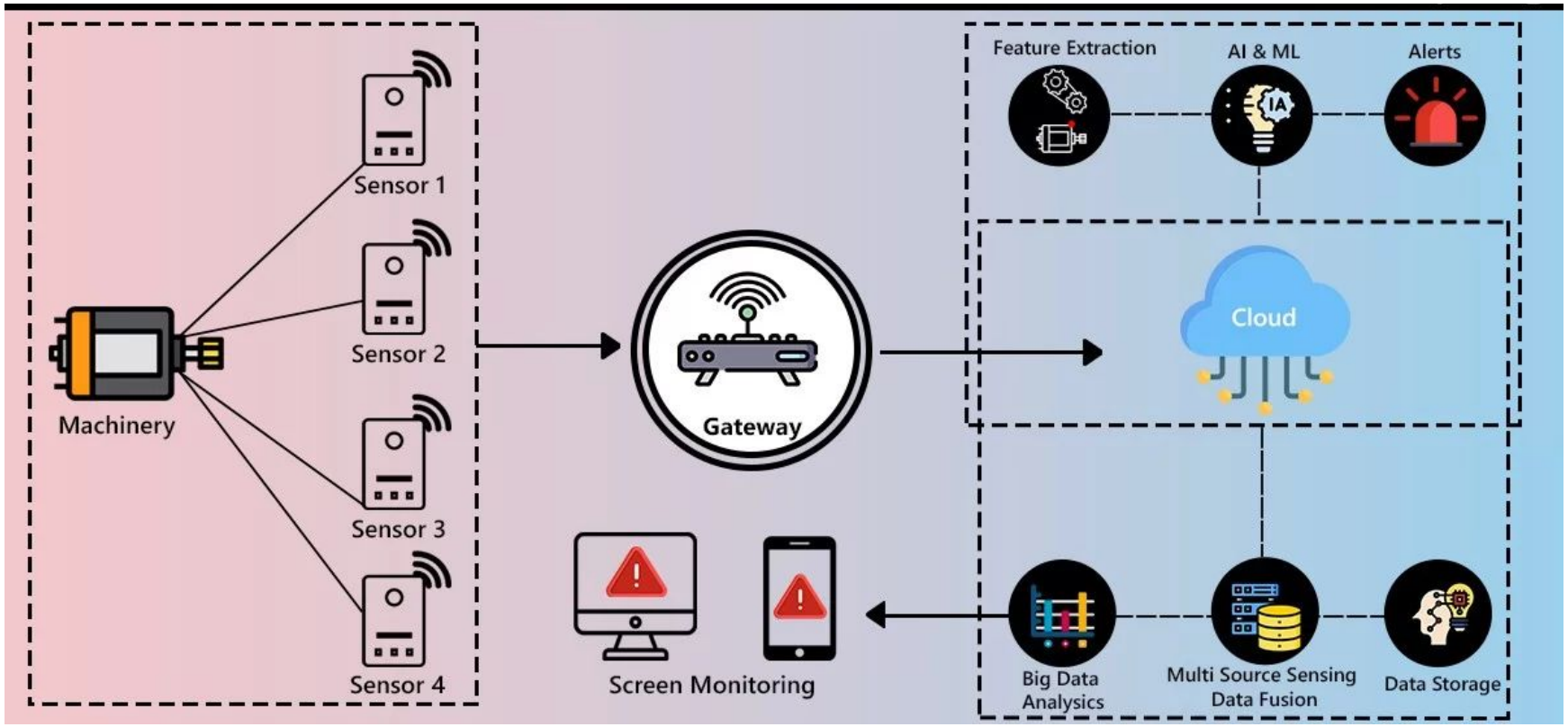
Technologies for fault detection

- Fault detection technologies improve the reliability, safety, and efficiency of systems, reducing downtime and preventing costly failures.

Self-Diagnosis Systems (Built-in Fault Detection)

Remote maintenance

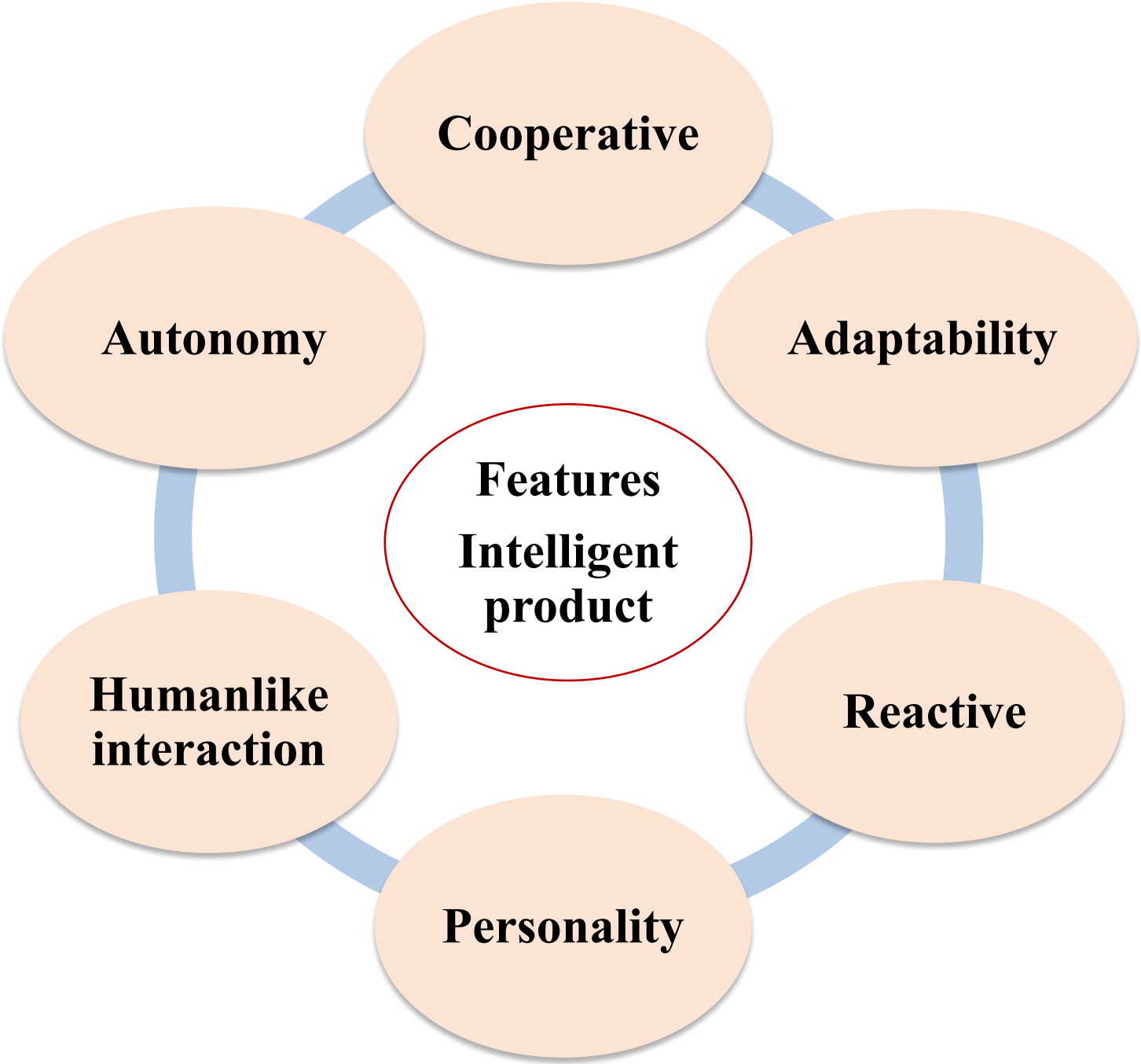
- Ability to monitor, diagnose, and perform maintenance on devices or systems from a distant location



Embedded sensors in machines collect real-time temperature, vibration, pressure, humidity, and other operational parameter

AI algorithms to detect any potential faults

Diagnose issues, schedule repairs, or update the device's software remotely, ensuring minimal downtime


Cooperative
Adaptability
Reactive
Personality
Humanlike interaction
Autonomy
Features
Intelligent product

Designing for intelligent behavior

FBS Framework in Intelligent Behavior Design

1. Function (F)

- Represents the **purpose** of the system.
- Focuses on the **goals and objectives** that the system should achieve.

2. Behavior (B)

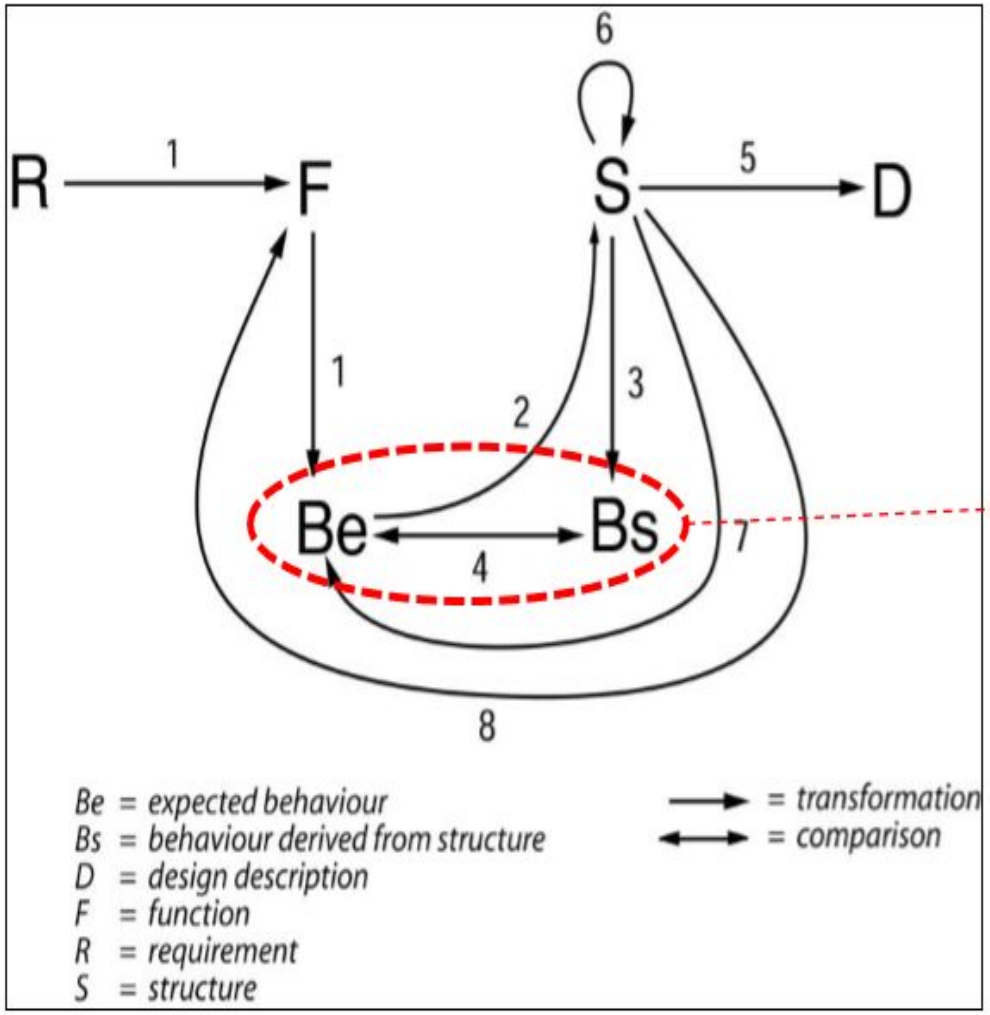
- Refers to **how the system performs its function**
- What actions, reactions, or processes the system undergoes to fulfill its purpose.
- Dynamic interaction of the system's components in response to different conditions, inputs, or environmental factors.

3. Structure (S)

- Physical components and the internal organization of the system.
- Refers to the material and technical aspects that **enable the system to operate and exhibit the intended behavior**.

Designing for intelligent behavior

FBS Framework in Intelligent Behavior Design



Intelligent behavior like any other behavior depends on function and structure

The definitions of intelligence guide us to use metaphors / analogies of human / living / natural systems for designing intelligent systems ... But, what do we hope to extract from the metaphors / analogies and how do we do it? Can they say something about F/S?

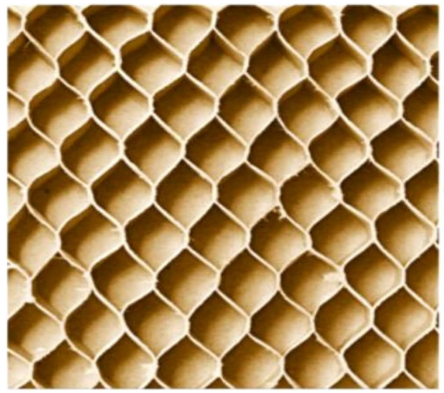
And, what is the connection between information intensity and intelligence?

Designing for intelligent behavior

FBS Framework in Intelligent Behavior Design

Structure Contributes to Functionality, Performance and Aesthetics, and User Experience

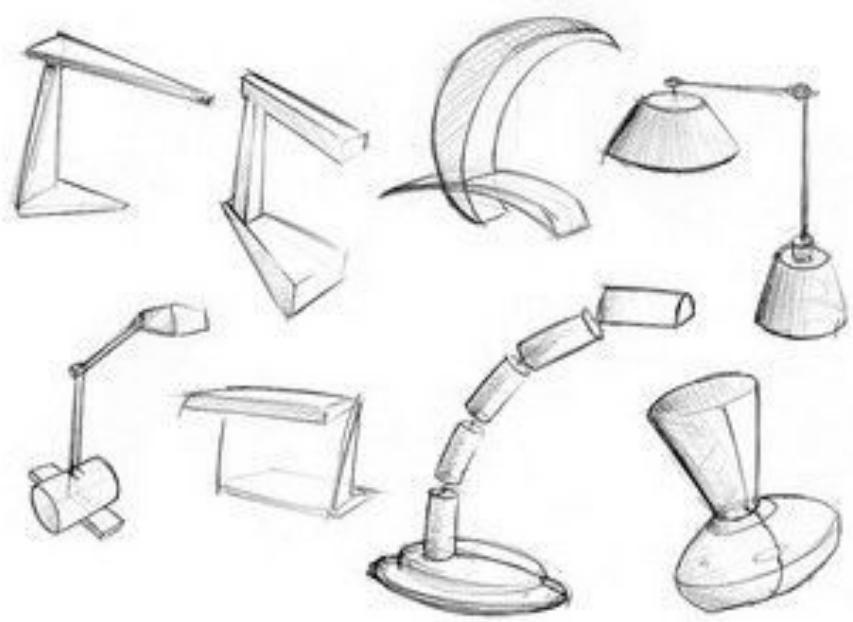
Bio-Inspired Design: Nature's Structural Intelligence



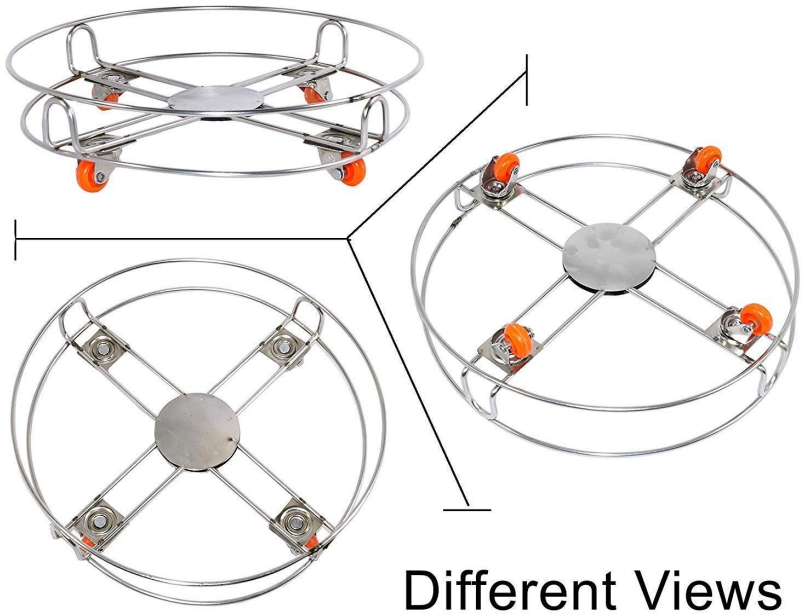
*Honeycomb structures are material-efficient, as they **maximize strength while minimizing material use**.*

*The unique geometry provides a **lightweight yet rigid structure**, which is critical for industries like aerospace and automotive.*

Ideation sketches of smart table lamp



Ideation sketches of Smart LPG Cylinder stand



Different Views

Designing for intelligent behavior

Activity 1

Ideate 15 sketches of the intelligent product for your project, each member of the team should come up with 2 sketches

Designing for intelligent behavior

Activity 2

Prepare a Bill of materials required for building the intelligent product

Smart Product Design-2025

Intelligence and Information Intensity

DS2001
Jan – May 2025

Dr. Arunachalam
Dr. Monisha Mohan

Intelligence and Information Intensity

Intelligence and Information

Intelligence is the **ability to process, analyze, and act upon information**, balancing efficiency and complexity

Intelligence and Information Intensity

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Information Intensity

The **density of information affects decision-making** and adaptation in both biological and artificial systems

Intelligence and Information Intensity

Equilibrium

A **balance between cognitive capacity and information processing** ensures optimal decision-making

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Amplification

High information intensity can enhance intelligence, but excessive data may lead to cognitive overload

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Feedback Loops

smart adaptive systems use feedback mechanisms to regulate information processing efficiency

Feedback Mechanisms

Feedback Mechanisms

↑

Positive Feedback

it occurs when a **system's output amplifies its initial input**, leading to accelerated growth or change

Feedback Mechanisms

↑

Positive Feedback

it occurs when a **system's output amplifies its initial input**, leading to accelerated growth or change

↓

Negative Feedback

it occurs when a **system's output results in a corrective action**, leading to stabilization and maintenance of equilibrium

Swarm Robots

Inspired by ants and bees, robots work together in teams for tasks like search and rescue.

Today's Team Activity - 1.1

15 minutes

Identify the Positive and Negative Feedback loops in your smart product

Examples

1. **Smart Bicycle Lock:** Uses fingerprint or phone unlocking, alerts owner if tampered, and adapts security settings
2. **Smart Bathtub:** Adjusts temperature and water levels automatically using sensors and feedback loops
3. **Smart Helmet:** Detects impacts, provides real-time alerts, and adjusts ventilation for comfort
4. **Smart Conveyor:** Adjusts speed and direction based on load, reducing energy waste and improving efficiency

Today's Team Activity - 1.2

120 minutes

1. **Finalizes the Bill of Materials (BOM)** for your new smart-product to start the prototype by next week

2. **3D modelling of concepts** for your smart-product using Rhinoceros 3D (or) Fusion 360

Smart Product Design-2025

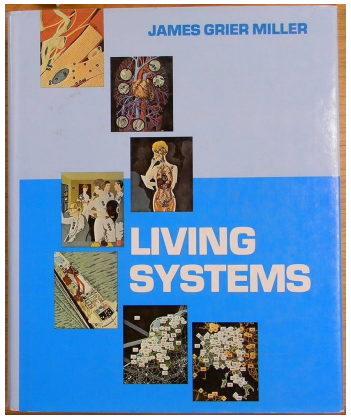
Theory of Living Systems

DS2001
Jan – May 2025

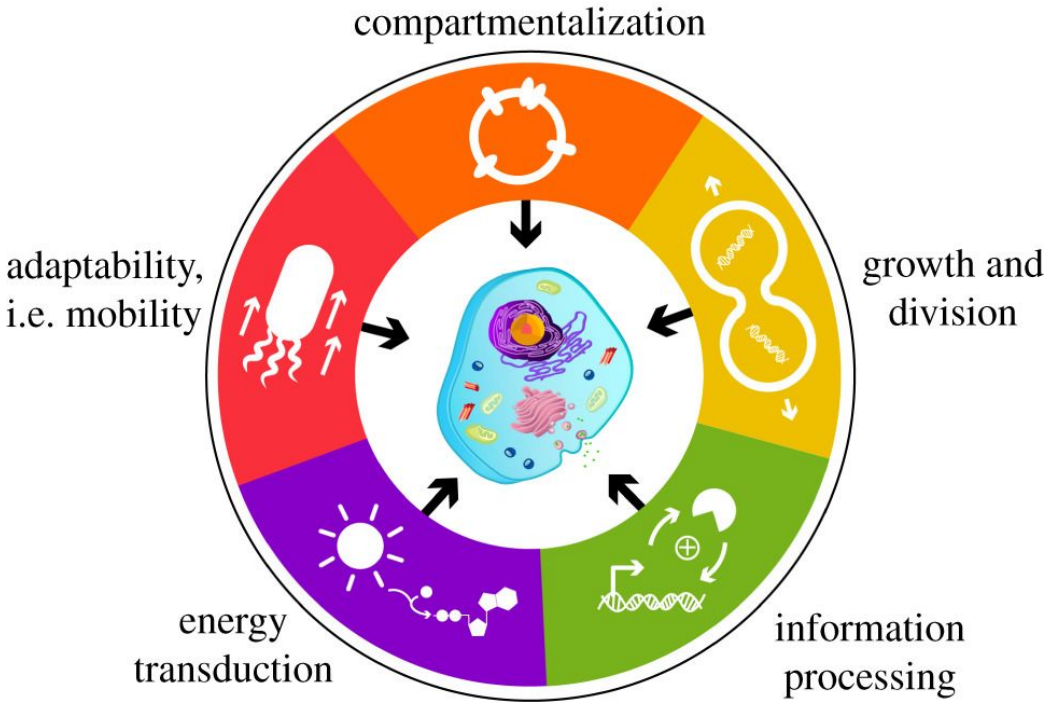
Dr. Monisha Mohan
Dr. Arunachalam

Theory of Living Systems

- **Theory of Living Systems** was developed by **James Grier Miller** in 1978.
- How all living systems ranging from cells to organisms
  - ***Function***
  - ***Interact***
  - ***Evolve***



- **In Smart product design TLS**, enables products to become ***self-aware, self-improving, and self-adaptive*** like living organisms



Core Principles of Living Systems Theory

1 *Living Systems Are Hierarchical & Multi-Level*

- Complex, dynamic entities composed of interconnected components that work together to sustain life

Atoms & Molecules → Cells → Tissues → Organs → Organ Systems → Organisms → Populations → Ecosystems → Biosphere

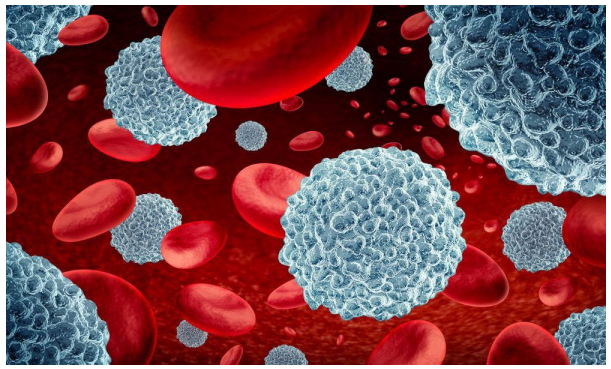
Smart Home System

Components	→ *Modules*	→ *Devices*	→ *Systems*
Sensors *Microcontrollers* *Actuators*	*Light module* *Thermostat module* *Camera module*	*Smart bulbs* *Smart thermostats* *Smart cameras*	*Home automation system integrating all smart devices*

Core Principles of Living Systems Theory

2 *Living Systems Are Self-Organizing*

- They can reconfigure their internal structure and functions in response to environmental changes.
- **Immune System** → White blood cells coordinate to detect and neutralize pathogens.



- ***Swarm Robotics: Drones or robots self-organize to complete tasks in disaster response.***

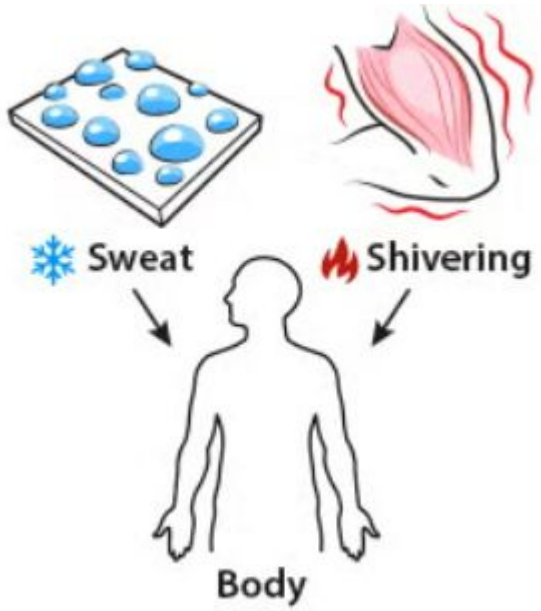
Core Principles of Living Systems Theory

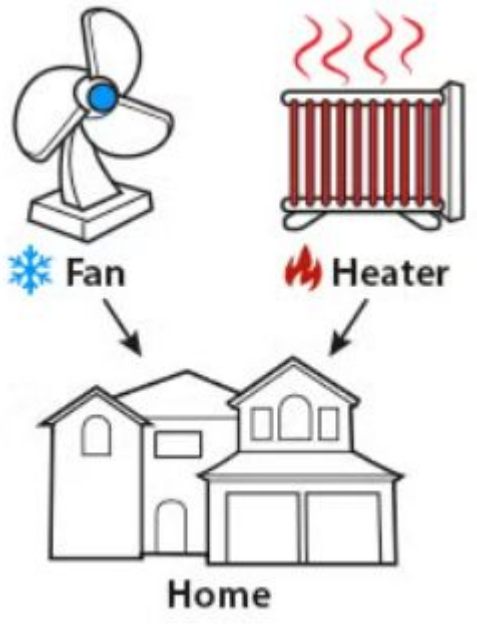
4 *Self-Regulation & Homeostasis*

- They regulate their internal state through **feedback loops** to maintain stability.

Thermoregulation in Humans: Body maintains 37°C via sweating or shivering.

Smart Thermostats: Adjusts temperature based on occupancy and weather.



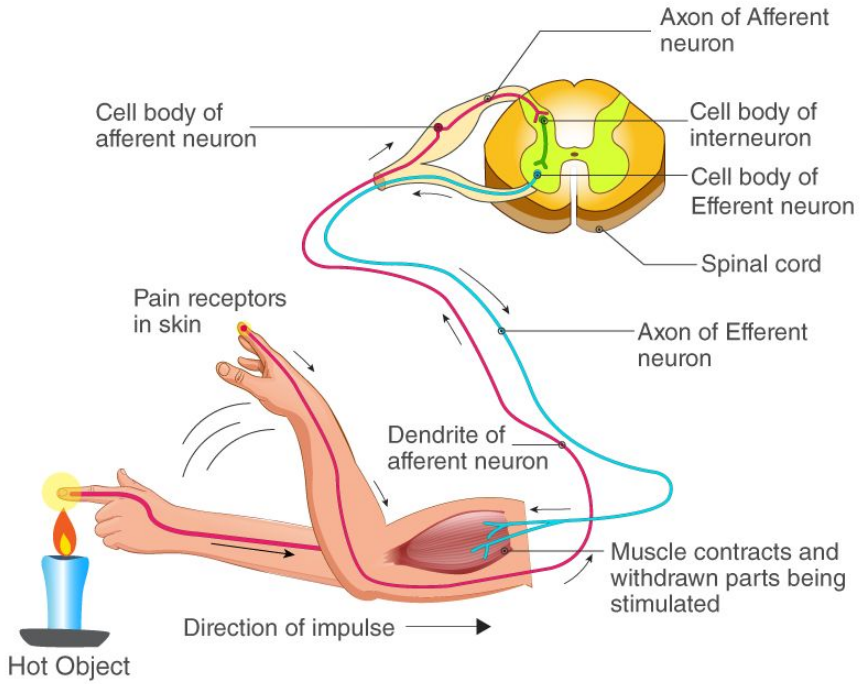


Core Principles of Living Systems Theory

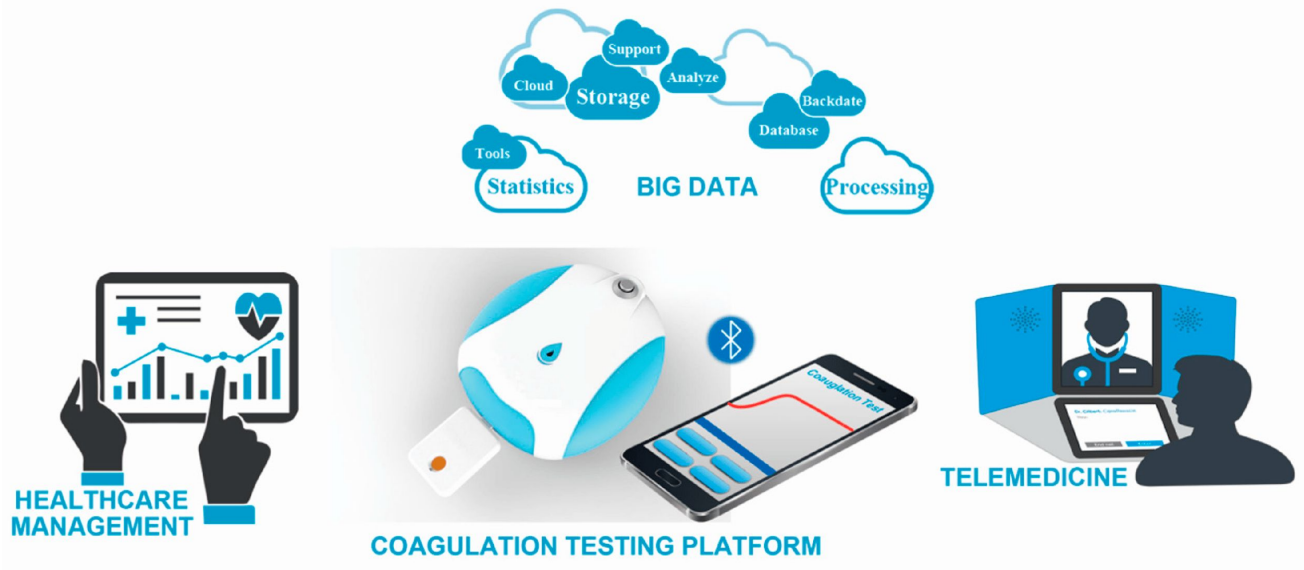
5 *Self-Awareness (Self-Organization & Autonomy)*

- A system understands its internal state and surroundings, allowing it to regulate and function autonomously.

Neural Awareness: The brain recognizes pain and moves the hand away from a hot surface



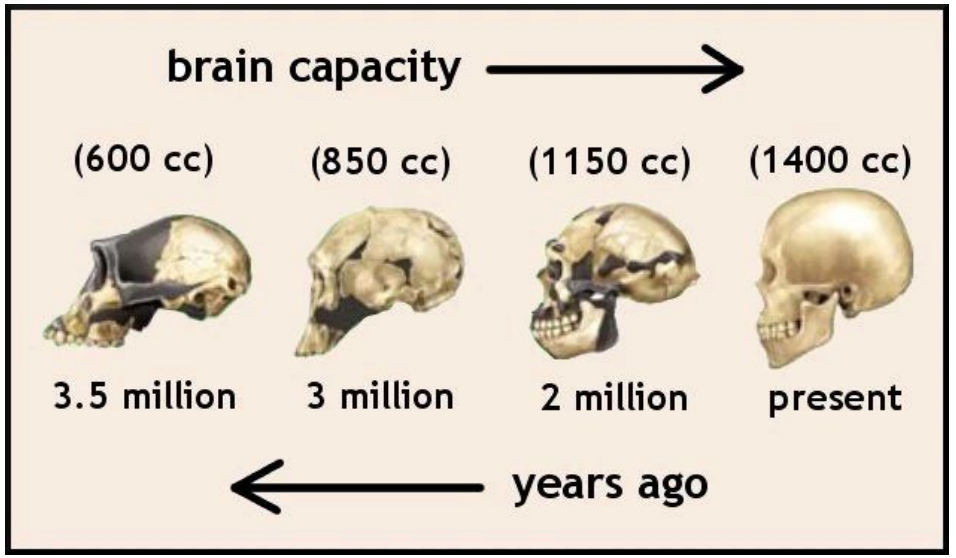
Smart Product Example: Portable Blood Clot Detector: **Analyzes real-time blood flow** and detects clot formation without human intervention.



Core Principles of Living Systems Theory

3 *Self-Evolution (Self-Configuration & Adaptation)*

- A system evolves by ***adjusting itself in response to changing environments***, improving performance over time.



Brain Growth → Over time, the human brain has increased in size, improving cognitive abilities

AI-Powered Smart Home Assistants

Learns user preferences (e.g., music, lighting, thermostat settings)

Core Principles of Living Systems Theory

3 *Self-Evolution (Self-Configuration & Adaptation)*

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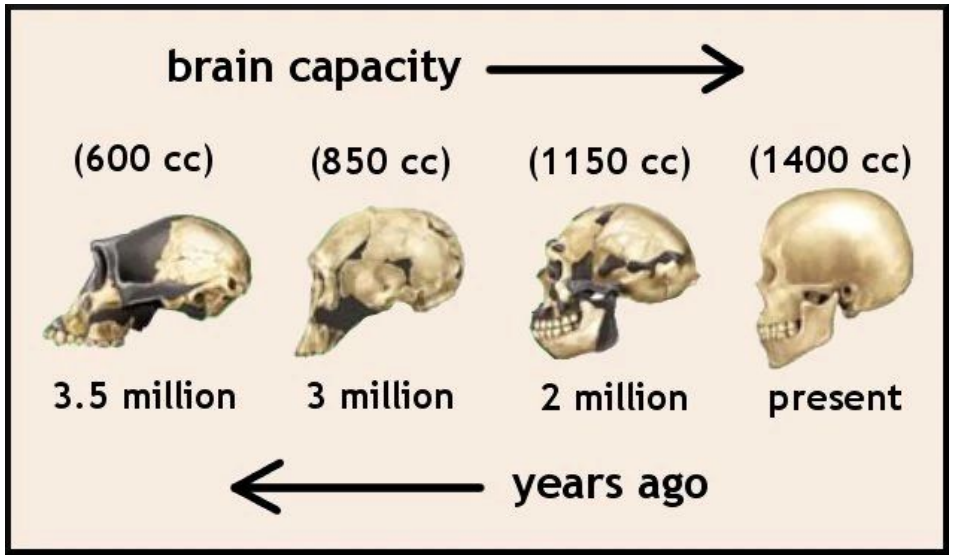


Brain Growth → Over time, the human brain has increased in size, improving cognitive abilities

Tesla Autopilot (Self-Driving Cars)

Uses **machine learning** to continuously evolve based on real-world driving data

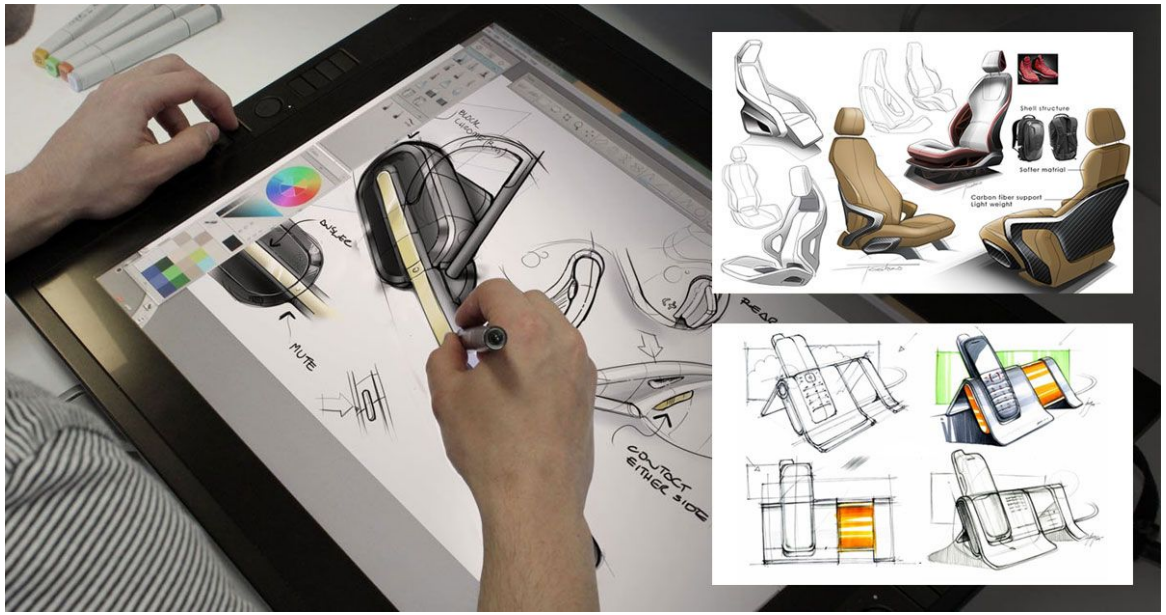
Core Principles of Living Systems Theory

By integrating **Core Principles of Living Systems Theory such as** self-evolution, self-improvement, and self-awareness, we can create truly autonomous and intelligent smart products that **adapt, learn, and optimize**.

Activity

- Finalize the Bill of Materials (BOM) for your new smart-product to start the prototype
- Complete 3D modelling of concepts for your smart-product using Rhinoceros 3D (or) Fusion 360 by today

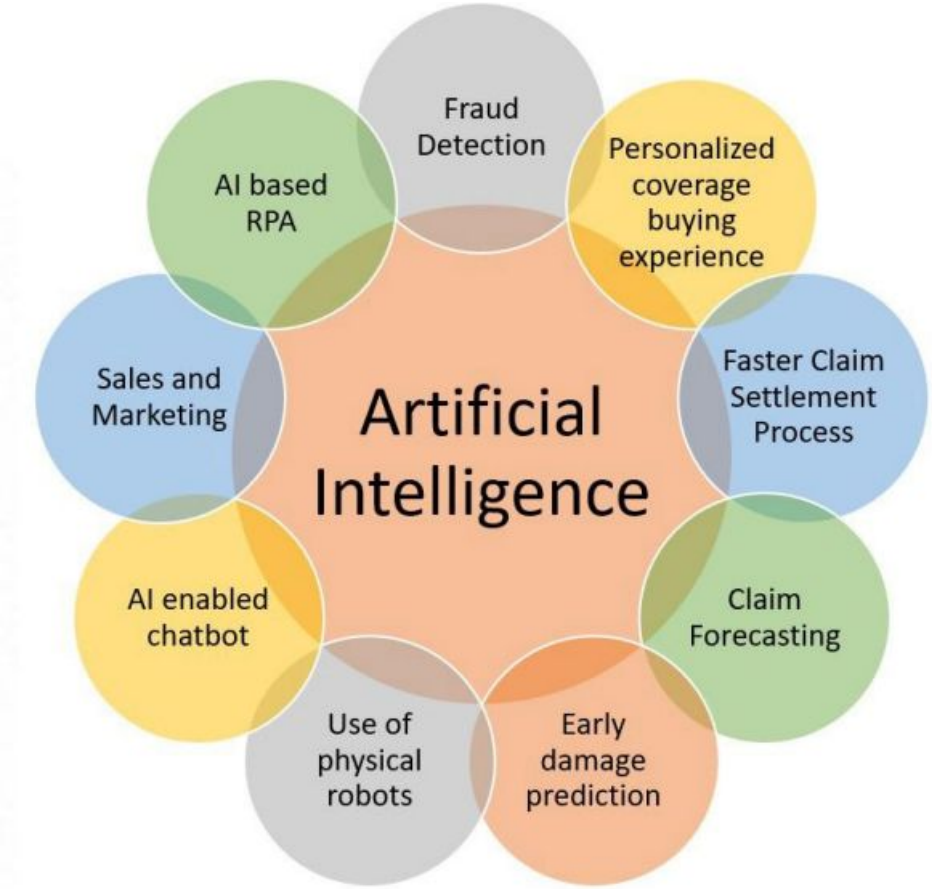
Selection of appropriate AI Techniques in smart product design



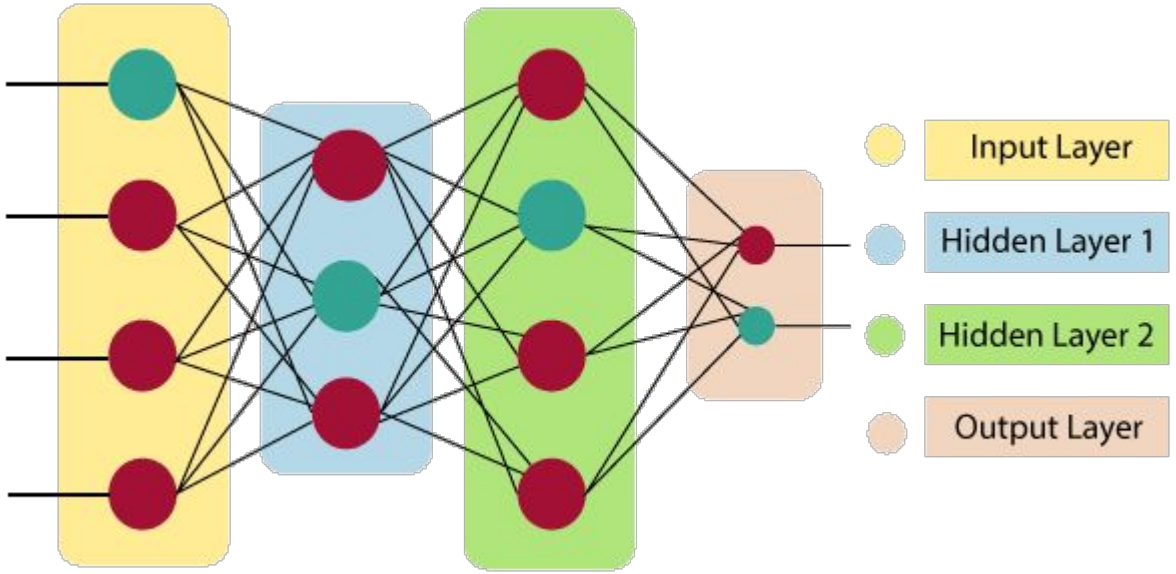
What is Artificial intelligence

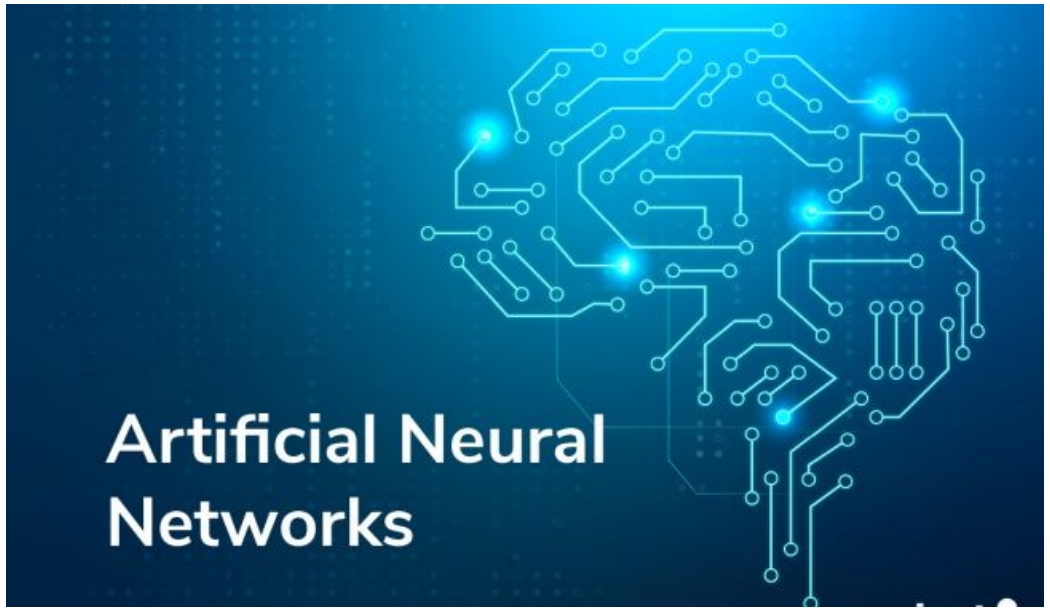
According to European Commission's 2018 definition of AI

AI refers to systems that display intelligent behavior by analyzing their environment and taking action – with some degree of autonomy – to achieve specific goals



Selection of appropriate AI Techniques in smart product design





Rule-Based System technology helps **develop knowledge-based systems and applications**, that is, **intelligent programs and software capable of providing specialized problem-solving expertise** in a specific subject by utilizing domain-specific knowledge.

In rule-based systems, knowledge is encoded in the form of

- **Facts**
- **Goals**
- **Rules is used to evaluate data.**

Rule-Based Systems

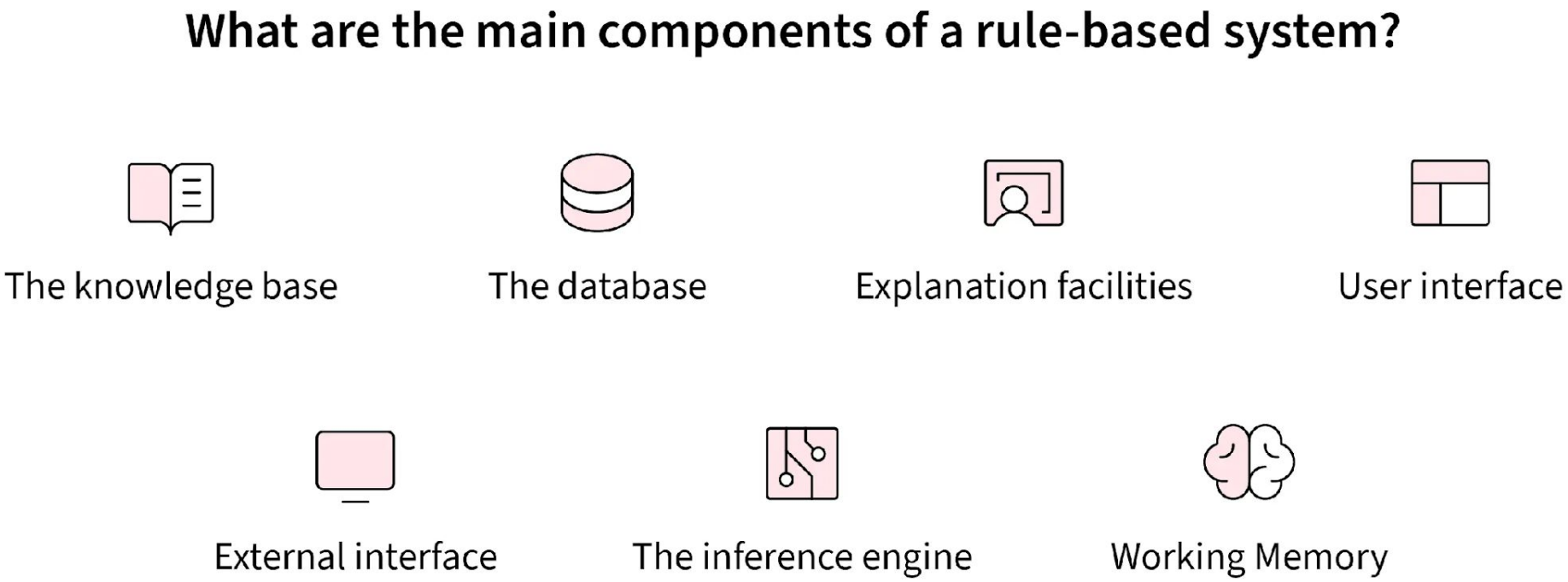
- Rule-based systems generate pre-defined outputs on the basis of a lot of rules programmed by humans.
- These rules are hardcoded into the system in the **form of if-else statements**.
- A rules-based system is built on two main components: a set of facts about a situation, and a set of rules for how to deal with those facts:

  A set of facts: Also known as the knowledge base.

  A set of rules: Also known as the rules engine. It is the rules that describe the relationship between the IF and the THEN statements.

A rule-based system

A rule-based system in AI generates an output by using **a collection of inputs and a set of rules**. The system first determines which principles apply to the inputs.

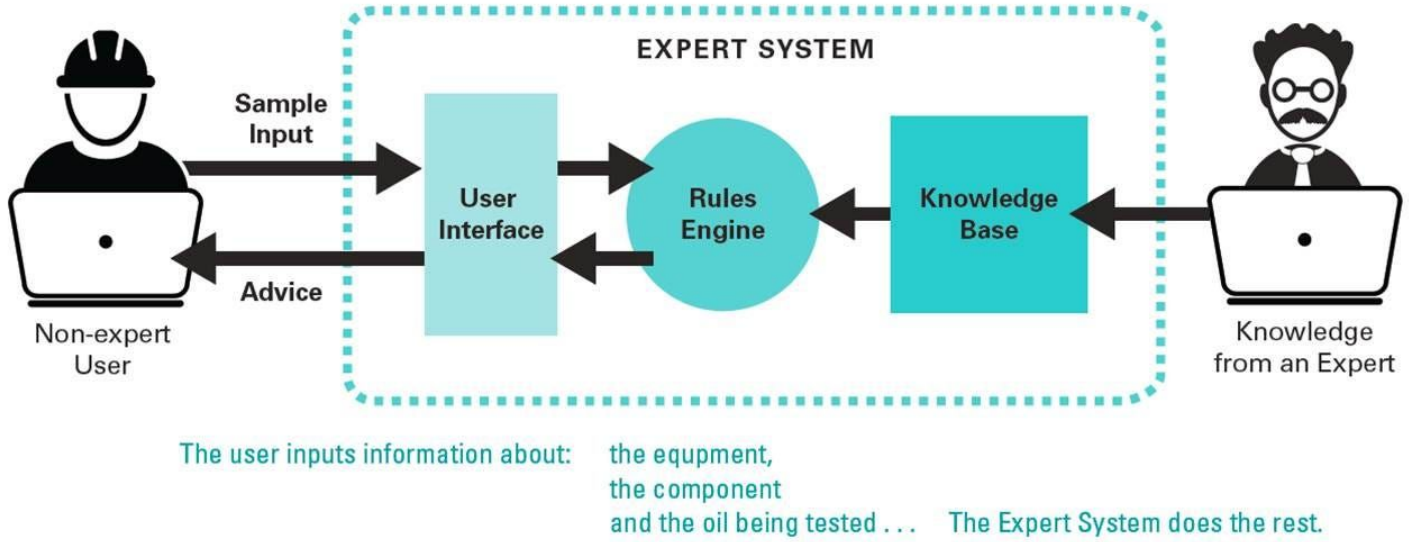


Knowledge base

- It contains the **specialized expertise required for problem-solving**.
- **Every rule has an IF (condition) THEN (action) structure**
- As soon as the condition part of the rule is satisfied, the rule gets triggered and the action part gets execute

Database

- The database contains a **collection of facts** compared to the knowledge base's rules IF (condition) clause.



The inference engine

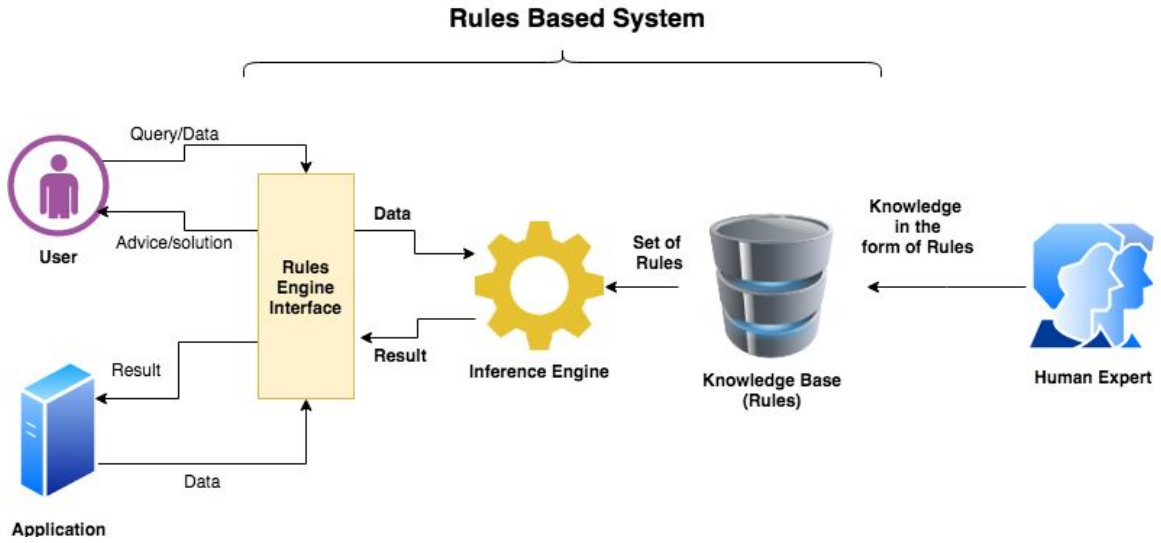
- The user interface is the **channel through which the user interacts with the expert system** to **find a solution to an issue.**
- The user interface should be as simple and intuitive as possible, and the dialogue should be as helpful and friendly as possible.

External interface

- The external interface enables an **expert system to work with external data files and programs** that are written in conventional programming languages like C, Pascal, FORTRAN and Basic

Working memory

- The working memory stores temporary information and data.



What are advantages of the rule-based system in AI?

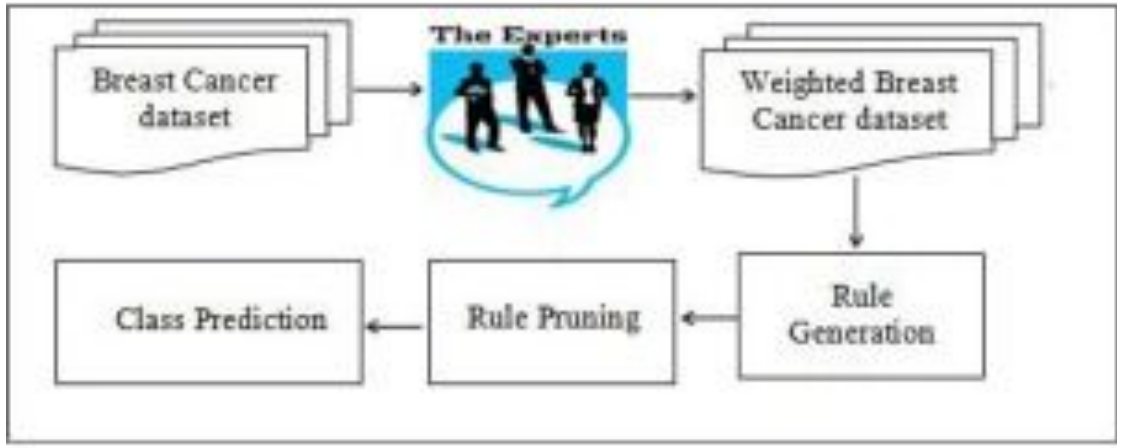
- A rule-based system is generally **cost-efficient and accurate** in terms of its results.
- The **outputs generated by the system are dependent on rules** so the output responses are stable and **not random**.
- The coverage for different circumstances is less, Rule Based system will provide **high accuracy**.
- The error rate goes down because of the **predefined rules**.
- Optimizing the speed of the system is easier as you know all the parts. So providing instant outputs, is not a big issue.

Examples of Rule-based Systems

Healthcare, finance, and engineering are just a few examples of the sectors and applications that use rule-based systems.

Medical Diagnosis

- Based on a patient's symptoms, medical history, and test findings, a rule-based system in **AI can make a diagnosis**.
- The system can make a diagnosis by adhering to a series of guidelines developed by medical professionals.



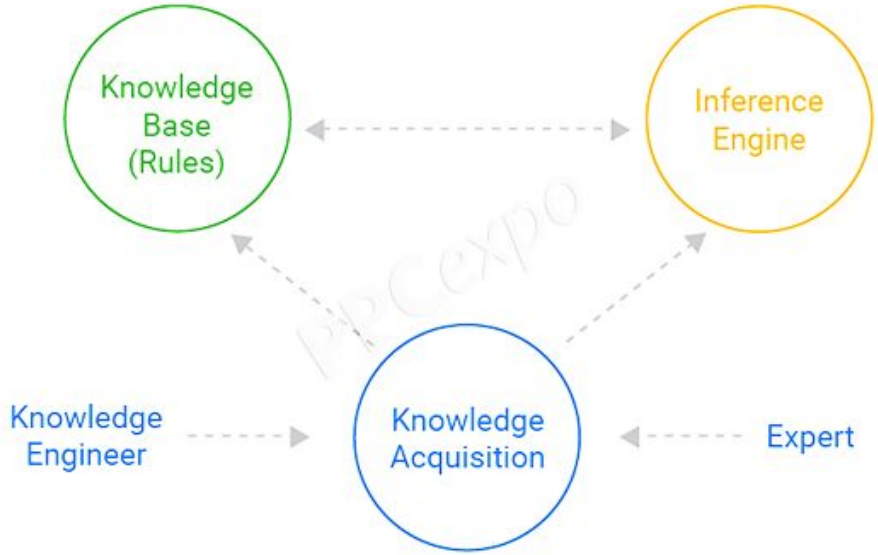
Examples of Rule-based Systems

Quality Control

- A rule-based system in AI can ensure that products satisfy particular **quality standards**.
- Based on a **set of guidelines developed by quality experts**, the system can check for flaws.

Decision support systems

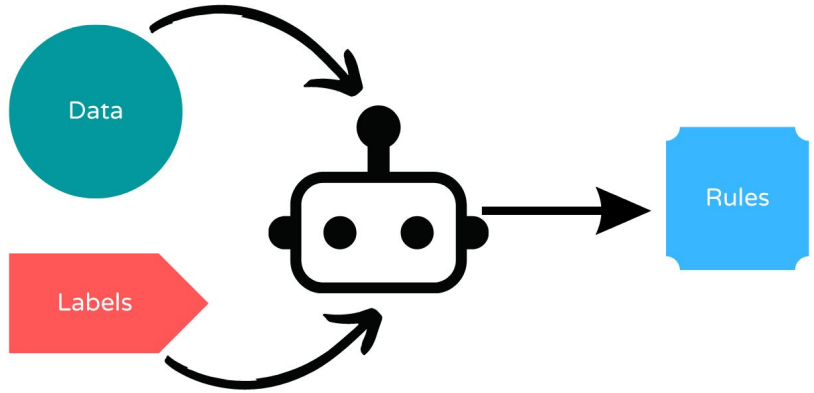
- They are created to aid decision-making, such as choosing which assets to buy or what to buy.



How to Create a Rule-based System?

- **Determine the problem**

Decide what issue needs to be resolved by a rule-based system.



- **Establish the rules**

Establish a **collection of guidelines** that can be used to address the issue.

The laws ought to be founded on professional expertise or data analysis.

- **Implement the rules**

Software tools that enable the development and administration of rule-based systems can be used for this.

- **Test and evaluate**

Verify that the rule-based system in AI operates as intended. Take stock of how it's performing and make any required modifications.

Disadvantages of Rule-based Systems in AI

- **Restricted Capabilities for Learning:**

Rule-based systems are created to function according to **predetermined rules and logical inferences**. They are incapable of **growing from mistakes or adjusting to novel circumstances**.

- **Difficulty Handling Uncertainty:**

Rule-based systems **may need more clarity or complete information**. Any **ambiguity in the data** can result in **errors or bad outcomes** because they need precise inputs and rules to make a decision.

- **Difficulty Handling Complex Interactions:**

Complicated interactions can be difficult for rule-based systems, especially when several separate rules or inputs are involved.

Assignment

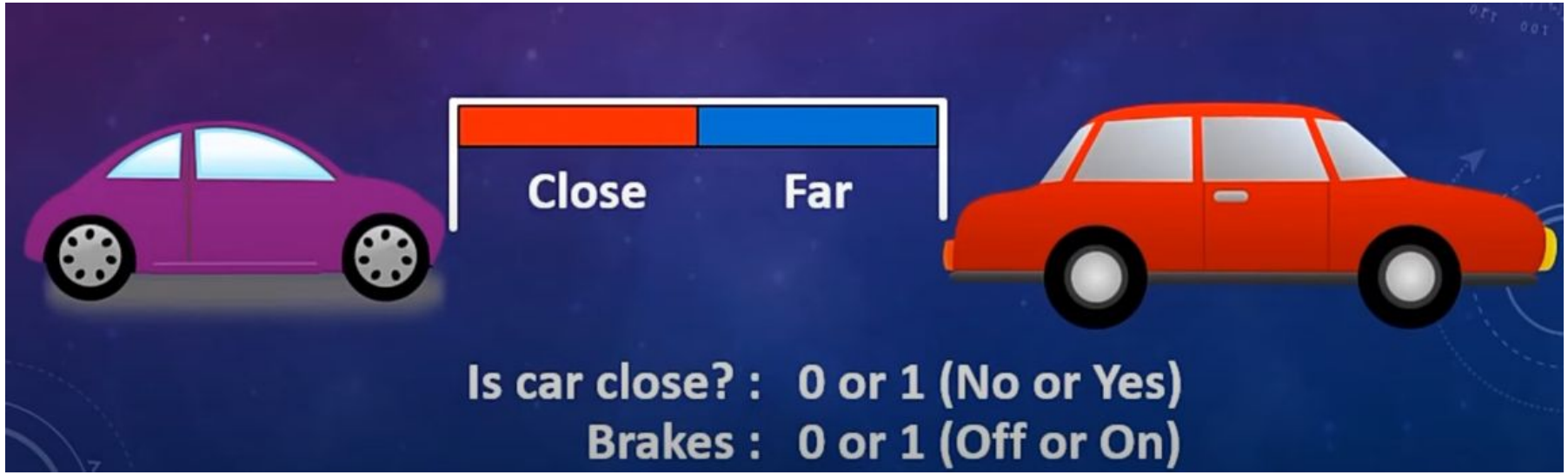
Teams have identified 15 features that are crucial for the designing the smart product. Now, based on today's session on Rule based systems, identify the features for which Rule based decision would be applicable and submit the report

Rule based Vs Fuzzy Logic?

Rule based

Fuzzy logic

Autonomous braking system



Rule based

Fuzzy logic

What is Fuzzy Logic?

- Fuzzy Logic is a computing approach based on **“Degree of Truth”** and is **not limited to Boolean “true or false.”**
- The term ‘Fuzzy’ means **something vague or not very clear**.
- The fuzzy Logic system is applied to scenarios where it is difficult to categorize states as a **binary “True or False.”** Fuzzy Logic can incorporate intermediate values like partially true and partially false.

CERTAINLY YES

POSSIBLY YES

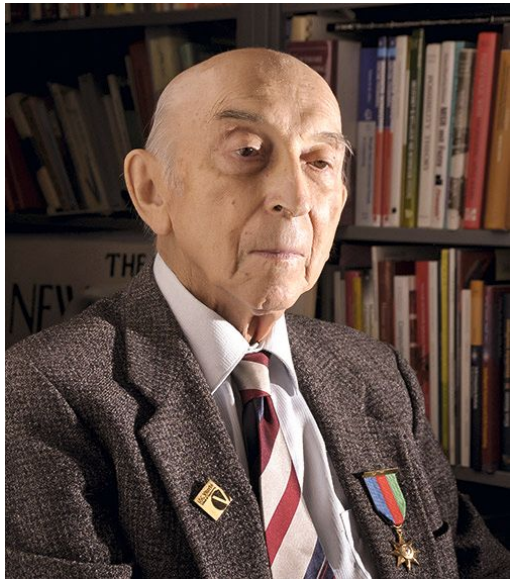
CANNOT SAY

POSSIBLY NO

CERTAINLY NO

What is Fuzzy Logic?

- Fuzzy Logic is a computing approach based on **“Degree of Truth”** and is **not limited to Boolean “true or false.”**
- The inventor of fuzzy logic, **Lotfi Zadeh**, observed that unlike computers, the human decision making includes a **range of possibilities between YES and NO**.



Implementation

- It can be implemented in **systems with various sizes and capabilities** ranging **from small micro-controllers to large, networked, workstation-based control systems.**
- It can be implemented in **hardware, software, or a combination of both.**

Why Fuzzy Logic?

- It **can control machines and consumer products**.
- Fuzzy logic helps to **deal with the uncertainty in engineering**.

Fuzzy Logic Systems Architecture

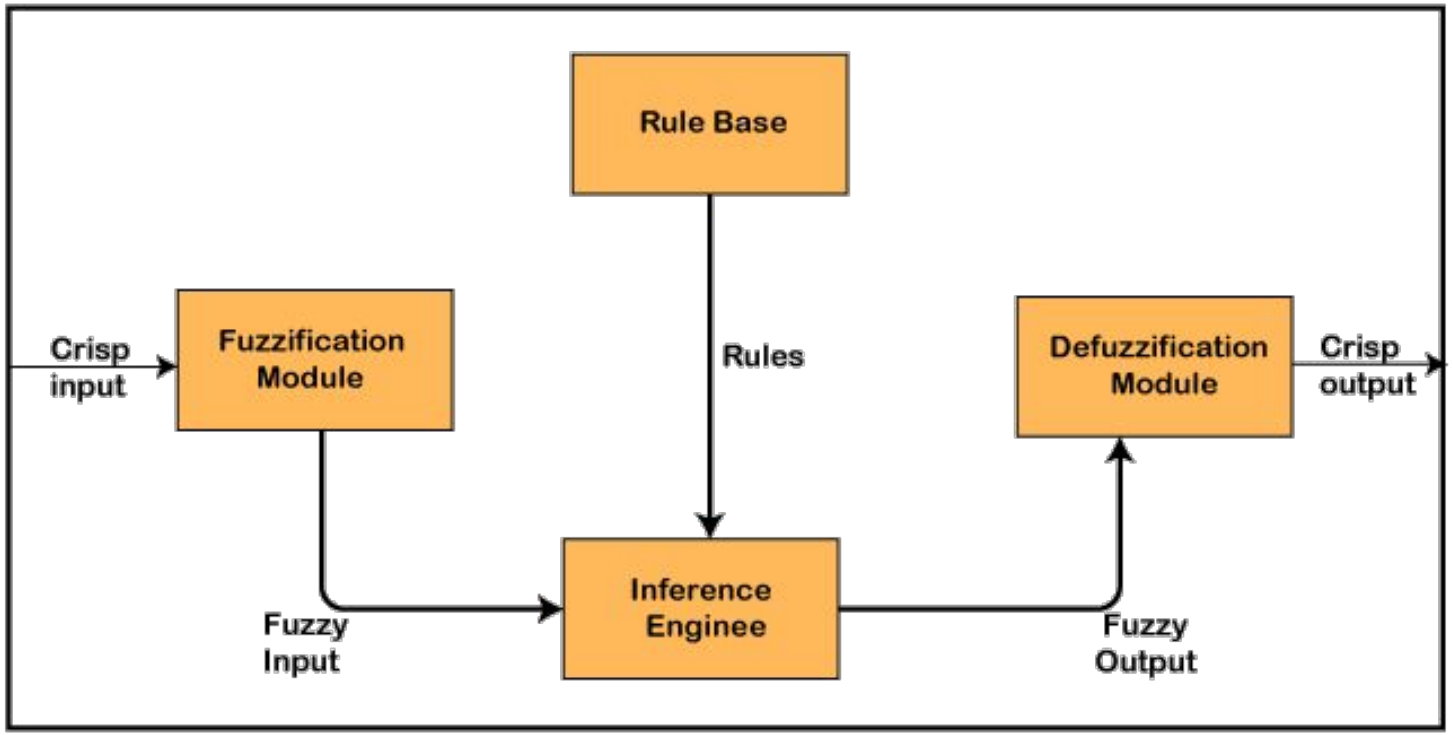
The architecture consists of the different four components which are given below.

1.Rule Base

2.Fuzzification

3.Inference Engine

4.Defuzzification



Fuzzy Logic Systems Architecture

Rule Base

- Rule Base is a component used for **storing the set of rules and the If-Then Else conditions given by the experts** are used for **controlling the decision-making systems**.
- Developments in Fuzzy Logic have **reduced the number of rules in the rule base**. These set of rules are also called a **knowledge base**.

Fuzzy Logic Systems Architecture

- **Fuzzification Module** − It transforms the **system inputs, which are crisp numbers, into fuzzy sets**. It splits the input signal into five steps such as −

LP	x is Large Positive
MP	x is Medium Positive
S	x is Small
MN	x is Medium Negative
LN	x is Large Negative

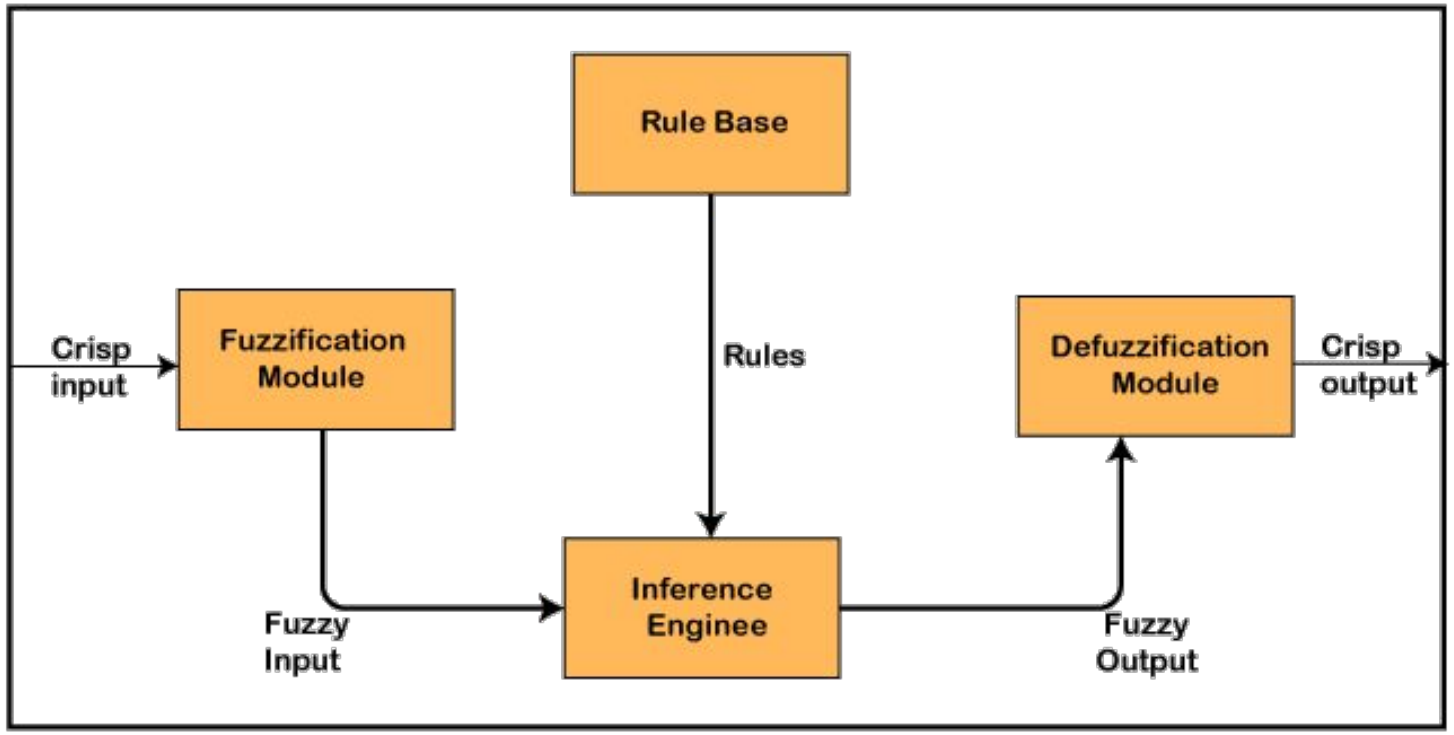
Fuzzy Logic Systems Architecture

The inference engine

- **It determines how much the input values and the rules match (**degree of match between fuzzy input and the rules)
- An inference engine cycles through three sequential steps: ***match rules*, *select rules*, and *execute rules***.
- According to the input field, it will decide the rules that are to be fired.
- **Then, the final set of rules are used to develop control actions.**
- **The inference engine and the knowledge base together are called a *Controller in a Fuzzy Logic system.***

Fuzzy Logic Systems Architecture

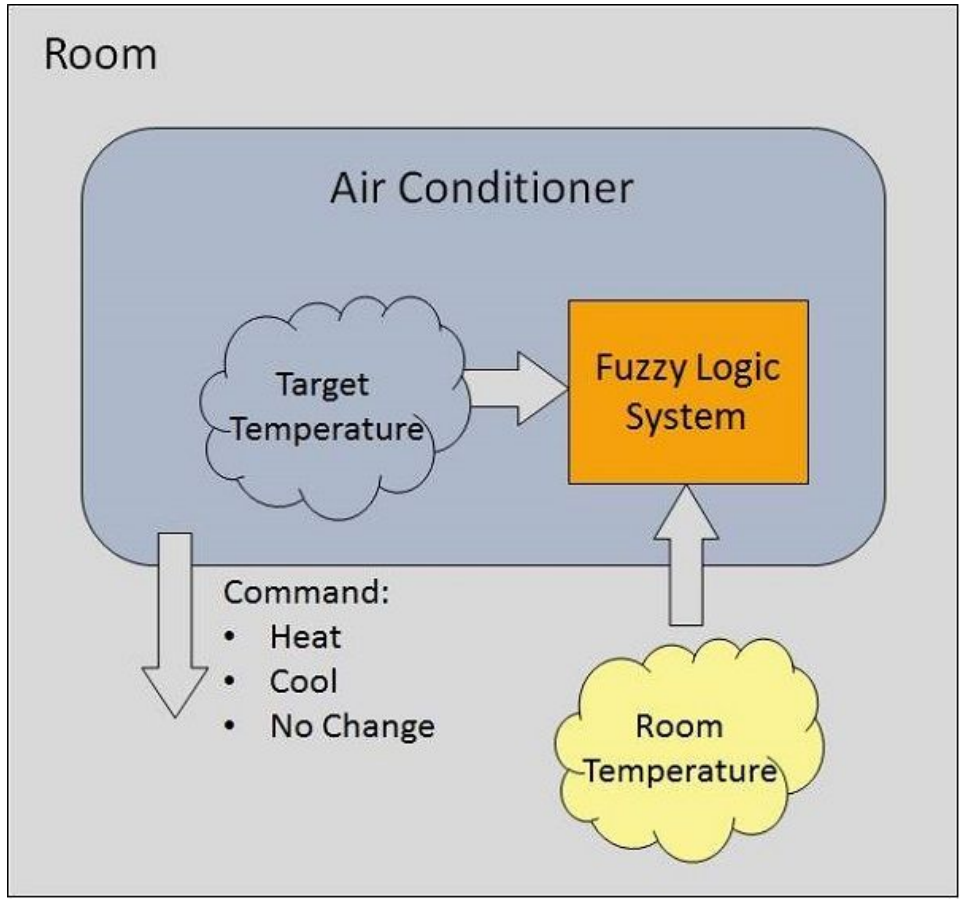
- **Defuzzification Module –** It transforms the **fuzzy set obtained by the inference engine into a crisp value.**



Example:

Example of a Fuzzy Logic System

An air conditioning system with 5-level fuzzy logic system. This system adjusts the temperature of air conditioner by comparing the room temperature and the target temperature value.



Example of a Fuzzy Logic System

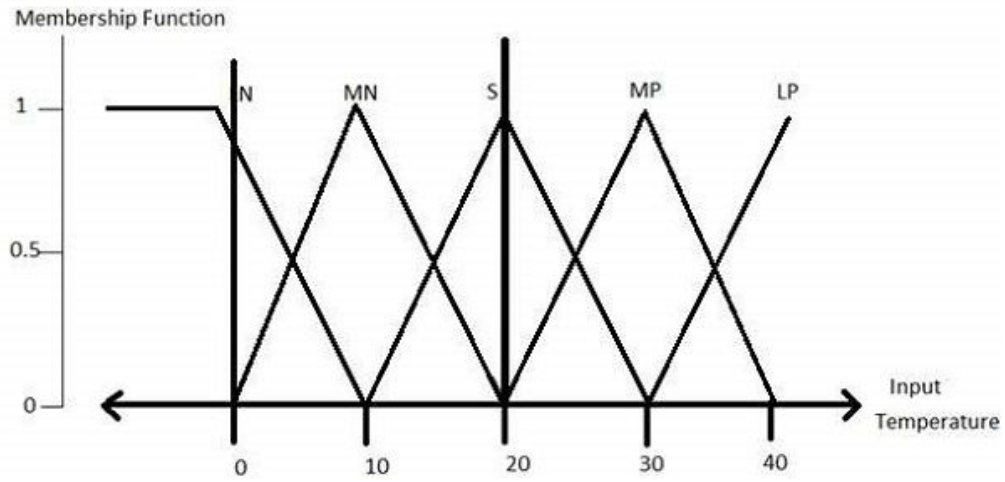
Step 1 – Define linguistic variables and terms

- **Linguistic variables are input and output variables in the form of simple words or sentences.**
- **For room temperature, cold, warm, hot, etc., are linguistic terms.**

Temperature (t) = {very-cold, cold, warm, very-warm, hot}

Step 2 – Construct membership functions for them

- **The membership functions of temperature variable are as shown –**



Membership functions allows to *quantify linguistic term and represent a fuzzy set graphically*.

Example of a Fuzzy Logic System

Step3 – Construct knowledge base rules

Create a matrix of room temperature values versus target temperature values that an air conditioning system is expected to provide.

RoomTemp. /Target	Very_Cold	Cold	Warm	Hot	Very_Hot
Very_Cold	No_Change	Heat	Heat	Heat	Heat
Cold	Cool	No_Change	Heat	Heat	
Warm	Cool		No_Change	Heat	Heat
Hot	Cool	Cool		No_Change	Heat
Very_Hot	Cool		Cool	Cool	No_Change

Example of a Fuzzy Logic System

Step3 – Construct knowledge base rules

Build a set of rules into the knowledge base in the form of IF-THEN-ELSE structures.

Sr. No.	Condition	Action
1	IF temperature=(Cold OR Very_Cold) AND target=Warm THEN	Heat
2	IF temperature=(Hot OR Very_Hot) AND target=Warm THEN	Cool
3	IF (temperature=Warm) AND (target=Warm) THEN	No_Change

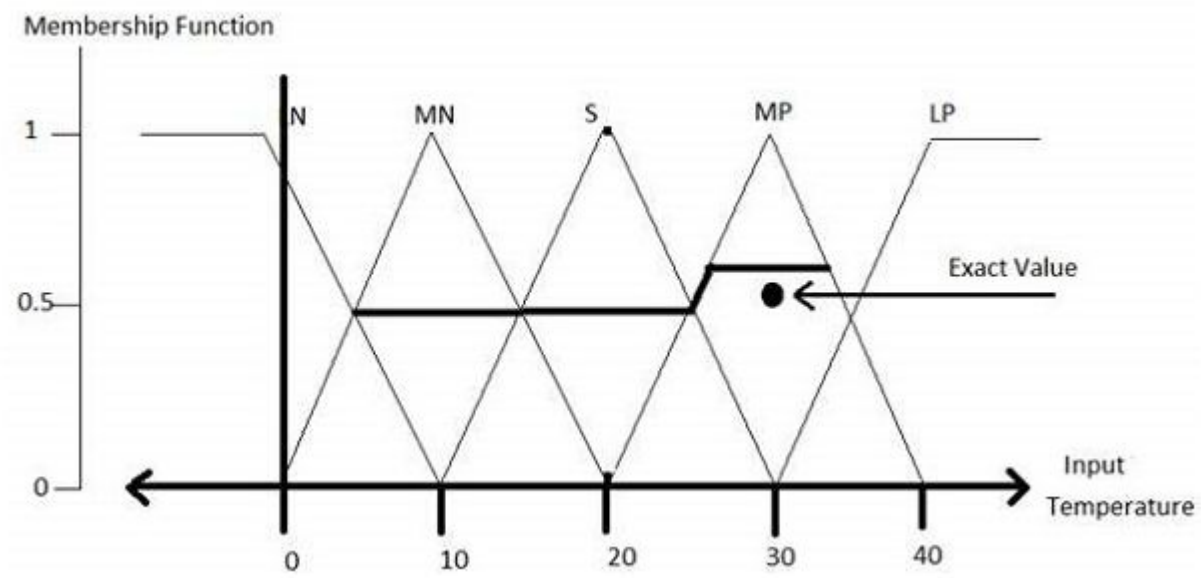
Step 4 – Obtain fuzzy value

Fuzzy set operations perform evaluation of rules. Combine all results of evaluation to form a final result. This result is a fuzzy value.

Example of a Fuzzy Logic System

Step 5 – Perform defuzzification

Defuzzification is then performed according to membership function for output variable.



Advantages of FLSs

- Mathematical concepts within **fuzzy reasoning are very simple**.
- You can **modify a FLS by just adding or deleting rules** due to flexibility of fuzzy logic.
- FLSs are **easy to construct and understand**.
- Fuzzy logic is a solution to complex problems in all fields of life, including medicine, as it resembles **human reasoning and decision making**.