Bootcamps for Emerging Technologies and essential Skills

Robotics and AI

developed by ECECT

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What will you learn from this bootcamp?

- Foundations of robotics and mechatronics
- Programming and control systems
- Artificial intelligence and machine learning
- Advanced robotics and emerging technologies

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HISTORY

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- 1920: Czech writer **Karel Čapek** first introduced the word “**robot**”, derived from the Czech word “robota”, meaning **forced labor.**

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- 1942: author **Isaac Asimov** introduced **The Three Laws of Robotics**:
  1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
  2. A robot must obey the orders given to it by human beings except where such orders would conflict with the First Law.
  3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

Evolution of robotics

- **First Wave (1940s-1970s):** Initial development of industrial robots for manufacturing.
- **Second Wave (1980s-2000s):** Advancements in computing and sensors led to more versatile robots.
- **Third Wave (2000s-present):** Integration of artificial intelligence (AI), machine learning, and advanced sensors for improved autonomy.

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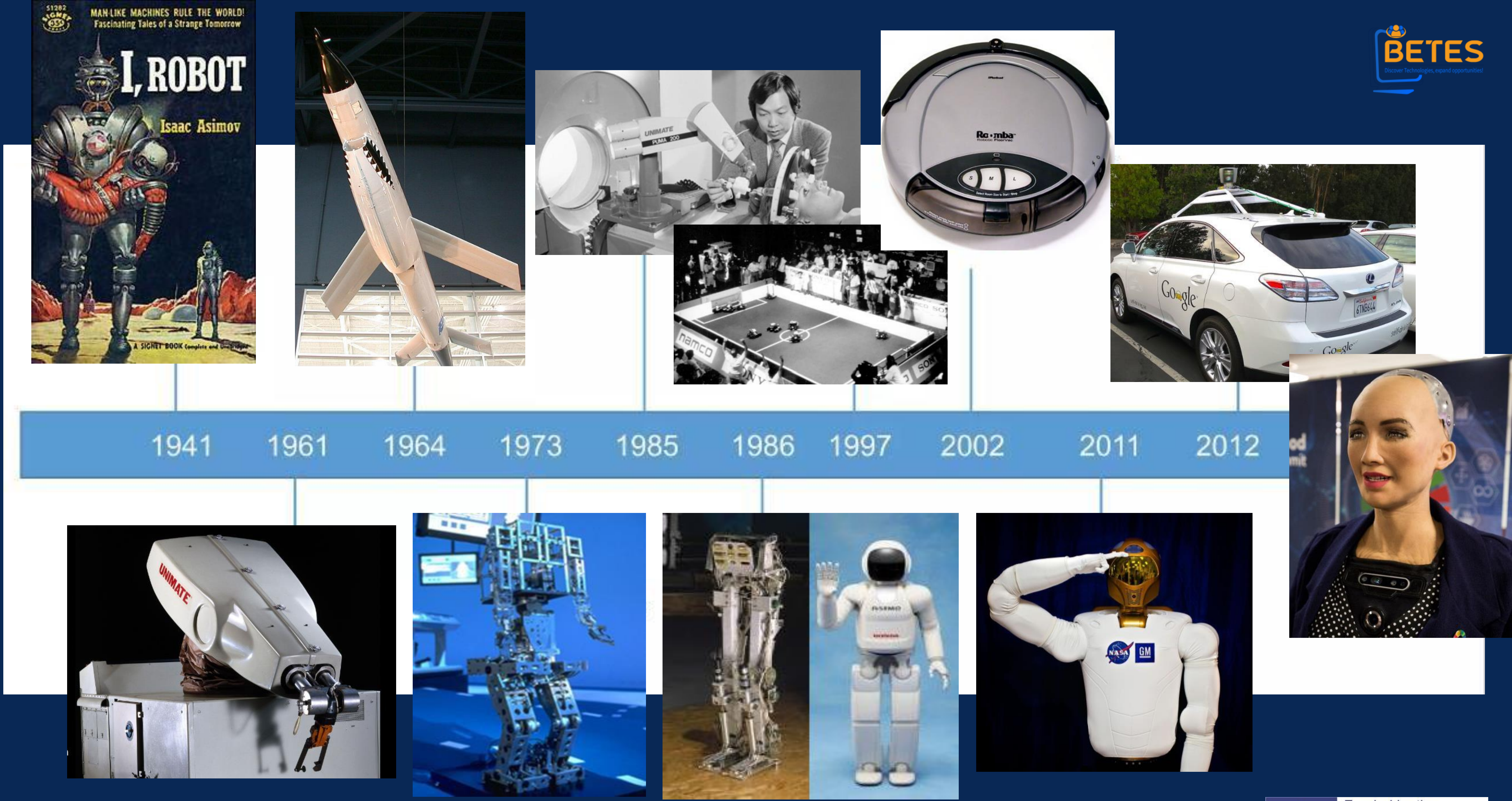

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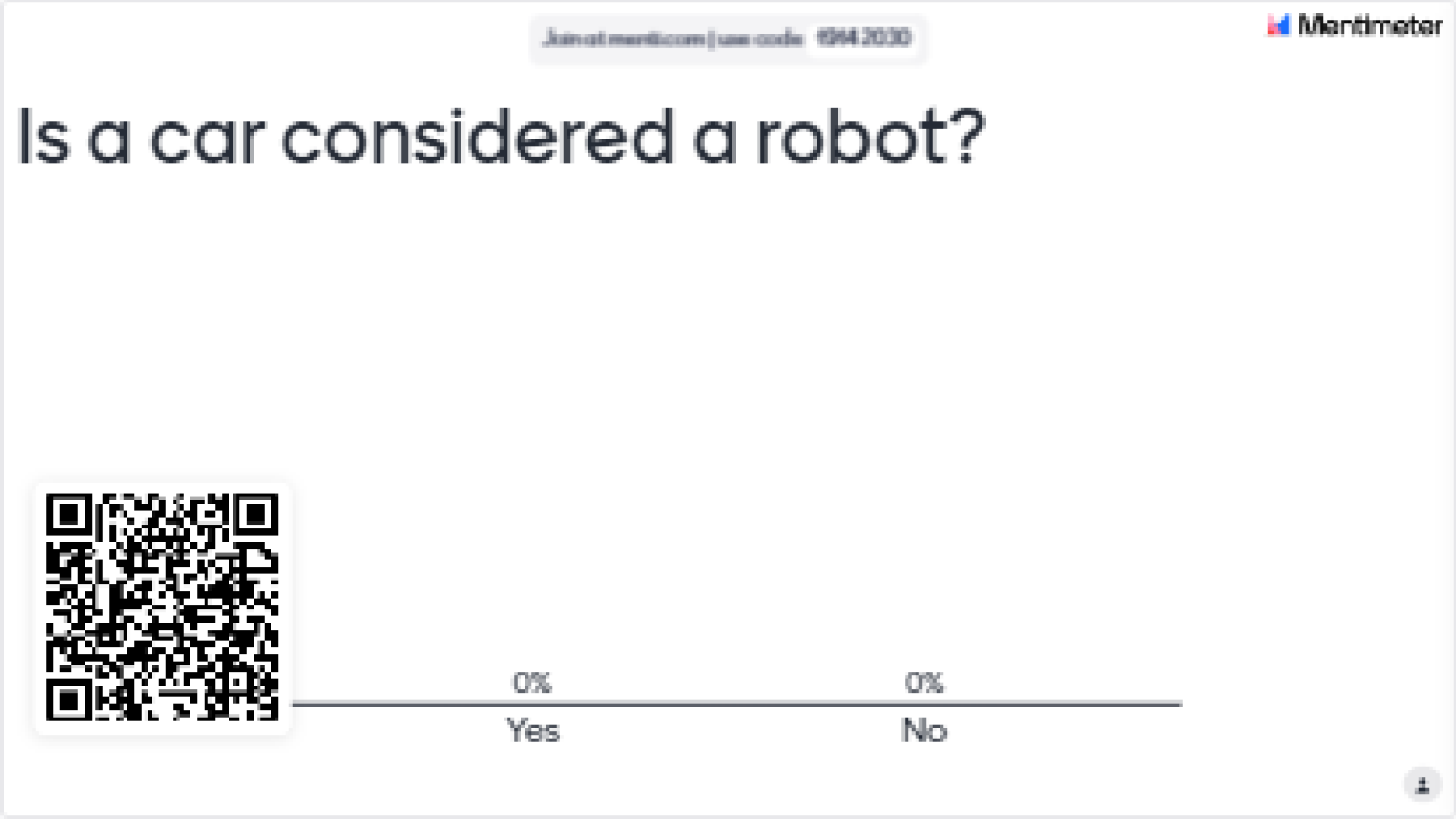
Mentimeter
Is a car considered a robot?
0%
Yes
0%
No

BETES

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Mentimeter

Is WALL-E considered a robot?

Yes	No
0	0

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BETES

Mentimeter

Is a washing machine considered a robot?

Yes	No
0	0

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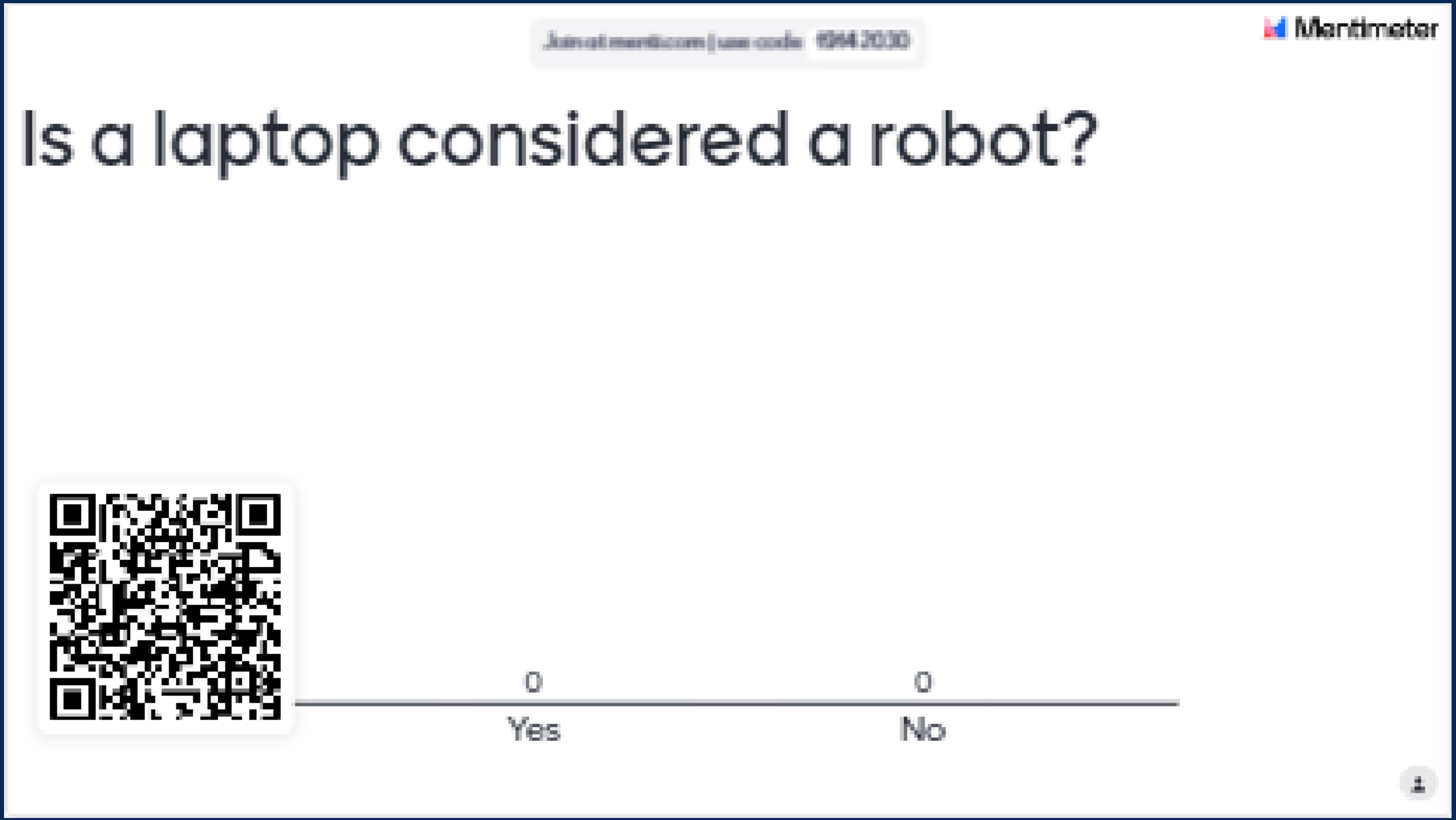

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Mentimeter

Is this considered a robot?

Yes	No
0	0

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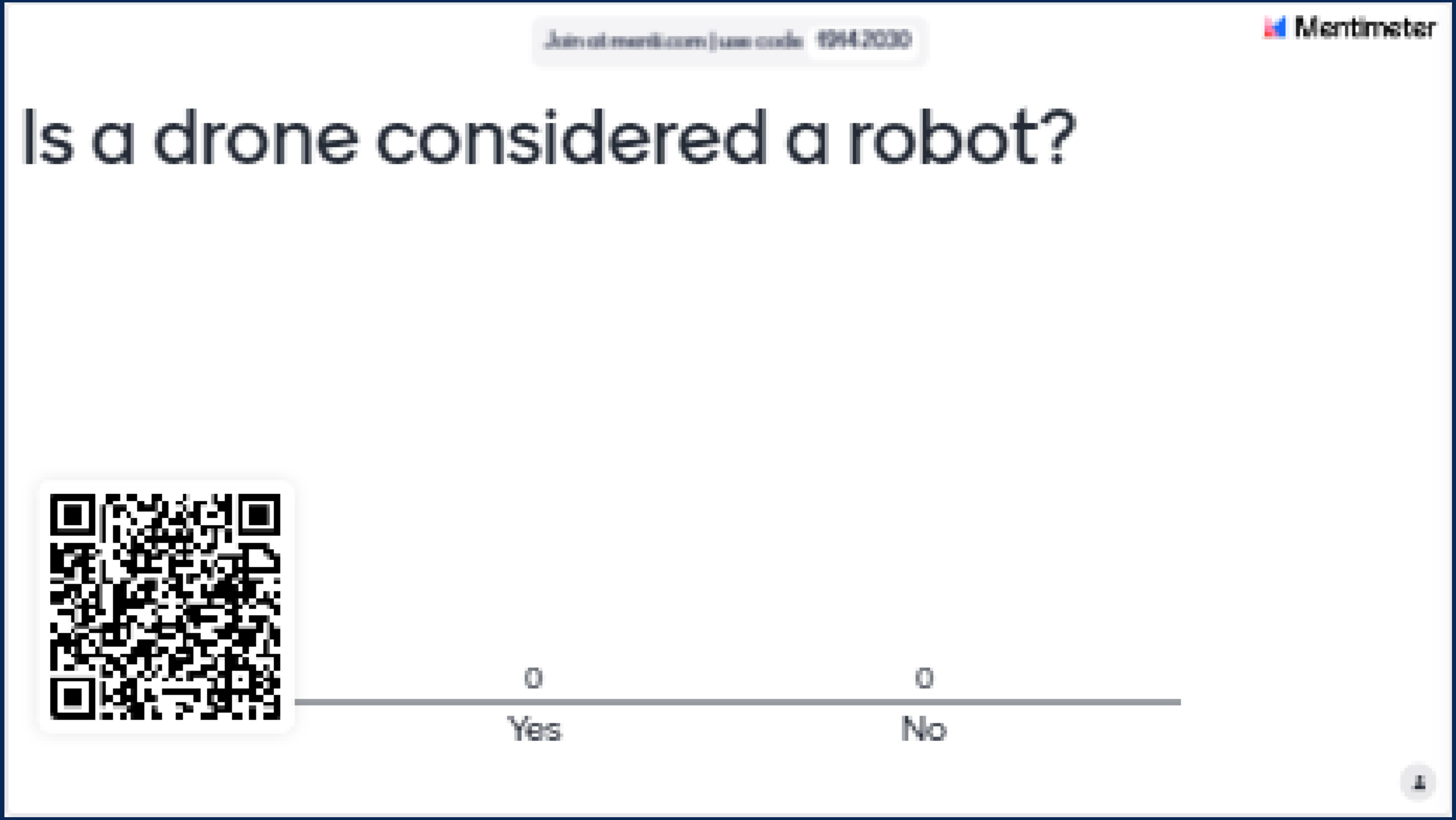

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Mentimeter

Is this considered a robot?

0	0
Yes	No

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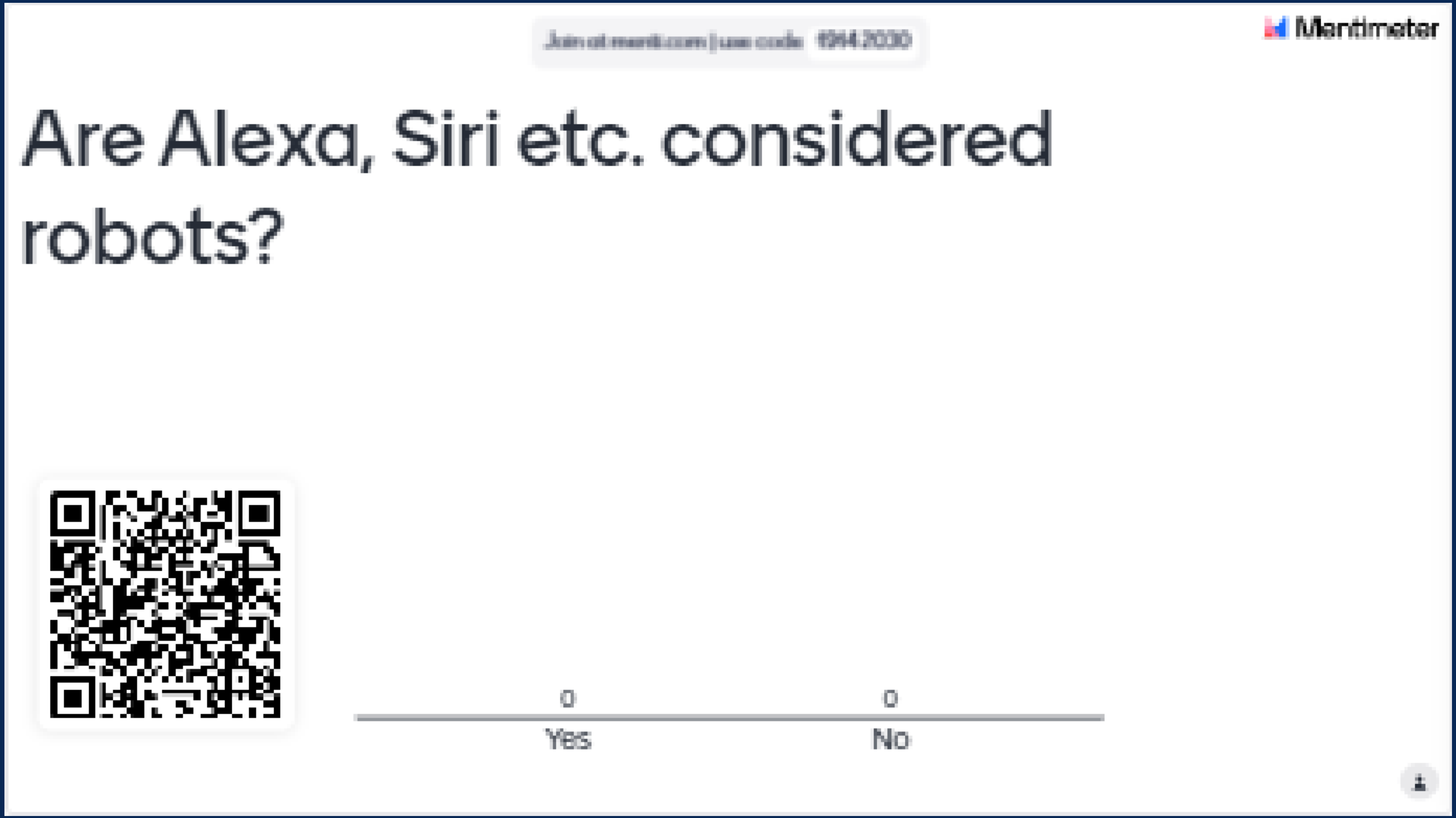

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What is a robot?

" Actuated mechanism programmable in two or more axes with a degree of autonomy, moving within its environment, to perform intended tasks. " (ISO 8373)

Actuated: to put into mechanical action or motion

Autonomy: Ability to perform intended tasks based on current state and sensing, without human intervention

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What is a robot?

- Robotics is the study of robots.
- Robots are machines that can be used to do jobs.
- Some robots can do work by themselves. Other robots must always have a person telling them what to do.

- A Robot is a system that contains sensors, control systems, manipulators, power supplies and software all working together to perform a task.
- Designing, building, programming and testing a robots is a combination of physics, mechanical engineering, electrical engineering, structural engineering, mathematics and computing.

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Robot characteristics

Obvious:

- Mechanical body to give it "presence"
- Sensors for "awareness" – internal and external
- Intelligence for "decision making"
- Actuators for moving itself and other objects
- Energy supply to power things

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Robot characteristics

<u>Not so obvious:</u>

- Use-ability: Teleoparated vs autonomy – how it communicates
- Robot kinematics: Forward vs inverse – how it moves
- Fixed and mobile robots
- Motion planning – how it navigates
- Constraints (e.g joint types)
- One? Many? With humans? (swarm/ collaborative)

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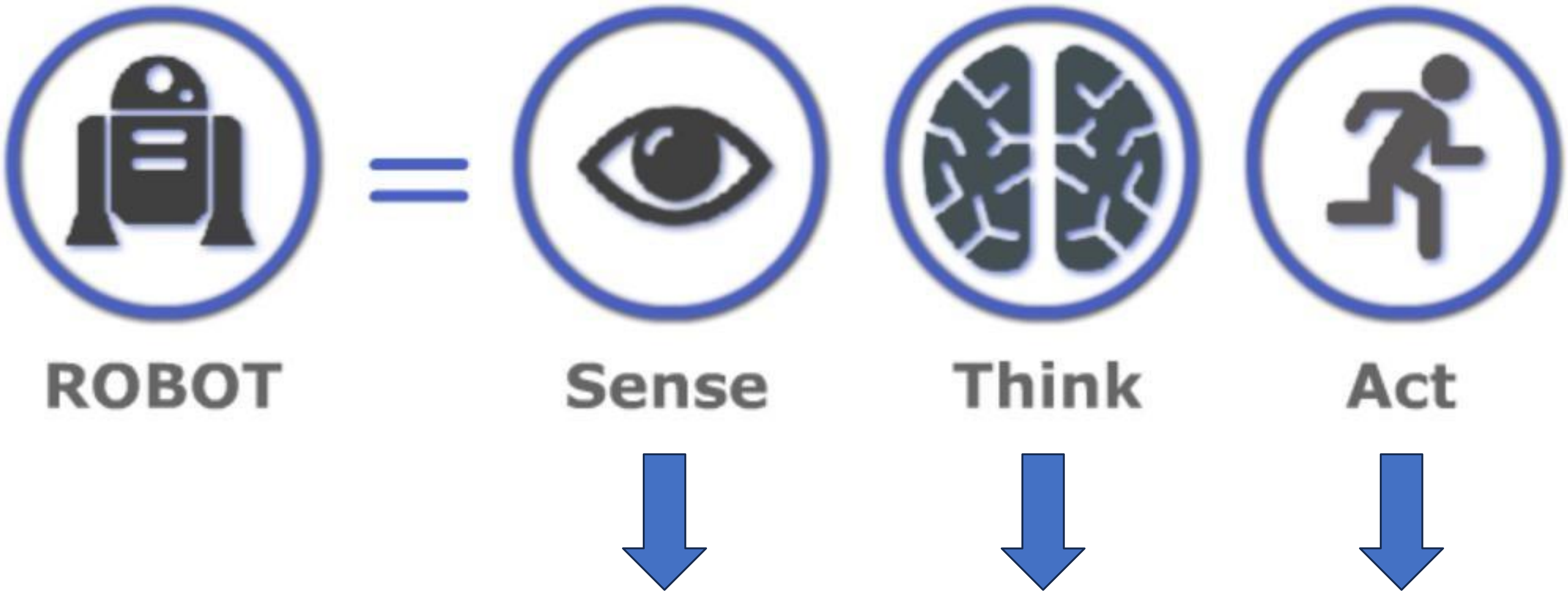
What is a robot?



INPUT: sensors

CONTROL SYSTEM: perception and cognition

OUTPUT: actuators

APPLICATIONS

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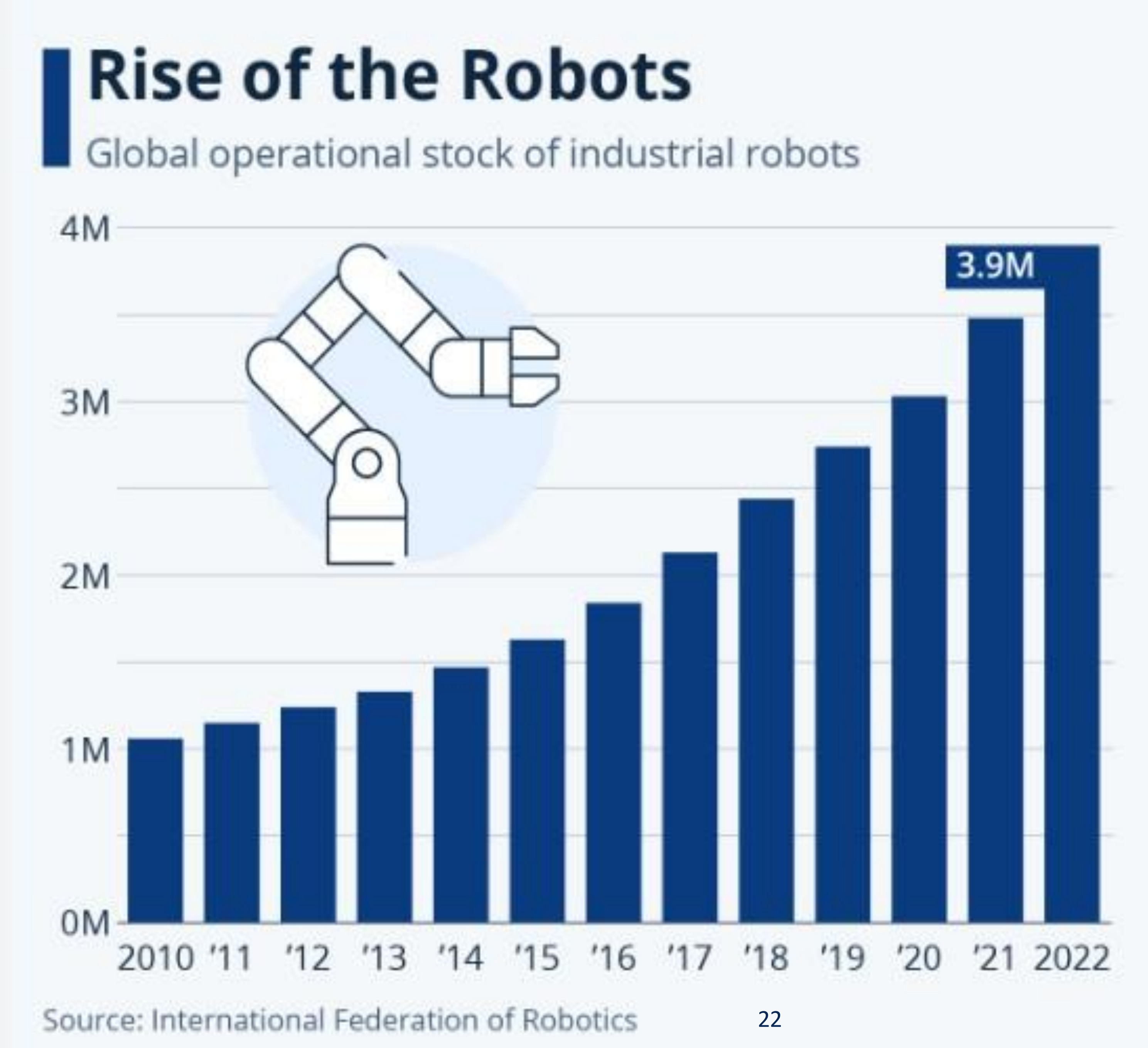
Industry

How does the industry feel about robot adoption?



Robot applications

1. **Industrial Robots:** used in manufacturing processes such as assembly, welding, painting, and packaging.
2. **Service Robots:** perform tasks for humans (personal or professional)
   - **Domestic Robots:** such as vacuum cleaners, lawnmowers, and other household helpers.
   - **Social/Entertainment Robots:** Interact with humans socially, often used in therapy or companionship and or
   - **Delivery Robots:** transport items like food, groceries, and medical supplies from one point to another.
   - **Medical Robots:** assist in surgeries, rehabilitation, and diagnostics.
   - **Military Robots:** used for surveillance, reconnaissance, bomb disposal, and combat.
   - **Search and Rescue Robots:** navigate challenging environments and assist in search and rescue operations.
   - **Space:** used for surveillance, navigate challenging environments

1. **Educational Robots:** assist in teaching programming, engineering, and STEM

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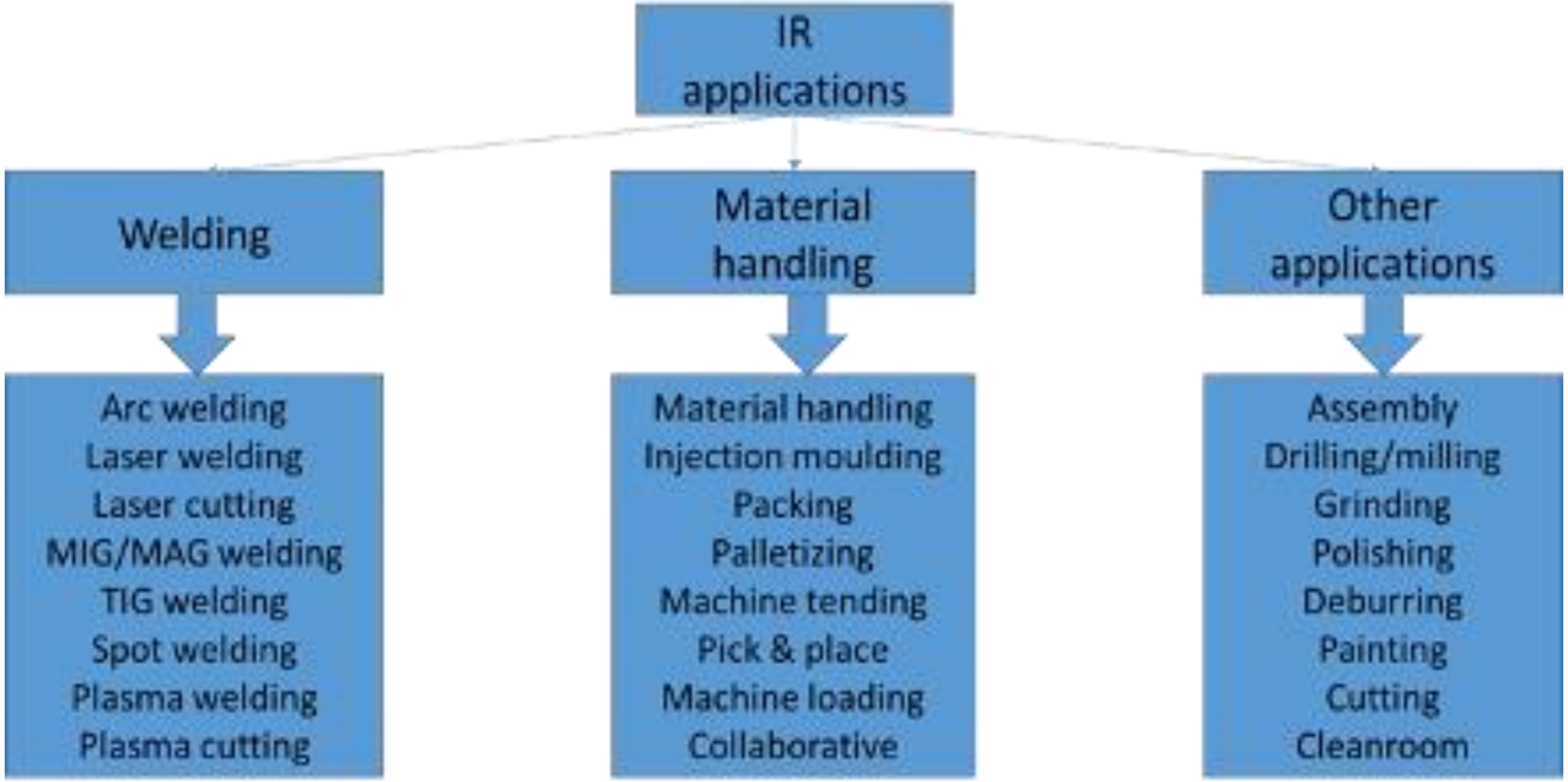
1. Industrial Robots

These play a crucial role in automating processes, increasing efficiency, and improving productivity in manufacturing and production environments



1. Industrial Robots

Articulated robots

Mobile robots

Articulated and mobile robots

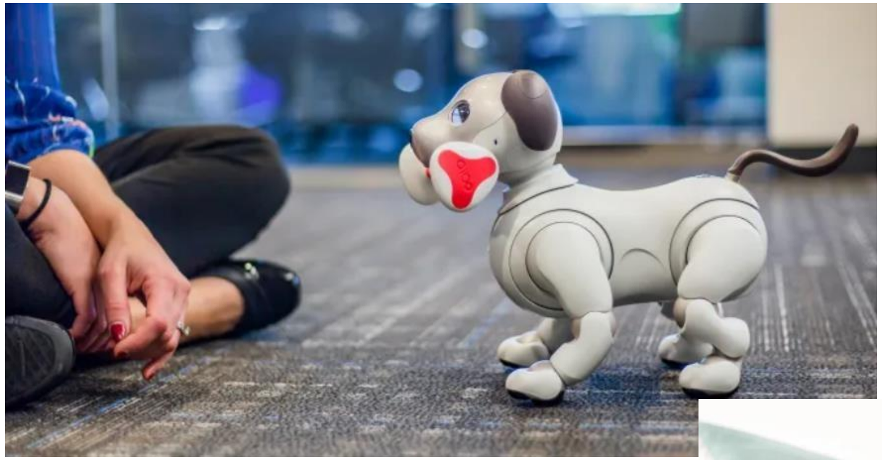
2. Service Robots – Domestic Robots

Robots designed to assist humans in various non-industrial settings, providing services to enhance quality of life, efficiency, and convenience.




2. Service Robots – Social robots

Robots designed to assist humans in various non-industrial settings, providing services to enhance quality of life, efficiency, and convenience.



AIBO

PARO

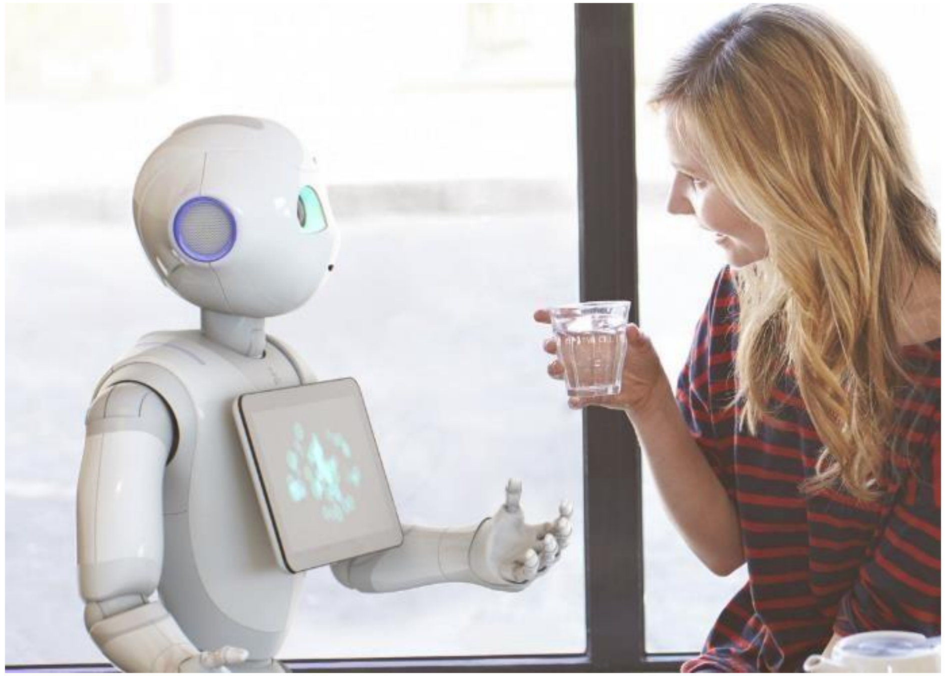
LOVOT

2. Service Robots – Social robots

Robots designed to assist humans in various non-industrial settings, providing services to enhance quality of life, efficiency, and convenience.

COZMO

SaviOne
“Botlr”



PEPPER

Ohmni

2. Service Robots – Delivery Robots

Robots designed to assist humans in various non-industrial settings, providing services to enhance quality of life, efficiency, and convenience.

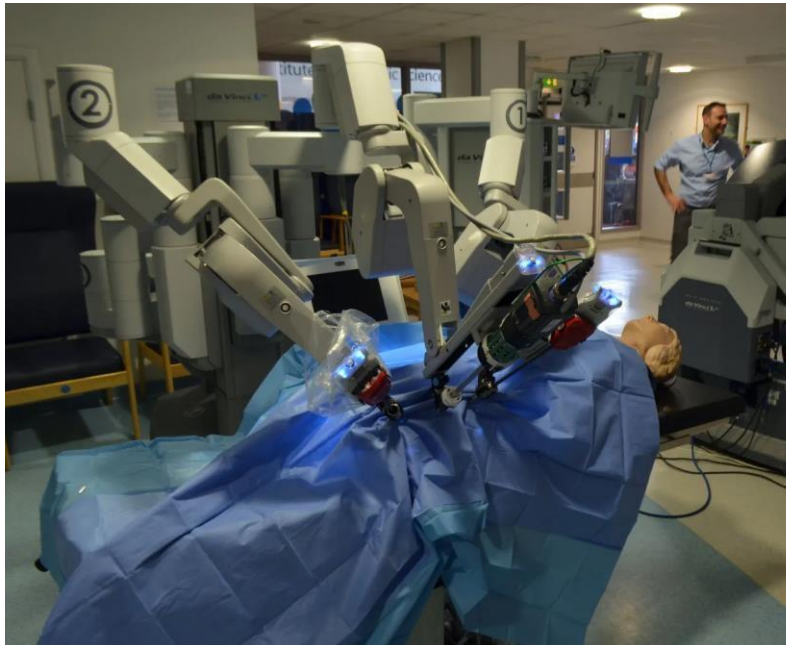
Starship

Relay

Zipline

2. Service Robots – Medical robots

Enhanced precision and accuracy in surgeries, support for minimally invasive procedures leading to faster recovery, and the ability to conduct telepresence and remote surgeries, extending medical expertise to underserved areas.



da Vinci Surgical System

CyberKnife System

Xenex Robot

2. Service Robots – Military robots

Military robotics offer advantages such as increased efficiency, reduced risks to human personnel, and enhanced capabilities, ethical concerns include issues related to autonomous weapons, accountability, and the potential for misuse.

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2. Service Robots – Search and rescue robots

Search and rescue robotics play a crucial role in enhancing the efficiency and effectiveness of emergency response efforts, reducing risks to human responders, and increasing the likelihood of locating and aiding survivors in disaster-stricken areas.

3.Educational Robots

Educational robots can serve various purposes in enhancing learning experiences. They can promote active engagement, problem-solving, and collaboration among students as active learning tools. By introducing robotics in the classroom, children can develop their critical thinking and creativity skills.

LEGO Mindstorm EV3

Replicator+

EMYS

SOCIETY AND ETHICS

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Societal Impact

1. **Automation and Job Displacement:** Increased use of robots in industries may lead to job displacement for certain manual tasks.
2. **Economic Growth:** Robotics can contribute to economic growth by increasing productivity and efficiency.
3. **Improved Quality of Life:** Robots in healthcare and assistance can enhance the quality of life for individuals with disabilities or the elderly.
4. **Safety:** Robots can perform dangerous tasks in hazardous environments, reducing human risk.!!!!!

Concerns

1. **Job Displacement:** Concerns about job loss and the need for retraining the workforce.
2. **Privacy:** Increased use of robots in surveillance and data collection raises privacy concerns.
3. **Autonomy and Decision-Making:** Ethical questions arise when robots make decisions, especially in critical situations.
4. **Security:** The potential for robots to be hacked or misused raises security concerns.
5. **Social Impact:** The use of robots in social roles may impact human relationships and interactions.

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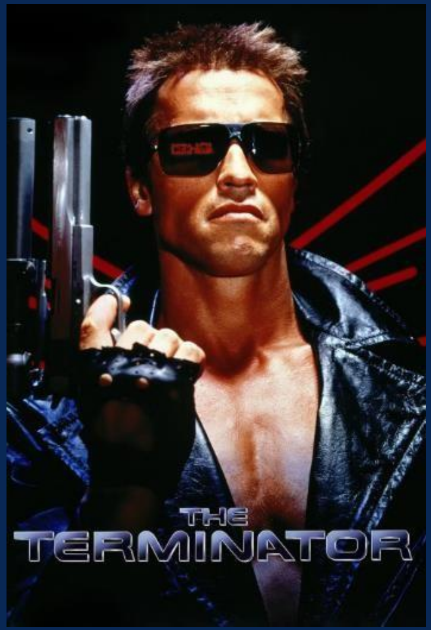
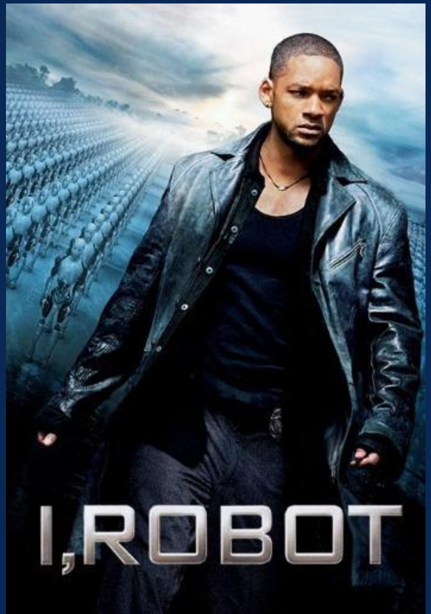
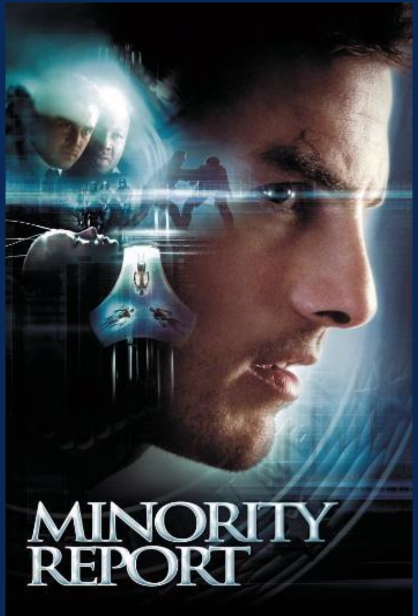
Robotics in Movies

- The Terminator
- The Matrix
- I, Robot
- RoboCop
- Avengers: Age of Ultron
- Minority report







Ethics – Kant and Blackburn

Ethics is crucial in guiding the development, deployment, and use of robotic technologies.

- Kantian ethics suggests that robots should respect human autonomy, dignity, and rights.
- Blackburn's views highlight the need to address ethical dilemmas while also considering technological advancements and societal needs.

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Roboethics

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“Roboethics is an applied ethics whose objective is to develop scientific/cultural/technical tools that can be shared by different social groups and beliefs. These tools aim to promote and encourage the development of Robotics for the advancement of human society and individuals, and to help preventing its misuse against humankind.” (Veruggio, 2002)

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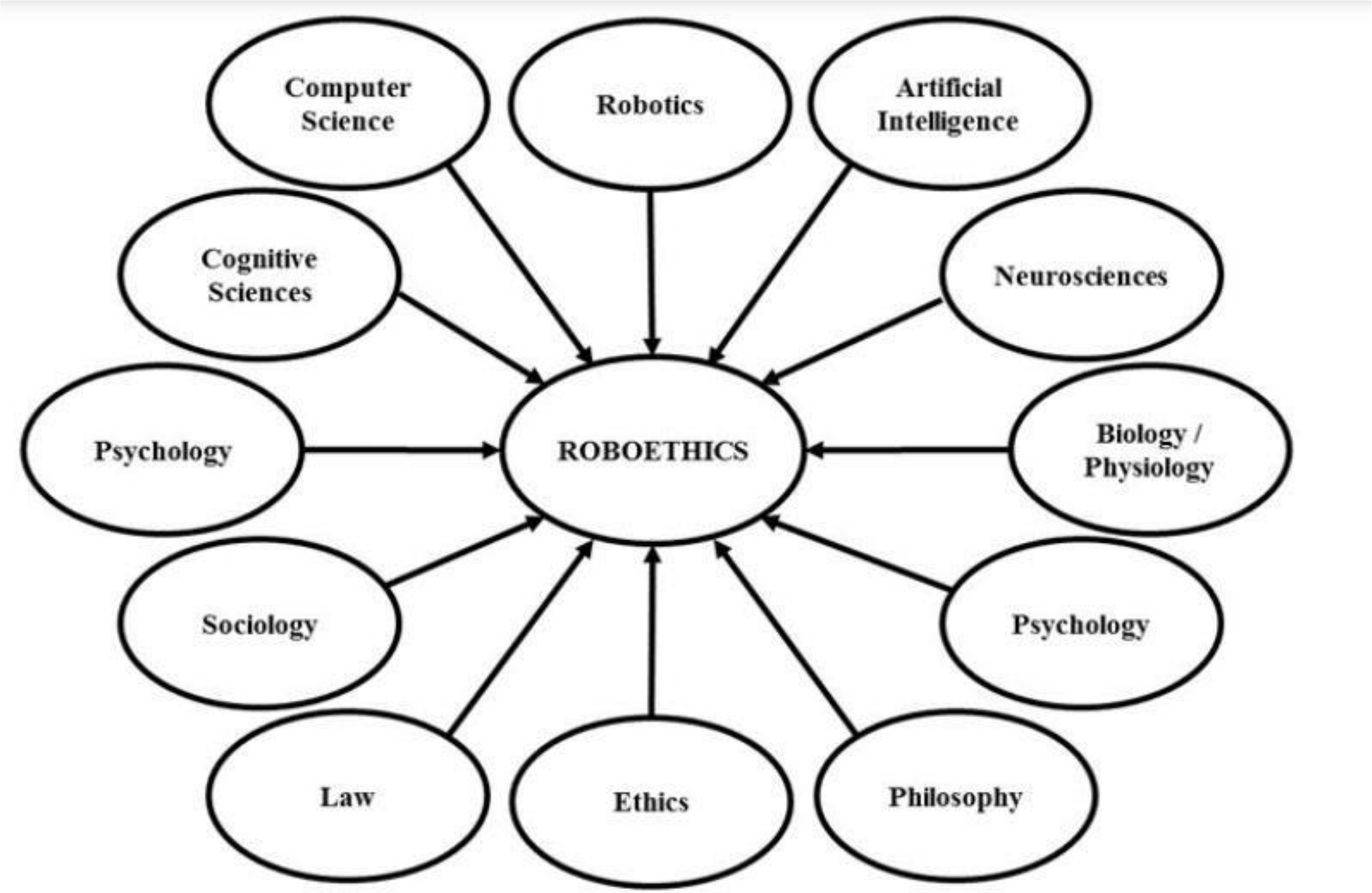
Disciplines related to Roboethics



Automation levels in Roboethics

Automation Level	Automation Description
1	No computer assistance: the human must make all decisions and take actions.
2	The computer offers a complete set of decision/action alternatives.
3	The computer narrows the selection down to a few.
4	The computer suggests one alternative.
5	The computer executes a suggestion if the human approves.
6	The computer allows the human a restricted time to veto before the automatic execution.
7	The computer executes automatically, then informs humans when necessary.
8	The computer informs the human only if asked.
9	The computer informs the human only if it decides to.
10	The computer decides everything and acts autonomously, ignoring the human.

TYPES OF ROBOTS

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Types of robots

- **Mobile robots:** vehicles capable of moving around their environments to carry out tasks; tele-operation, semi-autonomous and autonomous.

- **Robot manipulators**: fixed-base jointed robot arms which are now quite common in the manufacturing industry.

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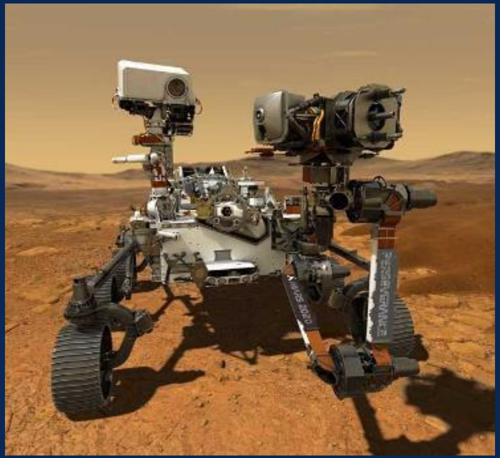
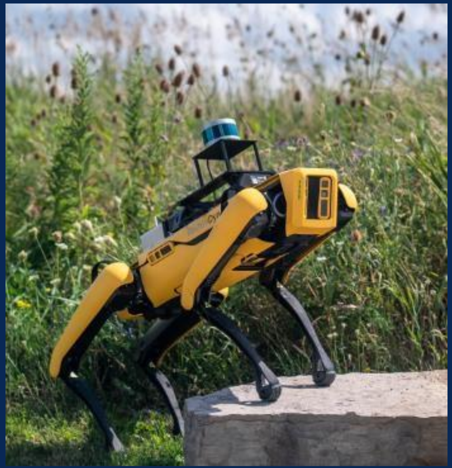
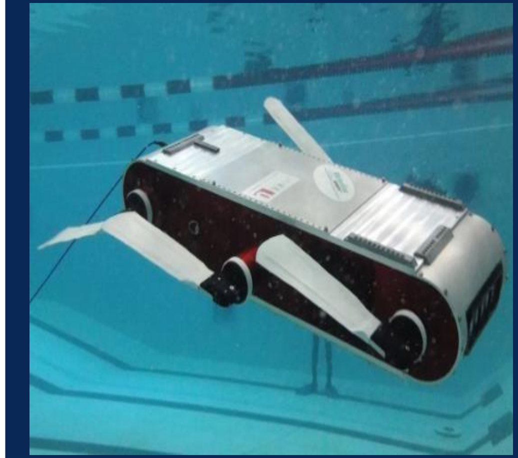
Mobile robots

- Locomotion
  - ➢ Climbing, Walking, Flying, Swimming etc.
- Wheeled mobile robots
  - ➢ fixed, steerable, caster wheels
- Legged mobile robots
  - ➢ Even/uneven terrains
  - ➢ Biped/multi-legged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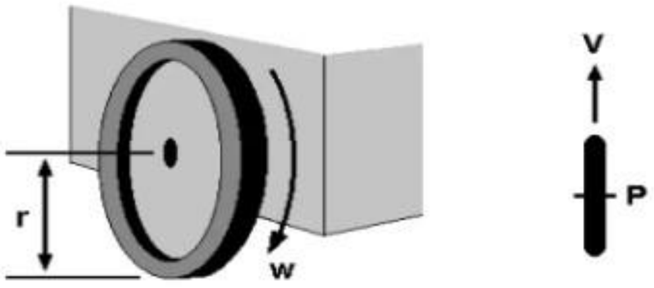
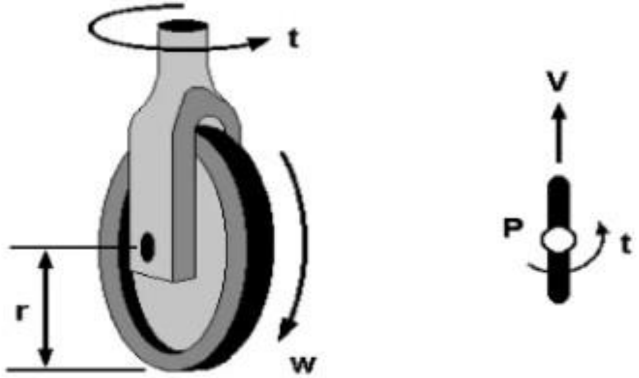
Types of wheels

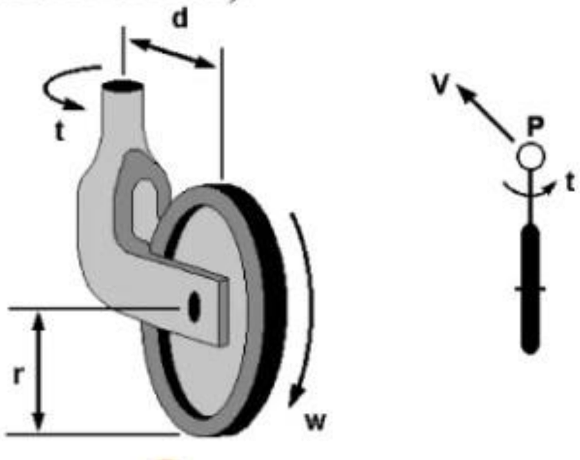
Fixed wheel



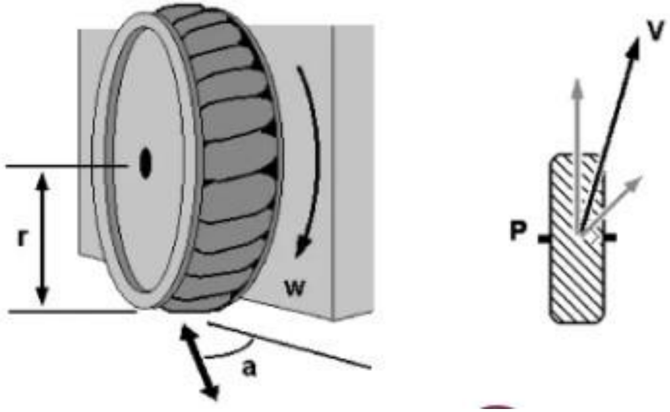
Centered orientable wheel



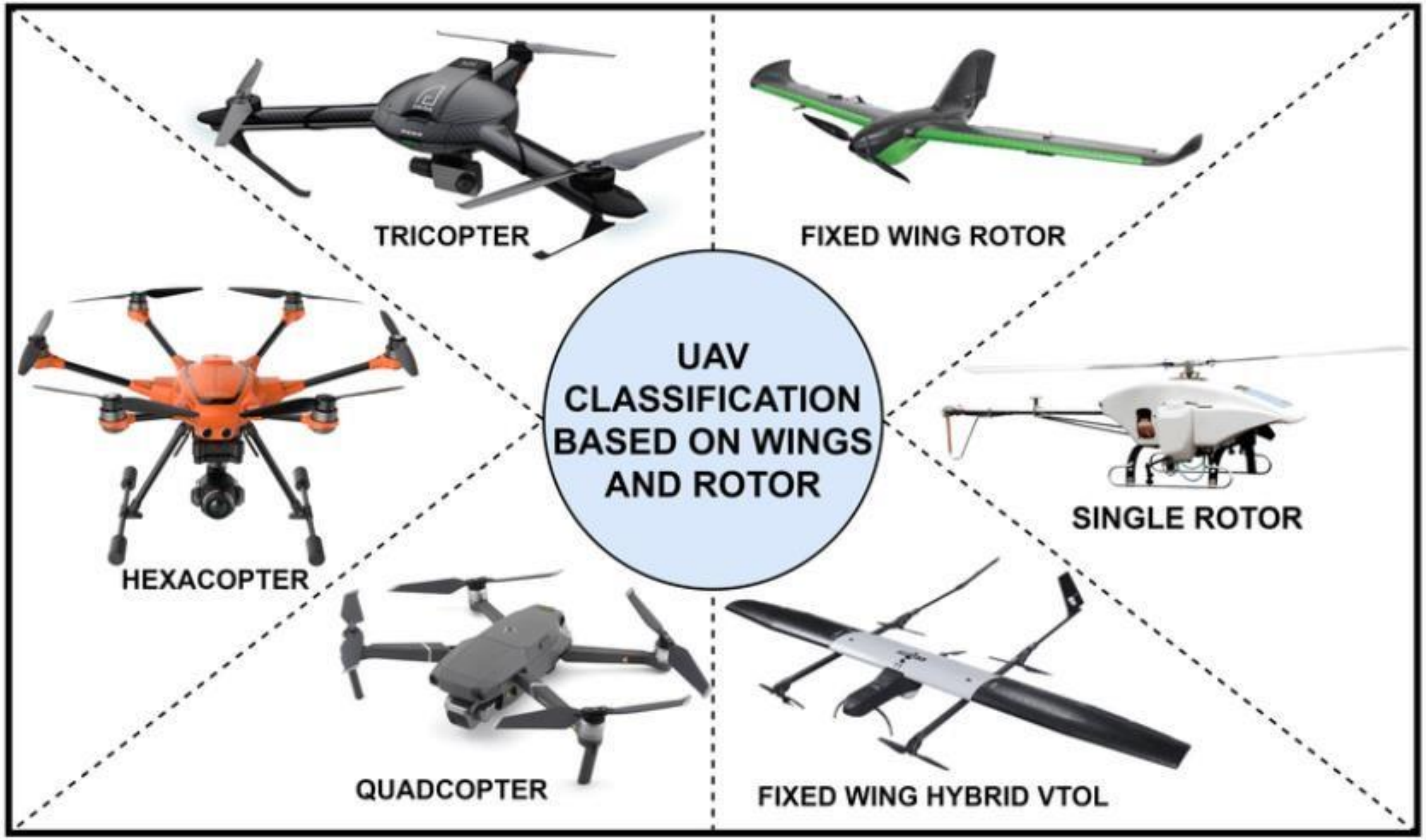
Off-centered orientable wheel
(Castor wheel)



Swedish wheel:omnidirectional property



Types of wings and rotor

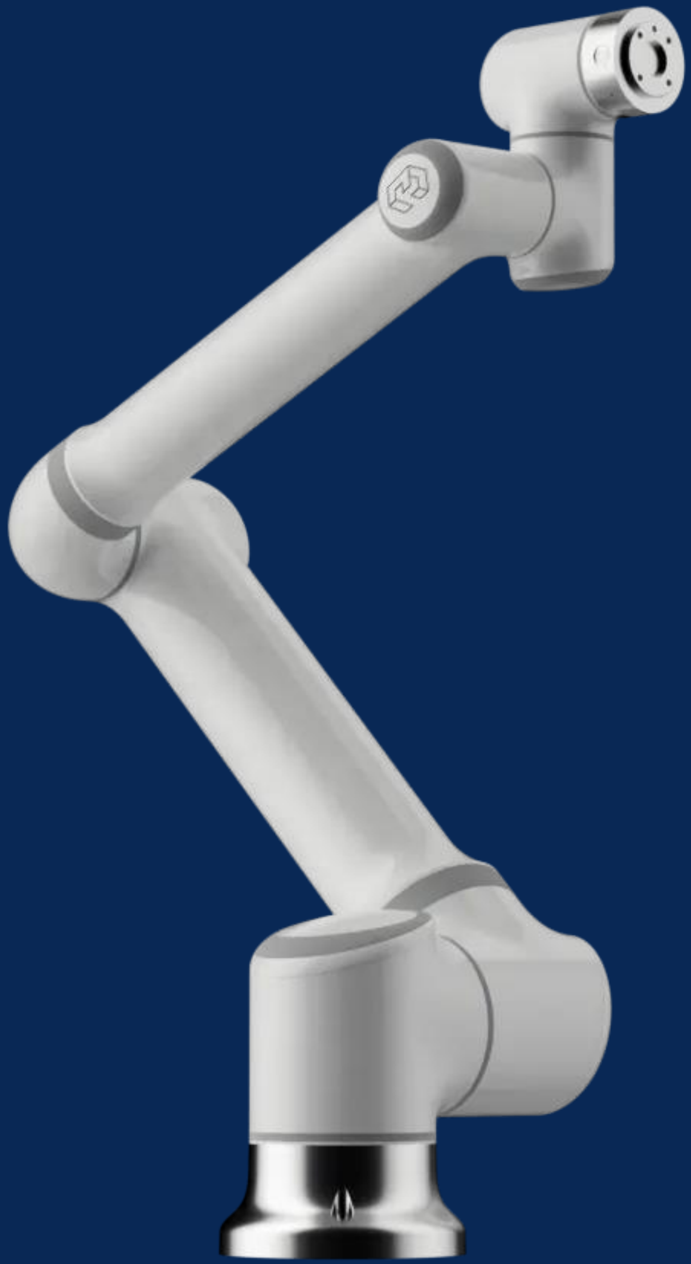


Robot manipulator

- The manipulator is the mechanical arm, containing **actuators**, **sensors** and **structural components**.

- The mechanical structure of a robot manipulator consists of a sequence of rigid bodies (**links**) interconnected by means of articulations (**joints**).

- A manipulator is characterised by an arm that ensures mobility, a wrist that confers dexterity, and an **end-effector** (gripper) that performs the task required of the robot.



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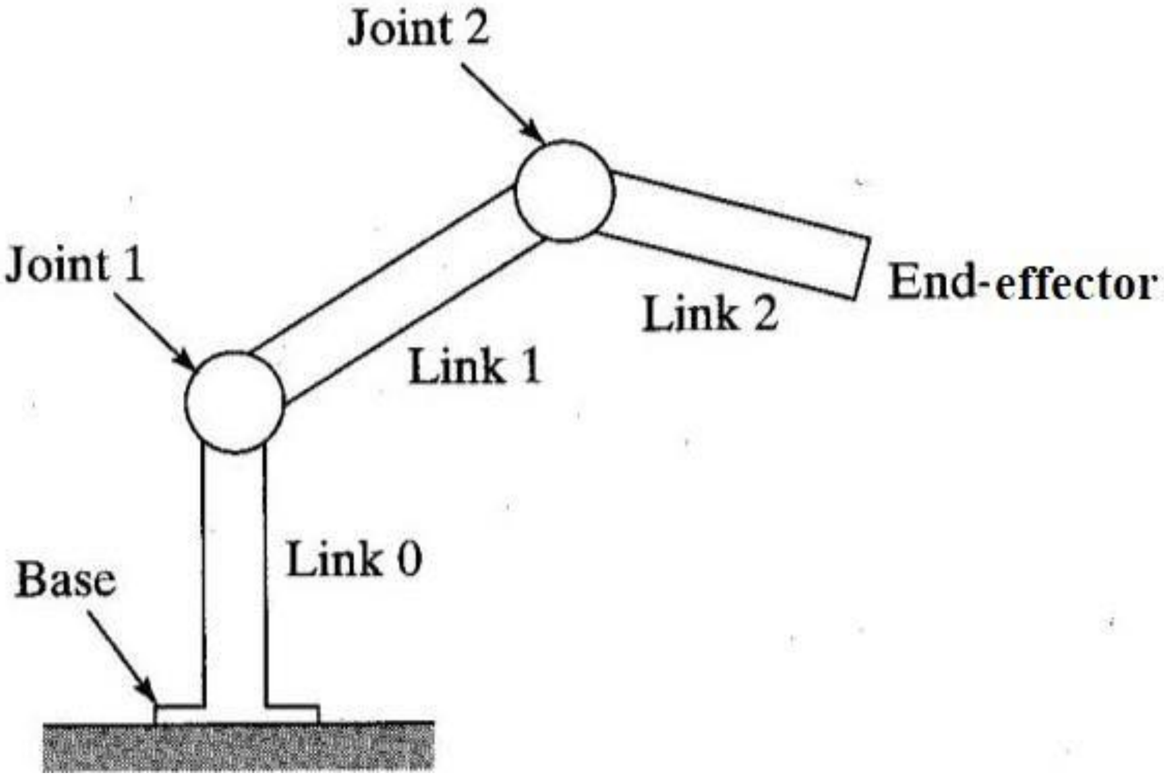
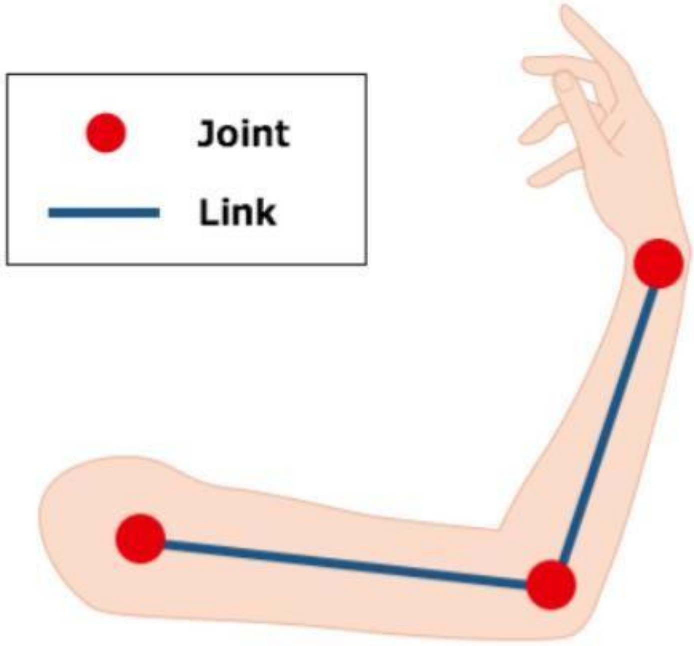
Robotic arm


Joint 2
Joint 1
End-effector
Link 2
Link 1
Link 0
Base

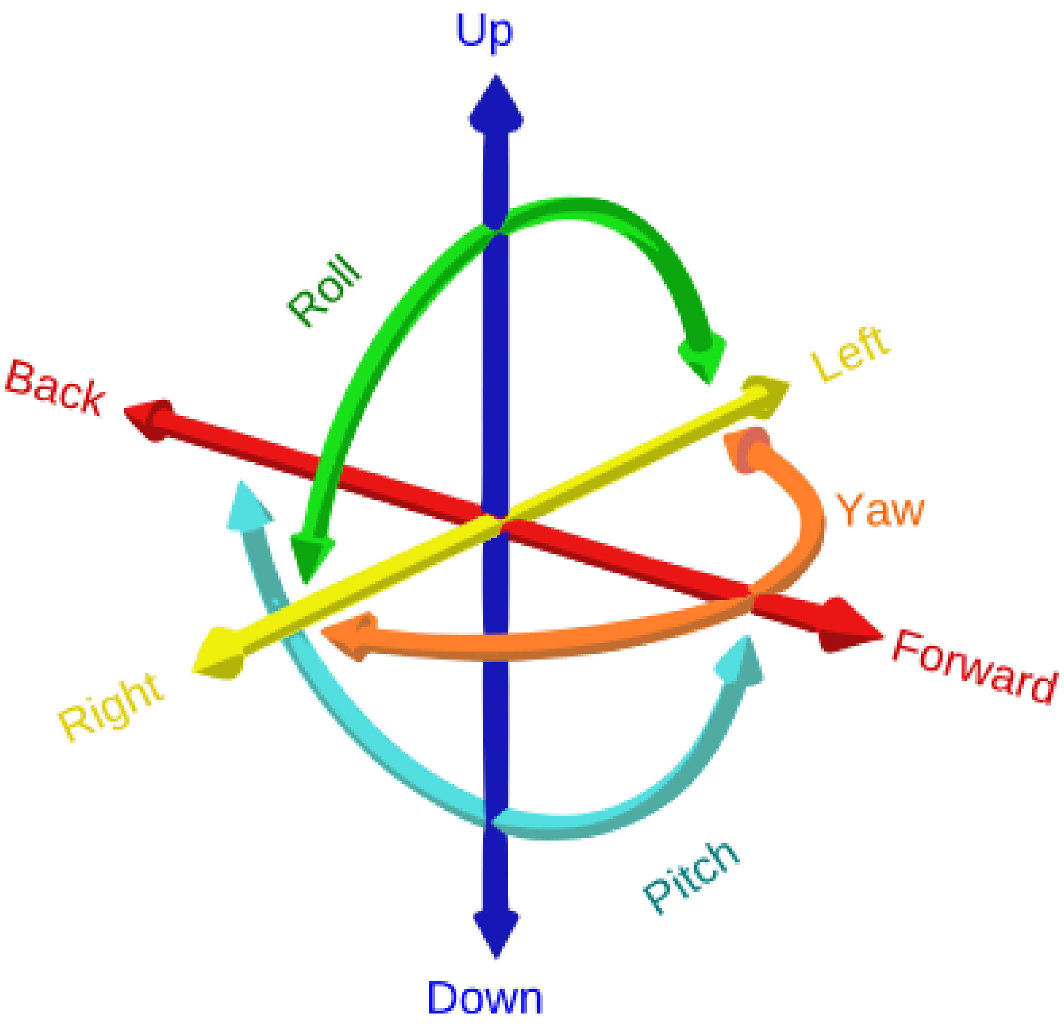

Joint
Link

Robot manipulator - DoF

- **Degrees-of-freedom** (DoF) of the manipulator the number of independent variables that define the possible positions or motions.

Two types:

- Translational (distance):
  - forward/backward
  - up/down
  - left/right
- Rotational (angle):
  - Yaw
  - Pitch
  - Roll

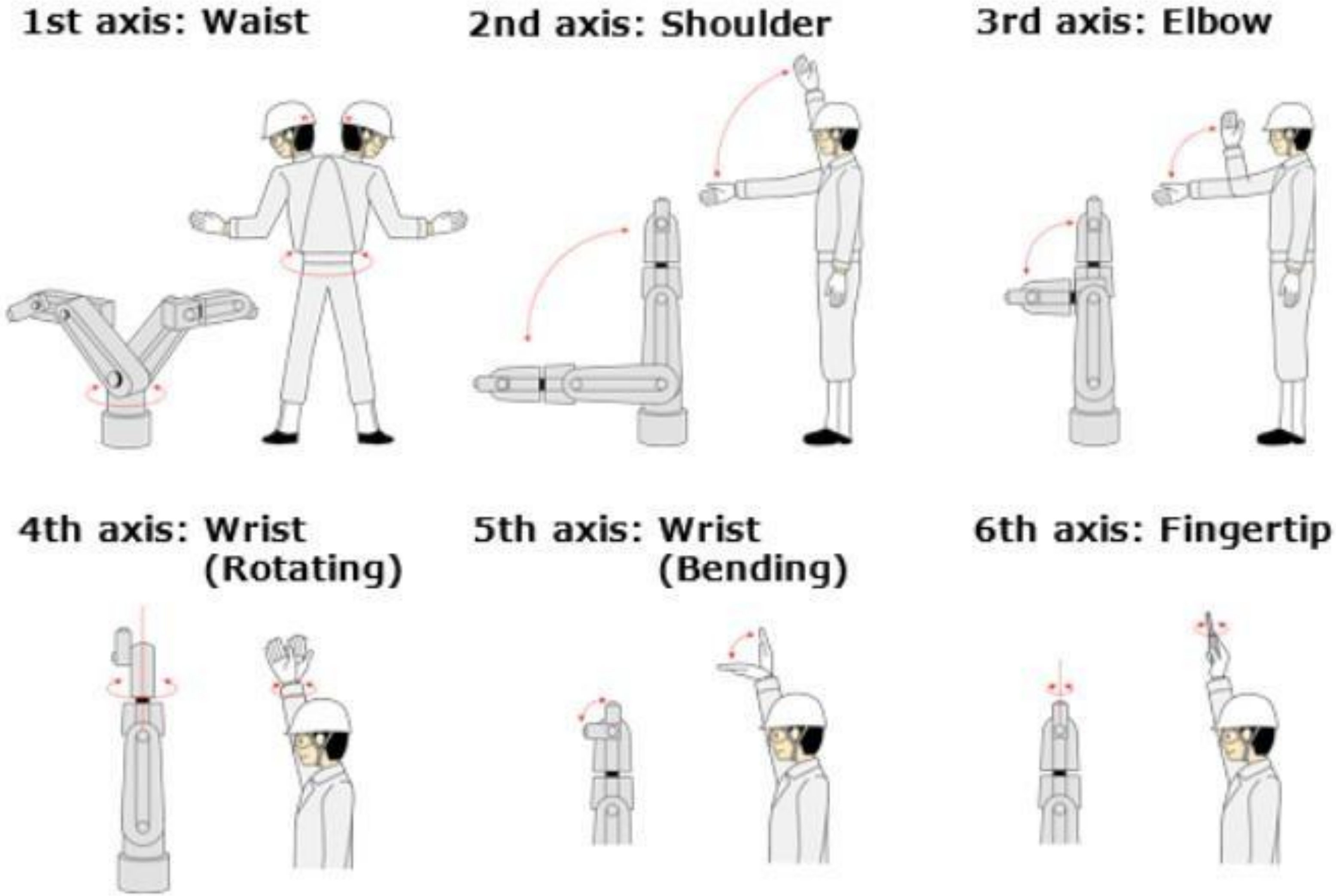


Q: How many degrees of freedom are shown here?

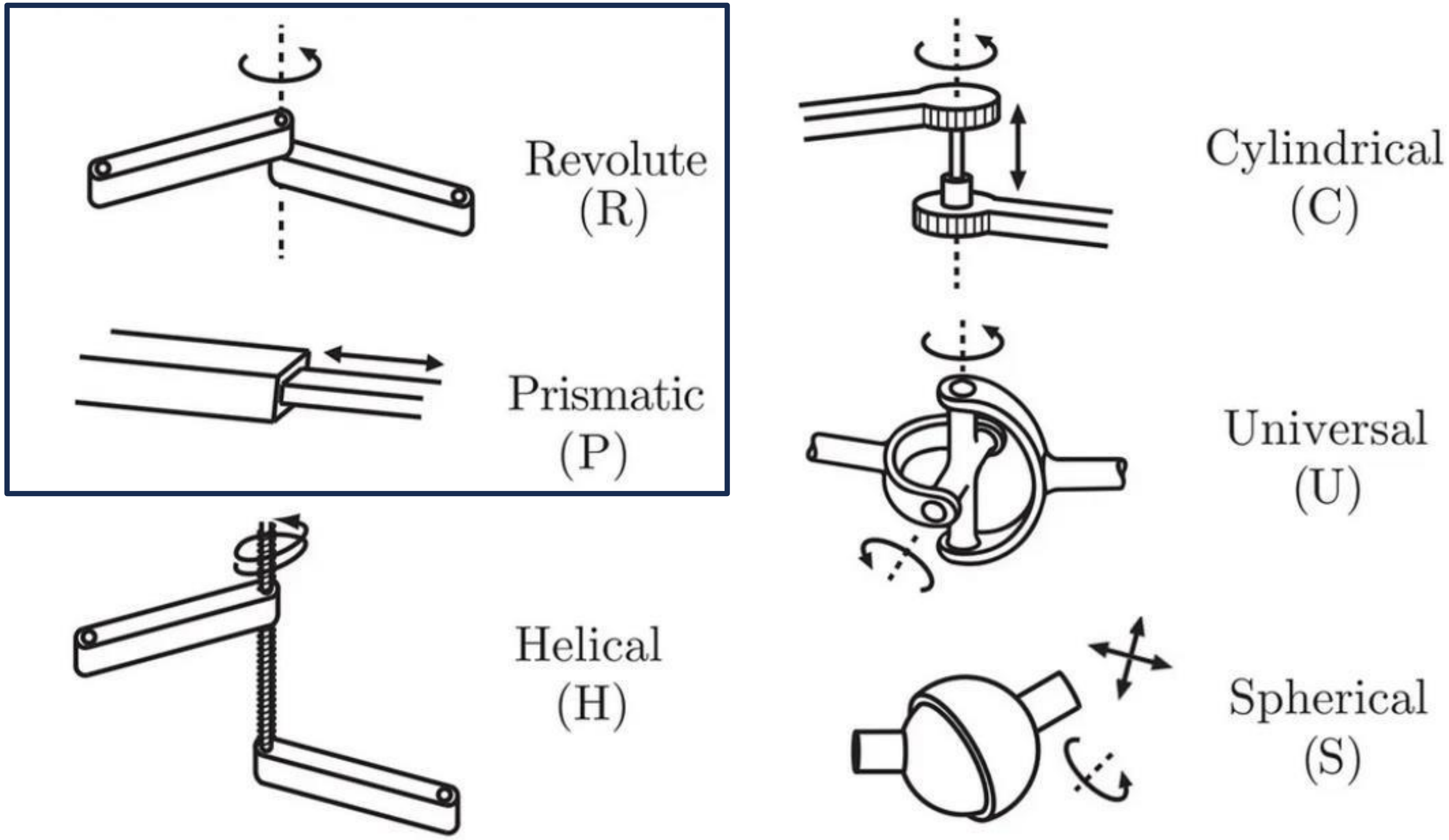
Wrong answer: I don't know!

Correct answer: 6 DOF (3 translational, 3 rotational)

Human vs Robot

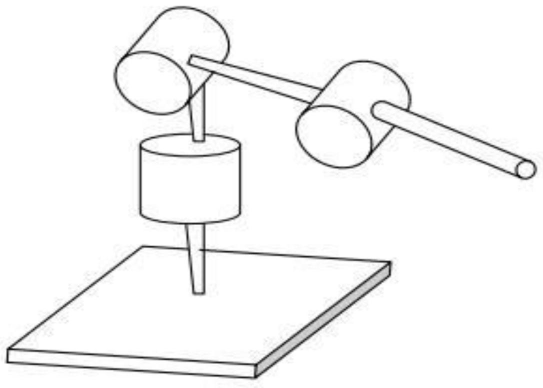


Joint types

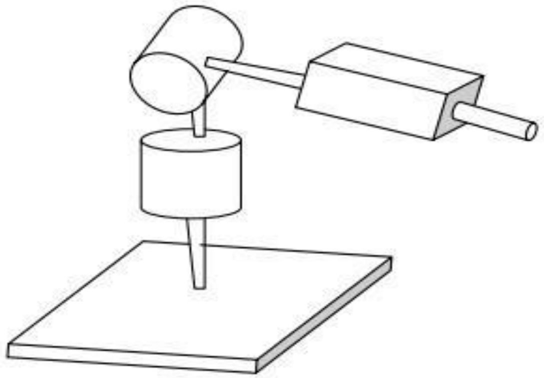

Revolute
(R)
Prismatic
(P)
Helical
(H)
Cylindrical
(C)
Universal
(U)
Spherical
(S)

Manipulator structures

- **Anthropomorphic (RRR):** All three joins of rotational type; second joint axis is perpendicular to first joint axes and third joint axes is in parallel to second one. The workspace (points reached by robot arm) forms spherical shape



- **Spherical (RRT):** Has two rotational and one translational DOF. Second joint axis is perpendicular to first and third joint axis is perpendicular to second one. Workspace is spherical.



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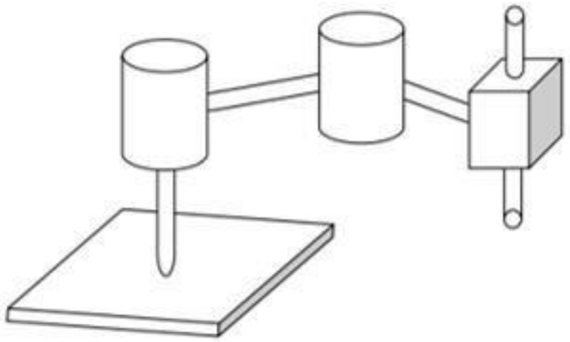
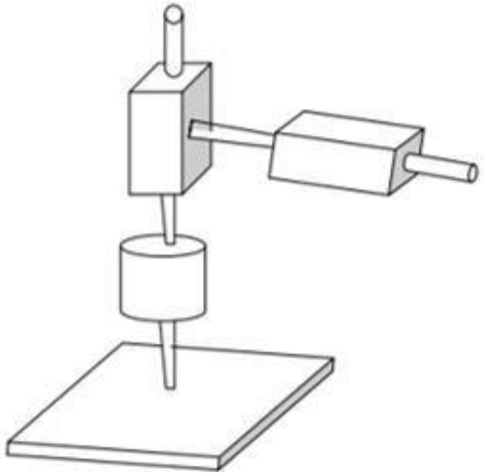
Manipulator structures

- **SCARA (selective compliant articulated robot for assembly) rob arm (RRT):** Has two rotational and one translational DOF. Axes of all three joints are parallel. The workspace is cylindrical.



- **Cylindrical robot arm (RTT):** Has one rotational and two translational DOF. Axes of first and second joints are parallel and axis of third joint is perpendicular to second joint. The workspace is cylindrical.



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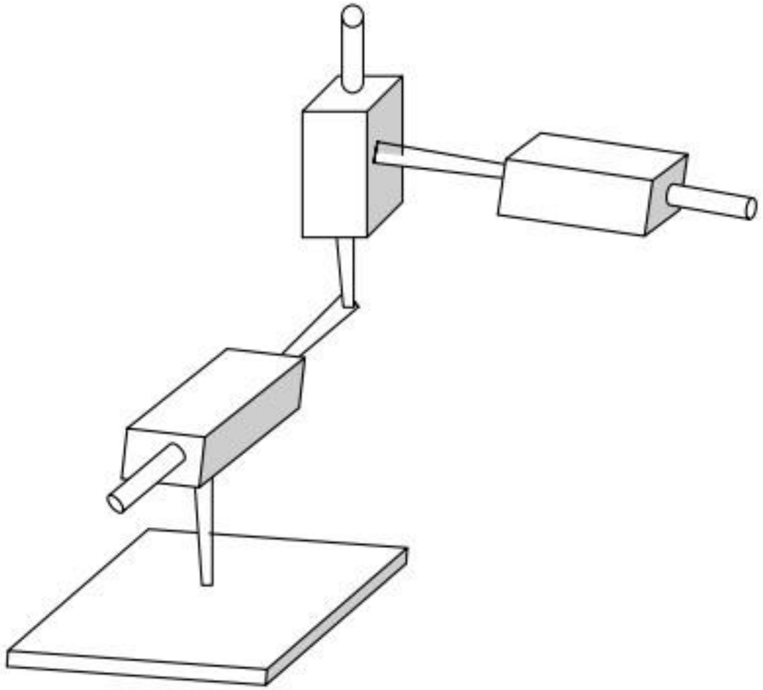
Manipulator structures

- **Cartesian (TTT):** Has all three joints of translational type. The axes are all perpendicular to one another. The workspace is a prism.

→ **Cartesian** robot arms are known for their **accuracy**, and **spherical** robot arms are suitable for handling **heavy loads.**



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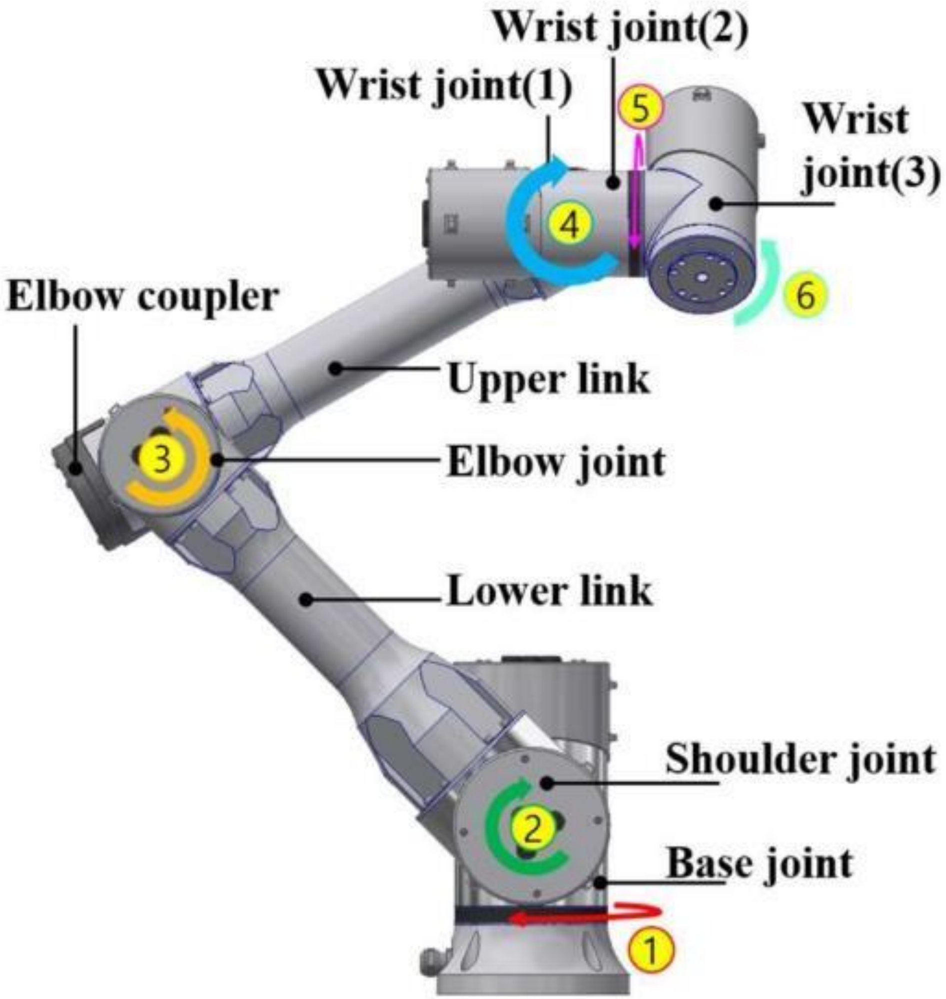
Manipulator structures

- **Articulated robot:** offers the most degrees of freedom possible and can consist of between 3 and 6 revolute joints (a revolute joint connects two segments and offers 1 degree of rotational freedom).

→ The most commonly recognized type of robotic manipulator in the industry, given the relatively high number of joints and segments, it provides the greatest advantage of **a wide range of motion**.



Robot characteristics

SENSORS FOR INPUT

CONTROL SYSTEMS FOR DECISION MAKING

EFFECTORS FOR OUTPUT

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SENSORS

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Sensory perception

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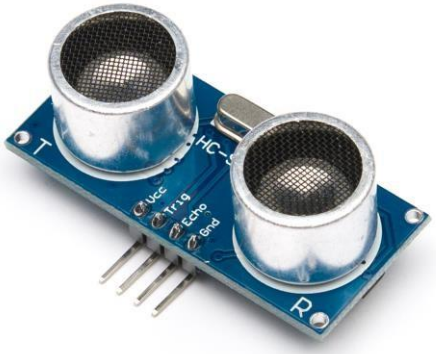
Sensors are devices that enable robots to perceive and gather information data from their environment, which is crucial for robots to make informed decisions.



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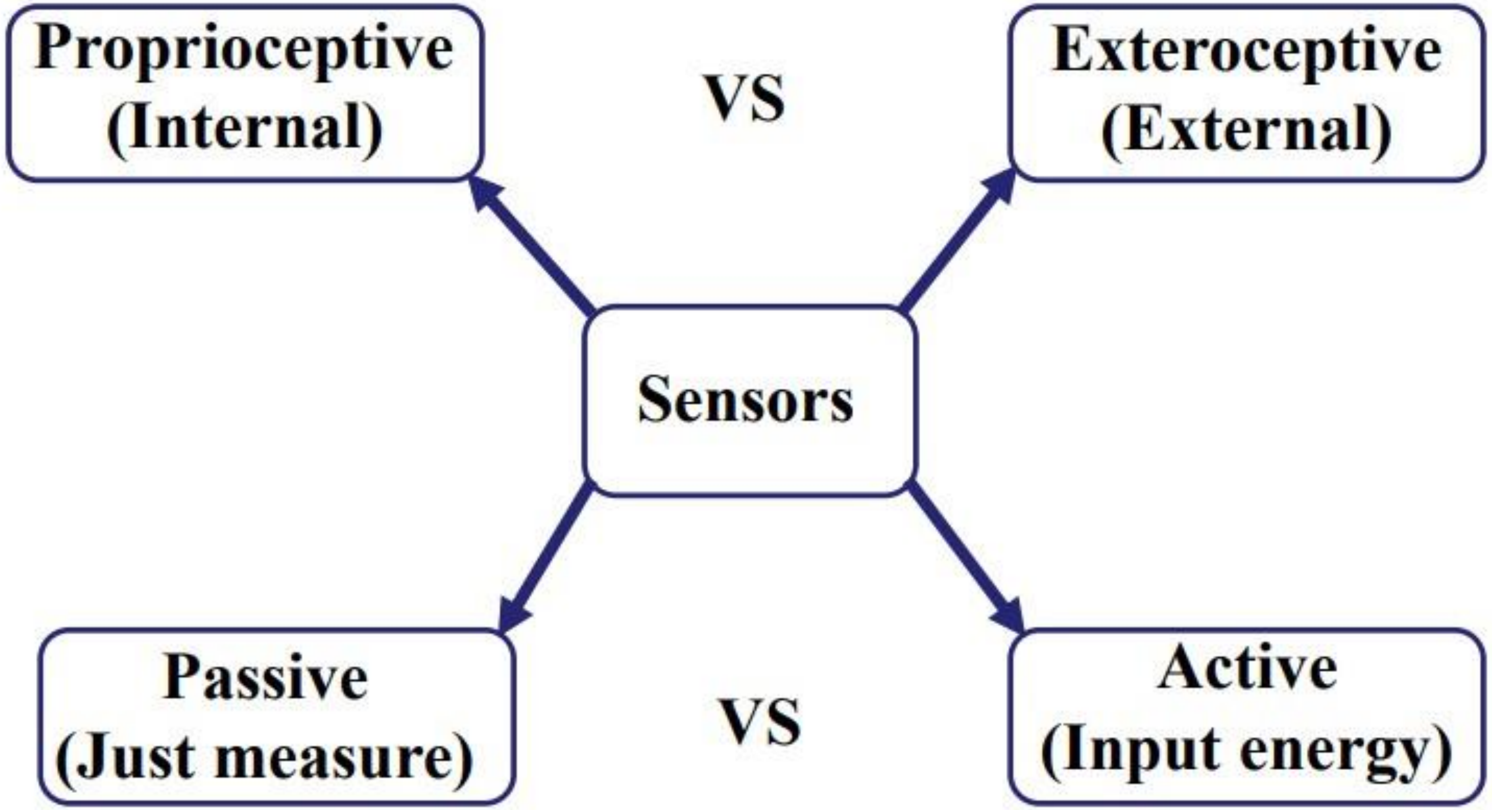
Sensor classification



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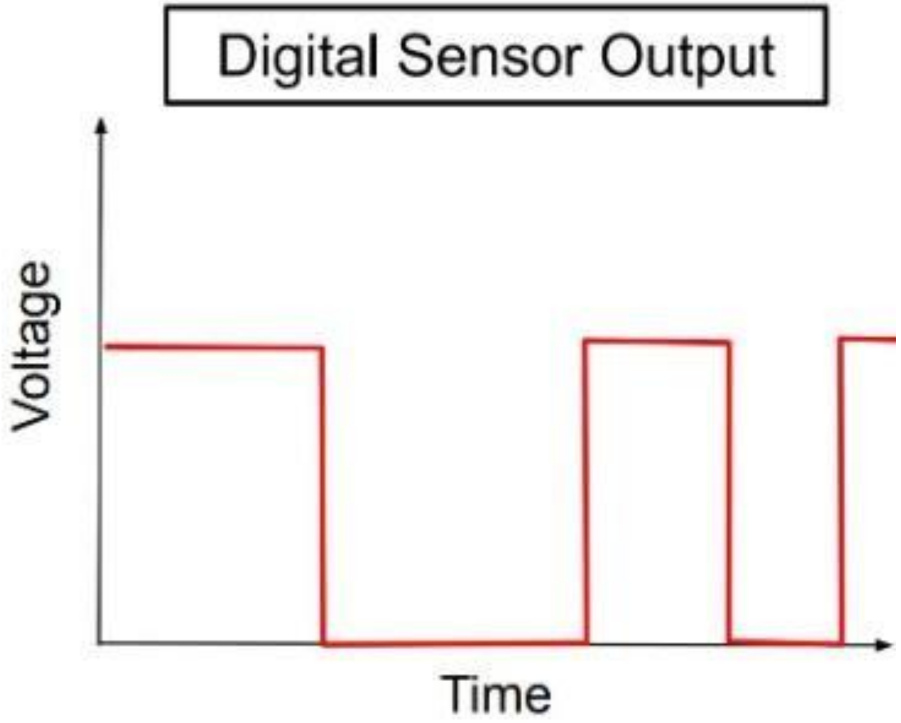
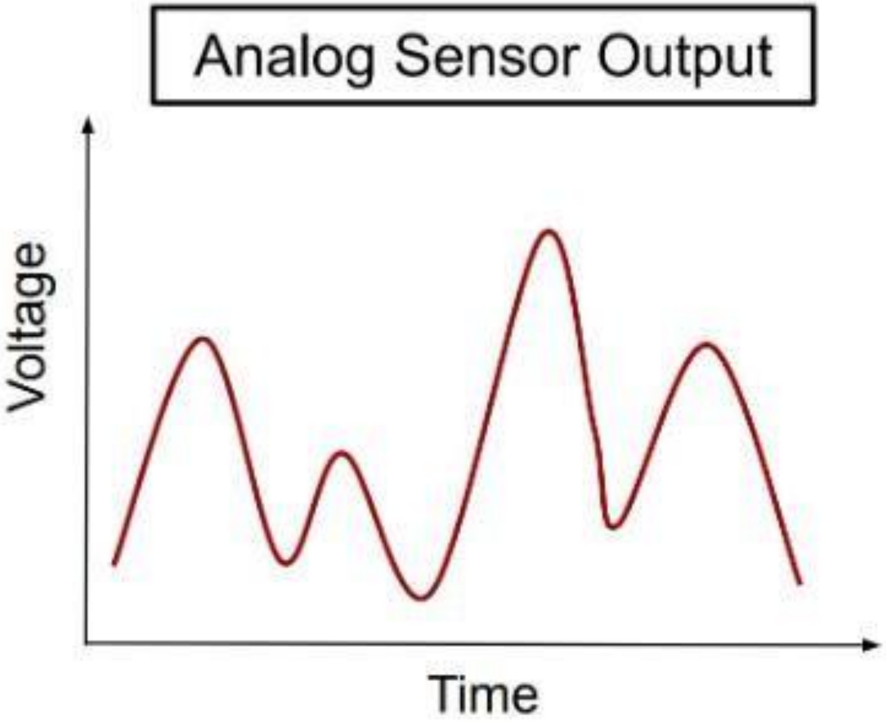
Sensor classification

Digital sensors, quantize data into discrete values (0-1)
Analog sensors, provide a direct representation of the measured physical quantity





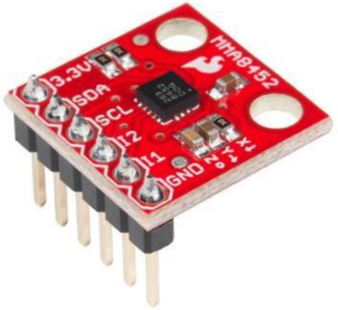
Sensor classification and types

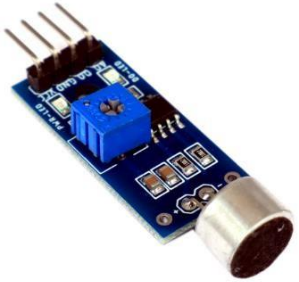
Classification	Sensor	Type	A/P
Tactile	Switches/bumpers	EC	P
	Optical barriers	EC	A
	Proximity	EC	A/P
Haptic	Contact arrays	EC	P
	Force/torque	EC/PC	P
	Resistive	EC	P
Motor/axis	Brush encoders	PC	P
	Potentiometers	PC	P
	Resolvers	PC	A
	Optical encoders	PC	A
	Magnetic encoders	PC	A
	Inductive encoders	PC	A
	Capacity encoders	EC	A

*PC: Proprioceptive, EC: Exteroceptive, P: Passive, A: Active

Sensor classification and types

Classification	Sensor	Type	A/P
Speed/motion	Doppler radar	EC	A
	Doppler sound	EC	A
	Camera	EC	P
	Accelerometer	EC	P
Identification	Camera	EC	P
	RFID	EC	A
	Laser ranging	EC	A
	Radar	EC	A
	Ultrasound	EC	A
	Sound	EC	P





*PC: Proprioceptive, EC: Exteroceptive, P: Passive, A: Active

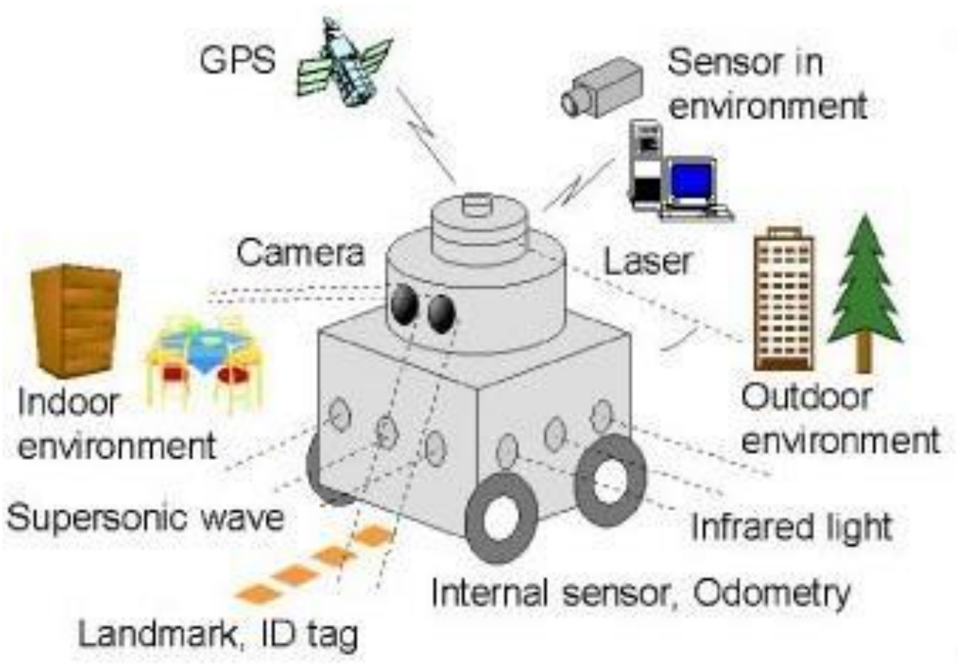
Sensor classification and types

Classification	Sensor	Type	A/P
Other sensors	Temperature	EC	A/P
	Humidity	EC	A/P
	Air pressure	EC	A/P
	Flow	EC/PC	A/P
	Particle	EC	A/P
	Carbon	EC	A/P

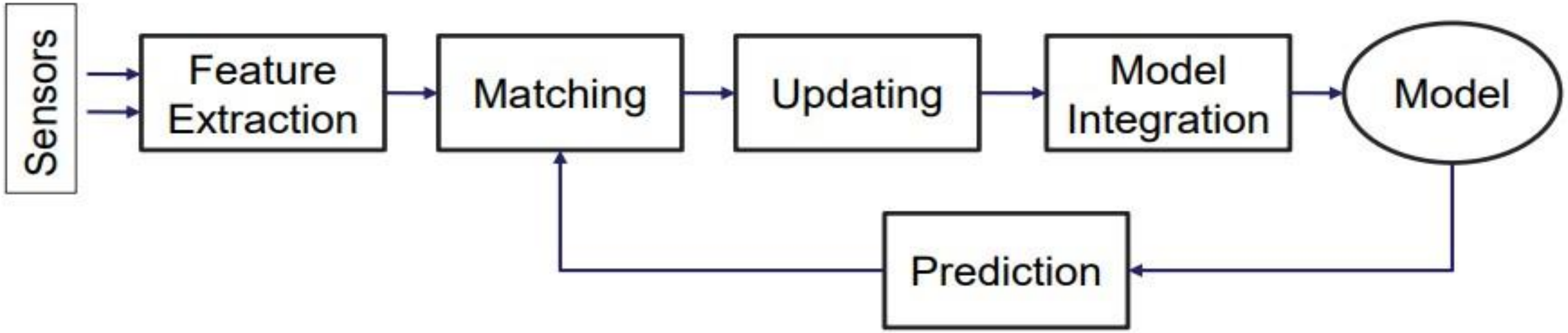


*PC: Proprioceptive, EC: Exteroceptive, P: Passive, A: Active

Localization



Perception process



- **Feature extraction – reduce noise, remove systematic errors, enhance data**
- **Matching – match data to existing model**
- **Update model – based on matched data**
- **Model integration – develop dynamic model of underlying system**
- **Prediction – use dynamic model to predict how world will change**

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IMAGE PROCESSING

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Image and video processing

Image processing - subclass of signal processing specifically concerned with pictures

Image processing areas:

- **Image compression:** concerned with how to decrease the redundancy of the image data to store or transmit data in an efficient form (lossless)
- **Image enhancement:** improve human perception of information in images, provide “better” input for other automated image processing techniques, reduce noise in an image and reveal features in the image
- **Image understanding:** process of interpreting regions, and objects in the image, to figure out what actually happens in the image

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Image enhancement

e.g Noise reduction

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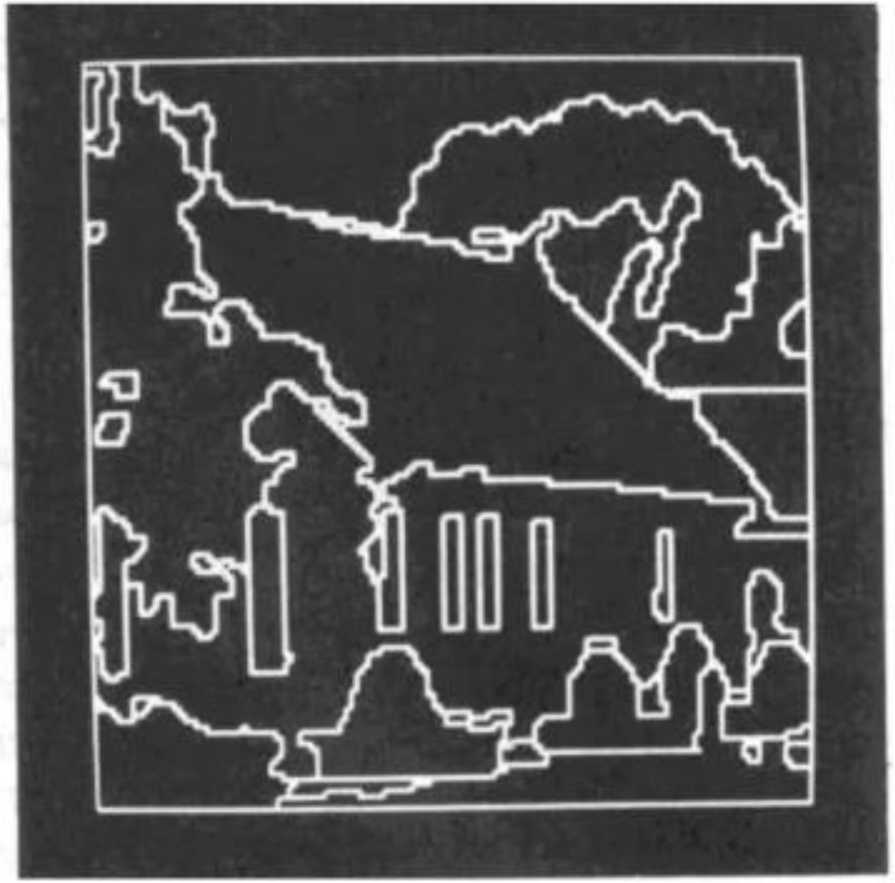
Data extraction



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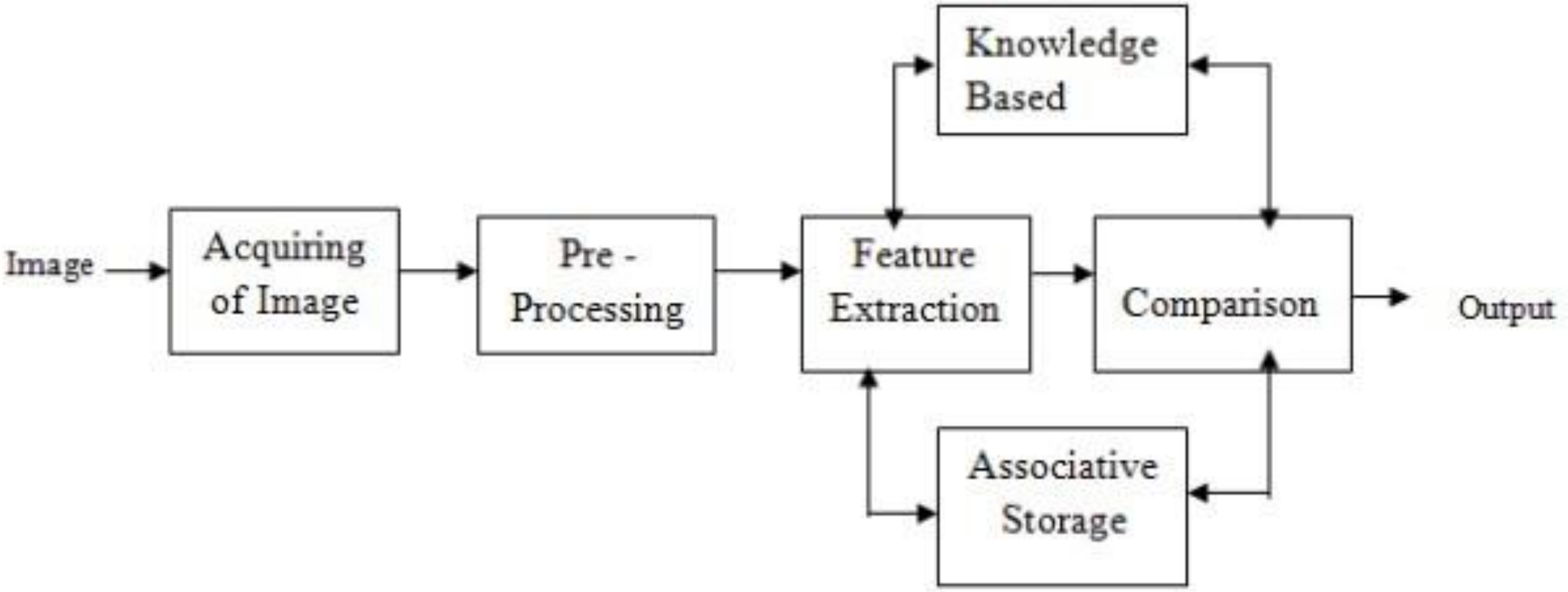
Digital Image processing system



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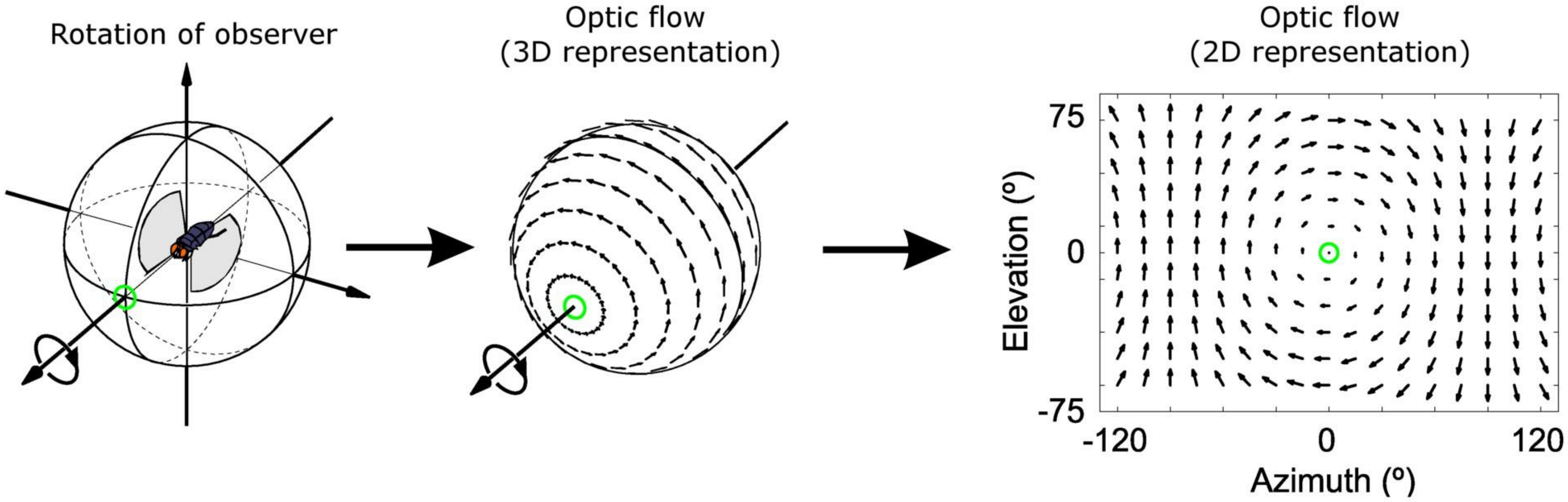
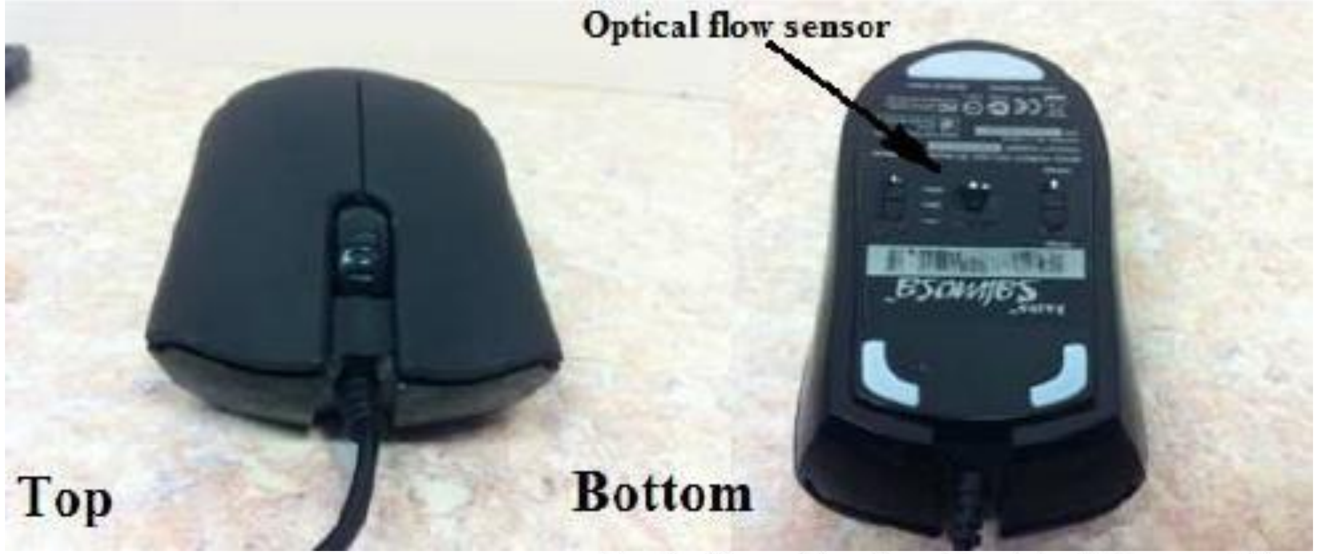
Optical or optic flow

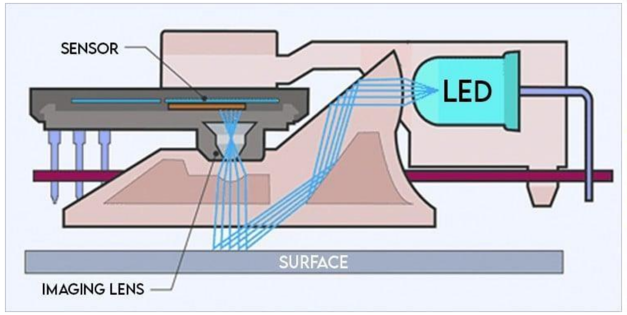
- Pattern of apparent motion of objects, surfaces, and edges in a visual scene.
- In robotics - encompasses techniques from image processing to navigation, including motion detection.



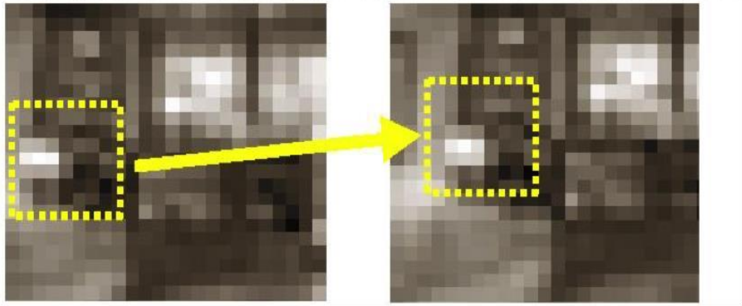
Optical flow - Mouse

- **Sizc of tkc optical sc→ısoí** - laígcí is gc→ıcíallQ bcttcí, ass"mi→ıg tkc otkcí mo"sc compo→ıc→ıts ca→ı ka→ıdlc tkc laígcí sizc. Sizcs ía→ıgc ríom **1G x 1G pixcls to «0 x «0 pixcls.**
- **Rcfícsk íatc** - it is kow ortc→ı tkc sc→ısoí samplcs imagcs as Qo" mo:c tkc mo"sc. Iastcí is gc→ıcíallQ bcttcí, ass"mi→ıg tkc otkcí mo"sc compo→ıc→ıts ca→ı píoccss tkcm. Ratcs ía→ıgc ríom 1500 to **G000 samplcs pcí scco→ıd.**
- **Imagc píoccssi→ıg íatc** - is a combi→ıatio→ı or tkc sizc or tkc optical sc→ısoí a→ıd tkc ícrícsk íatc. Agai→ı, rastcí is bcttcí a→ıd íatcs ía→ıgc ríom 0.4®6 to 5.® mcgapixcls pcí scco→ıd.





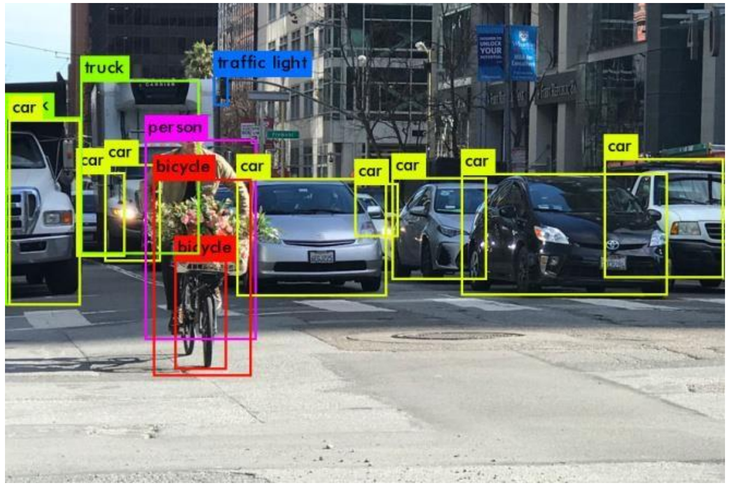
Interpreting differences in image fingerprints can be translated to movement of the mouse

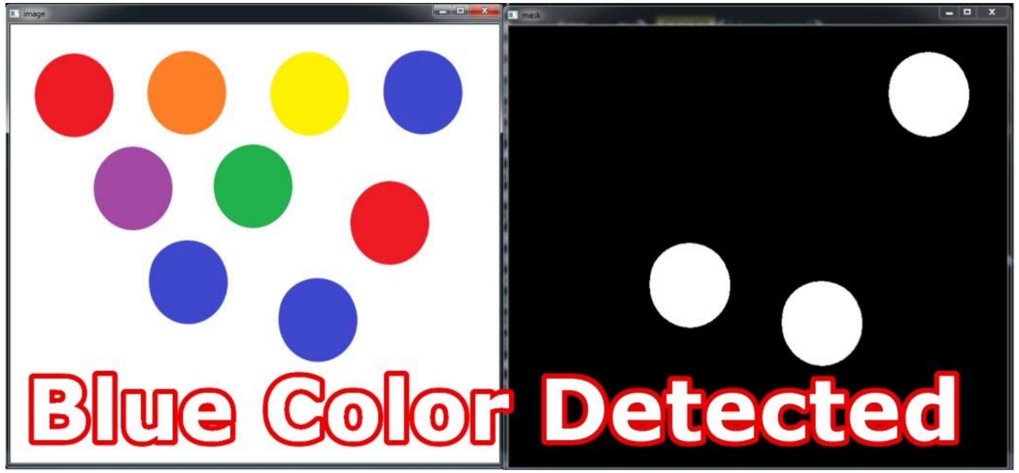


Computer Vision systems – OpenCV

OpenCV (Open Source Computer Vision Library) is an open-source computer vision and machine learning software library. OpenCV was built to provide a common infrastructure for computer vision applications and to accelerate the use of machine perception in the commercial product.

- It has C++, Python, Java and MATLAB interfaces and supports Windows, Linux, Android and Mac OS. OpenCV leans mostly towards real-time vision applications

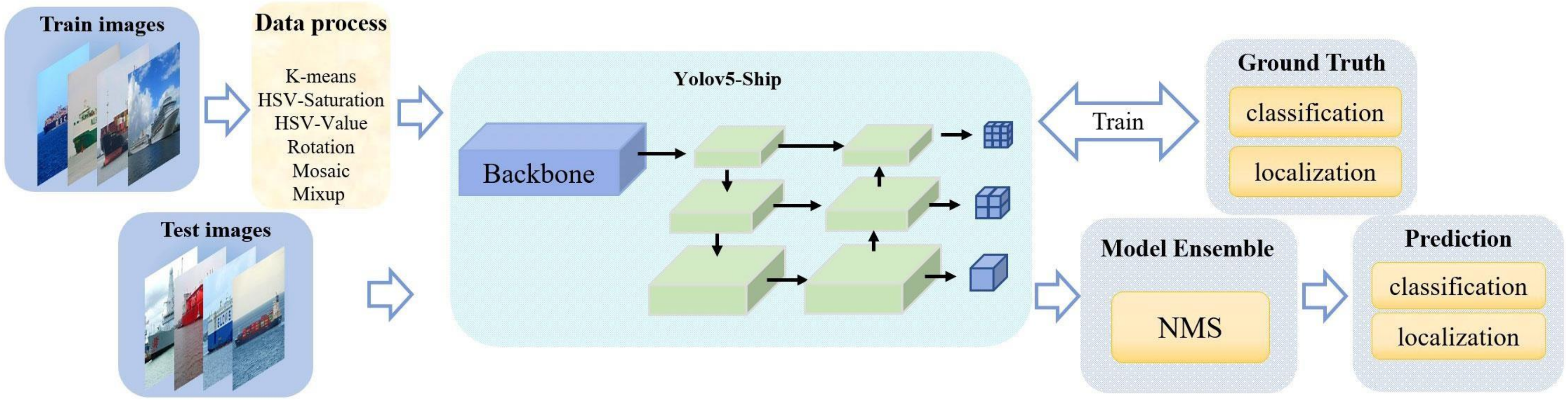




Computer Vision systems - YOLO v5

YOLOv5 is a model in the You Only Look Once (YOLO) family of computer vision models. YOLOv5 is commonly used for detecting objects.

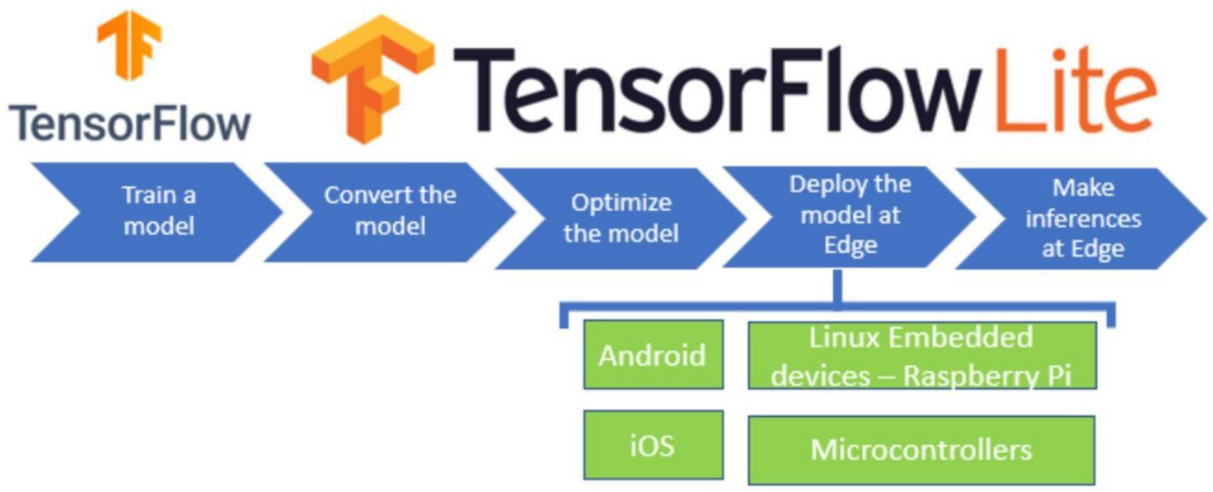
- Visual detection technology is essential for an unmanned surface vehicle (USV) to perceive the surrounding environment; it can determine the spatial position and category of the object, which provides important environmental information for path planning and collision prevention of the USV. During a close-in reconnaissance mission, it is necessary for a USV to swiftly navigate in a complex maritime environment.

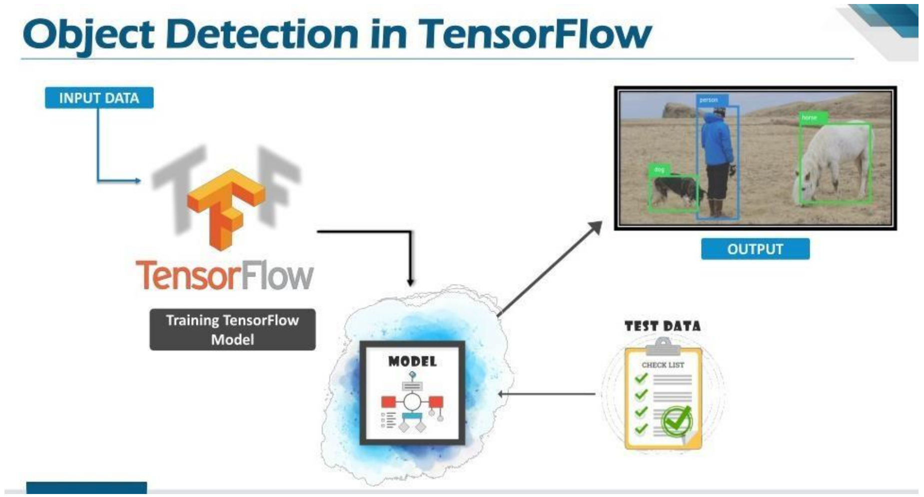


Computer Vision systems - TensorFlow

TensorFlow is an open-source machine learning framework developed by Google. It is widely used for various tasks in artificial intelligence, including deep learning and neural network implementations. TensorFlow provides a flexible and comprehensive ecosystem for building, training, and deploying machine learning models across a range of platforms and devices.

- TensorFlow primarily uses Python as its programming language
- TensorFlow provides APIs and bindings for other programming languages such as C++, Java, and Swift





ACTUATORS

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Powering Movement and Action

An actuator is a mechanical or electromechanical device responsible for converting energy into physical motion. Actuators are essential components in robotics where controlled movement is required.

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Actuator types

- Linear – move objects along a straight line and use a belt and pulley, rack and pinion, or ball screw to convert electric motor rotation into linear motion

- Rotary - convert energy into rotary motion through a shaft to control equipment speed, position, and rotation.

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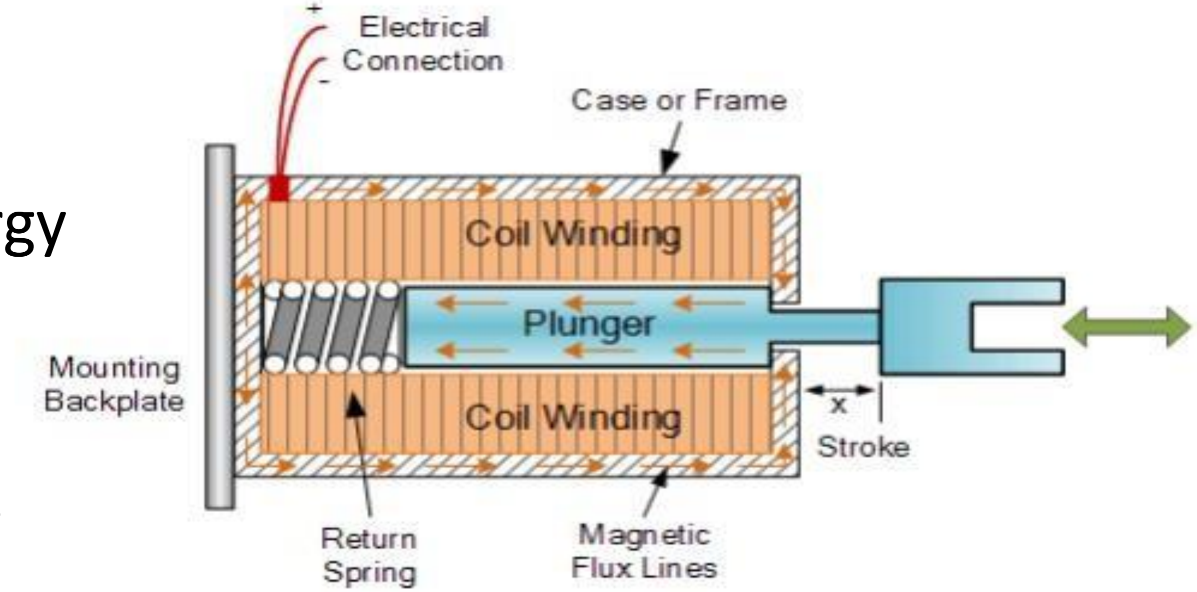
Actuator power source

- Pneumatic – transform pneumatic energy from compressed air
- Hydraulic – transform hydraulic energy into mechanical via pumps
- Electromagnetic – transform electric energy into mechanical



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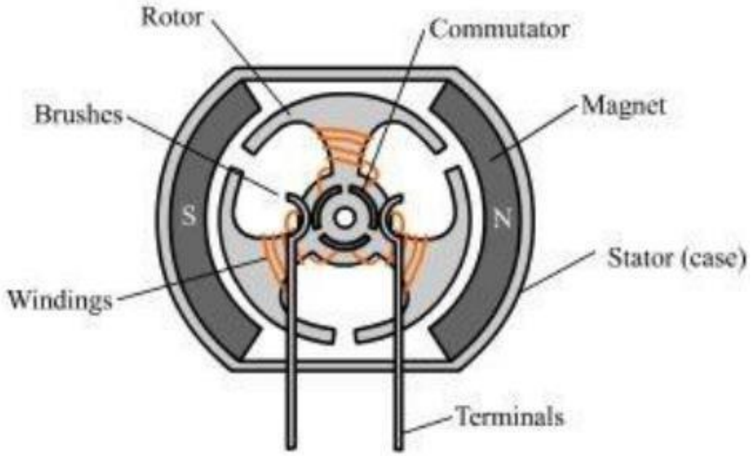
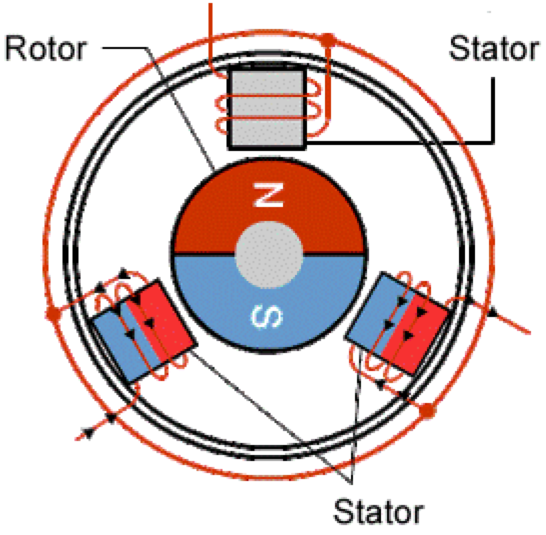
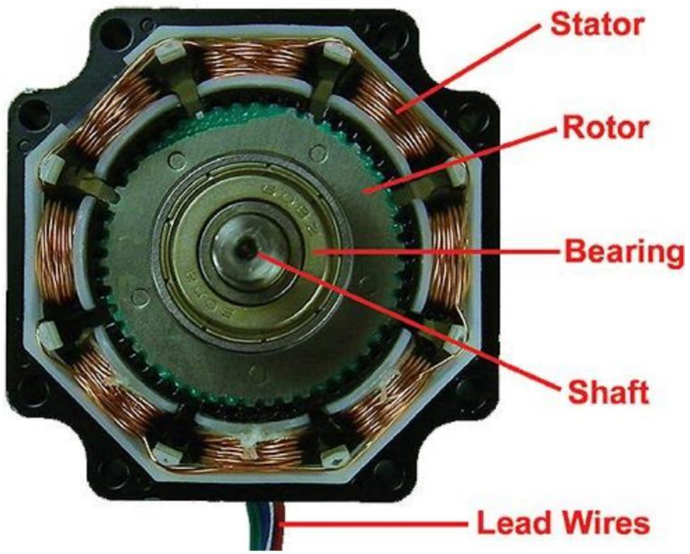
Motor types

- Permanent Magnet DC Motors
- Brushless Motors
- Stepper Motors
- DC Servo Motors
- AC Servo Motors







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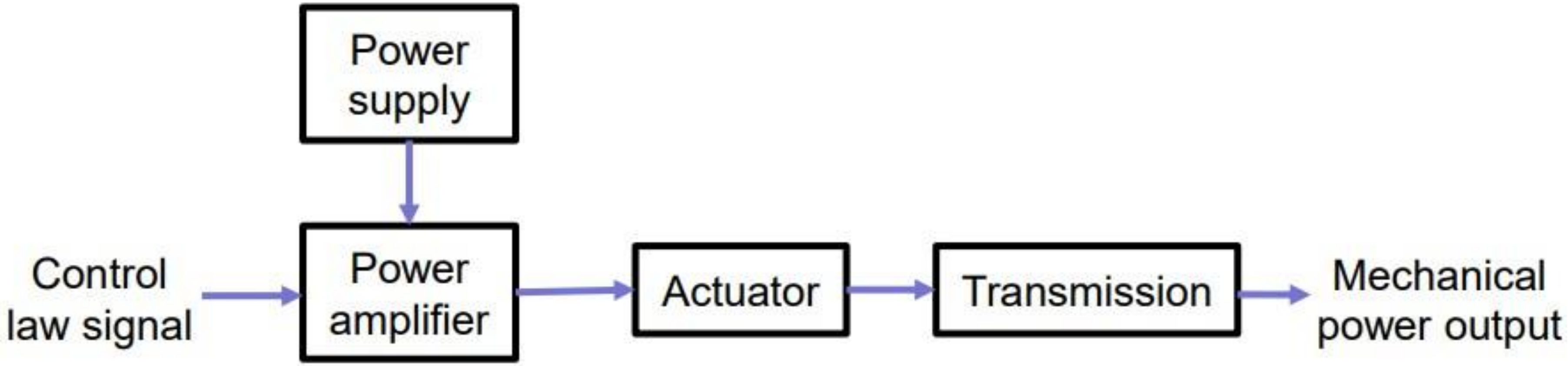
Block Diagram



- **Power supply – supply primary power**
  - ➢ **Electric voltage**
  - ➢ **Hydraulic fluid**
  - ➢ **Pneumatic air**

KINEMATICS AND DYNAMICS

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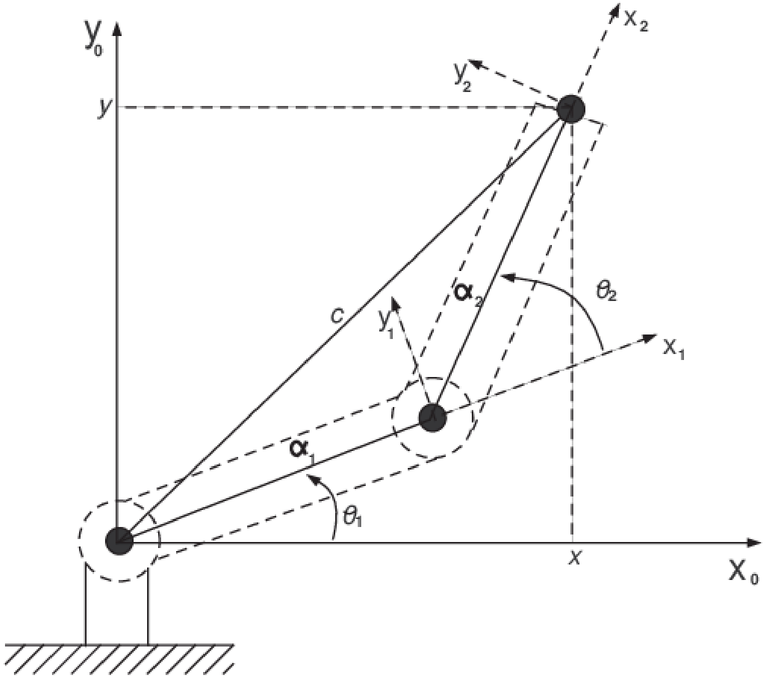
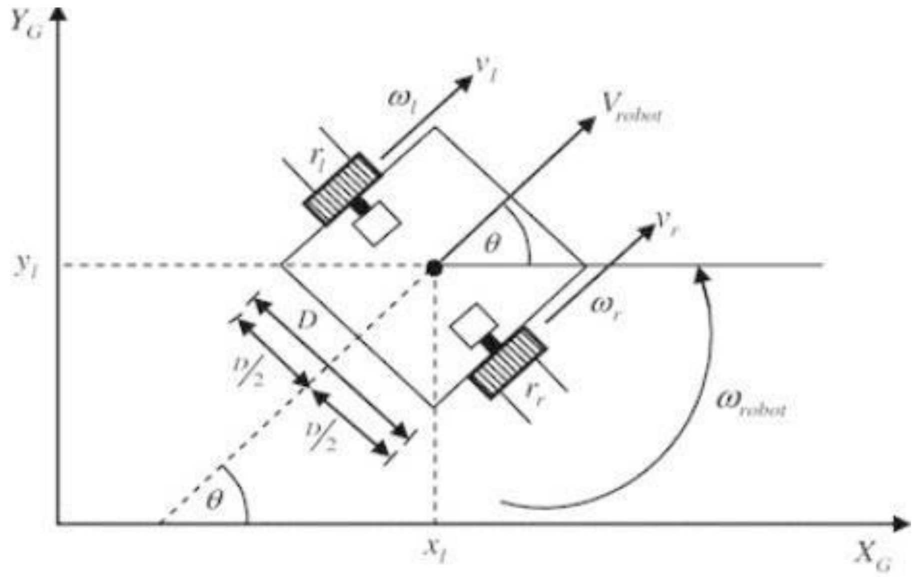
Kinematics

“The study of the motion of mechanical points, bodies, and systems without consideration of their associated physical properties and the forces acting on them. ”





Types of Kinematics

Forward/Direct:

- **Manipulator robot:** calculating the position and orientation of the end effector (usually a tool or gripper) given the joint angles or positions of its joints.
- **Mobile robot:** determining the robot's position and orientation in its environment based on its wheel velocities and steering commands.

Inverse:

- **Manipulator robot:** calculating the joint angles or positions required to position the end effector at a specified location and orientation.
- **Mobile robot:** determining the wheel velocities necessary to achieve a desired trajectory or pose in the robot's environment.

Types of Kinematics

Differential/Instantaneous:

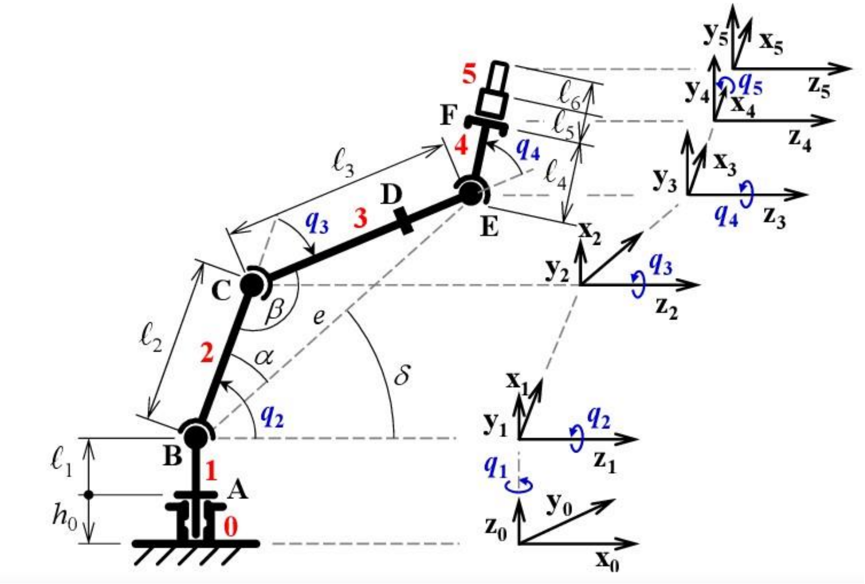
- **Manipulator robot:** how changes in joint velocities affect the velocity of the end effector
- **Mobile robot:** describe how changes in wheel velocities affect the robot's linear and angular velocities in its environment.

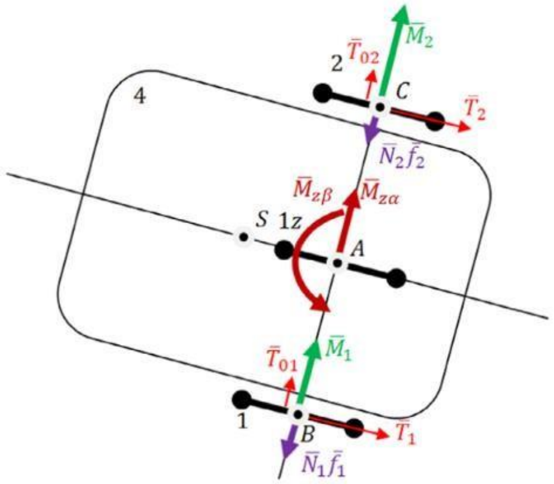
Inverse Differential:

- **Manipulator robot:** calculating the joint velocities necessary to achieve the desired velocity of the end effector
- **Mobile robot:** determining the wheel velocities required to achieve a desired velocity of the robot's body.

Dynamics

“The dynamics of a robot refer to its behavior with respect to forces, torques, accelerations, and motions as it interacts with its environment”





Types of Dynamics

Forward/Direct:

- **Manipulator robot:** joint trajectories, velocities, and accelerations are calculated from known forces and torques produced by actuators in the robot joints.
- **Mobile robot:** determining the velocity of the robot's body from known forces and torques produced by the actuator in the robot wheels.

Inverse:

- **Manipulator robot:** joint motion (e.g trajectories) is known, while torques and forces producing the motion must be calculated.
- **Mobile robot:** determining the wheels' forces and torques, while the robot's body velocity is known.

Dynamics Analysis

Double role in robotics:

- Dynamic model is central to simulation of robot mechanism
- Dynamic equations offer relevant information for design of robot controllers

Enables:

- Torques necessary to compensate for the gravity forces of robot segments
- The differences in moments of inertia occurring during the robot motion
- Dynamic coupling caused by simultaneous movements of all robot segments.

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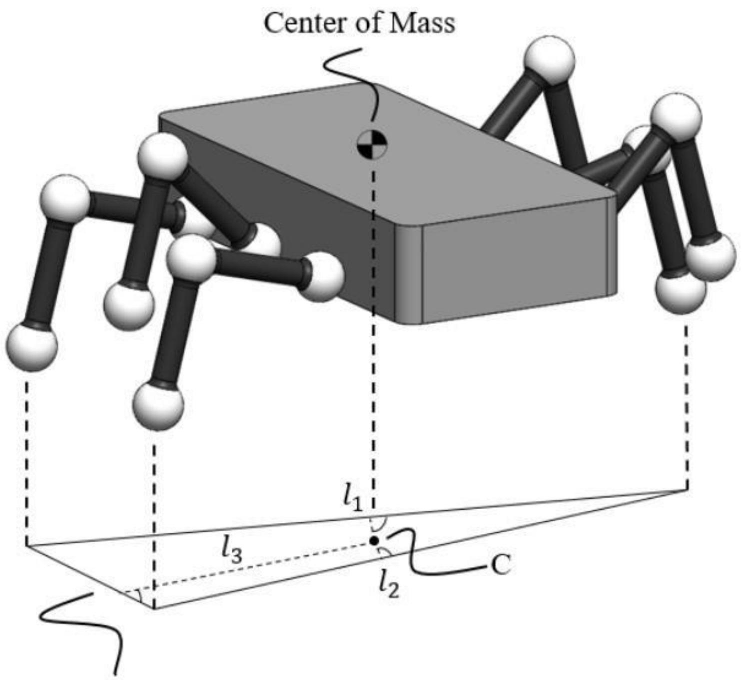
Static Balance

The ability of a robot to maintain its equilibrium and remain stable without any motion or externa assistance.

Achieves static balance if:

- Projection of its center of mass to the ground is within the support polygon
- The robot’s velocity and acceleration are negligible

If stability margin is close to zero → robot falls

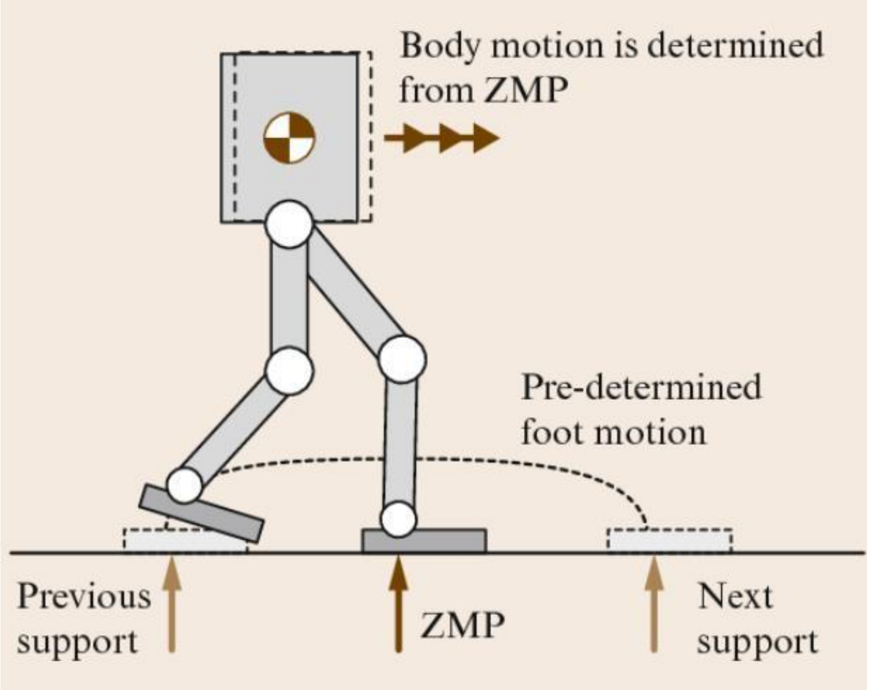


Support polygon
(convex hull of the robot’s contact points)

Dynamic Balance

The ability of a robot to maintain stability and control its motion while experiencing external forces, disturbances, or changes in its environment.

- In a stable gait, the ZMP remains within the support polygon (not the edge)
- A biped robot alternates between a single support phase and double support phase to move the ZMP from within one foot to the other.

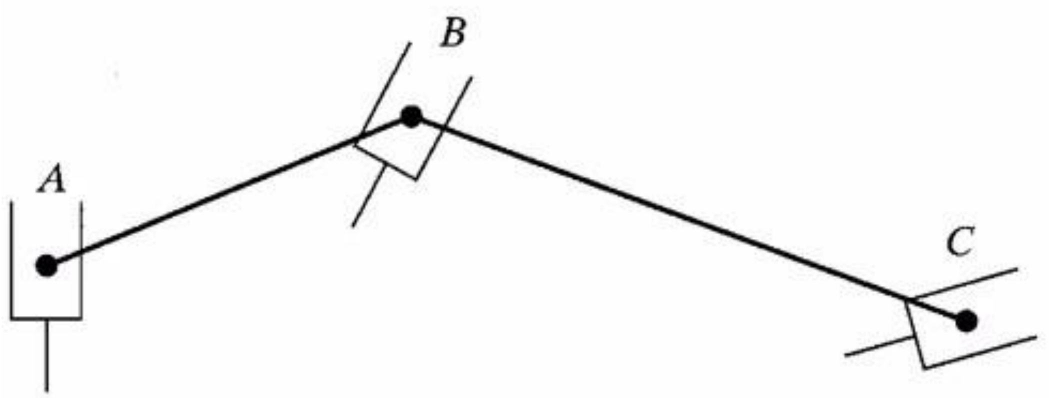


Zero movement point (ZMP) is the point of the ground plane around which the sum of the horizontal rotation momentums of the gravitational and dynamic forces is zero.

Trajectory and path planning

Path: is an ordered locus of points in the space, which a robot should follow. It is a pure geometric description of motion.

Trajectory: a path on which timing law is specified e.g. velocities and accelerations in each point (timing constraints)



Sequential robot movements in a path.

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CONTROL SYSTEM

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The brain of operation

"A controller is a computing unit that controls the motion of the robot parts in a programmable manner. The controller could be microcontrollers, specialized controllers, or computers."

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Control method and types

Robot control systems play a vital role in the operation of manipulator robots, as they govern the robot's movements and ensure that it performs its tasks accurately and efficiently.

There are two main types of control systems used in manipulator robots:

- Open-loop control systems
- Closed-loop control systems

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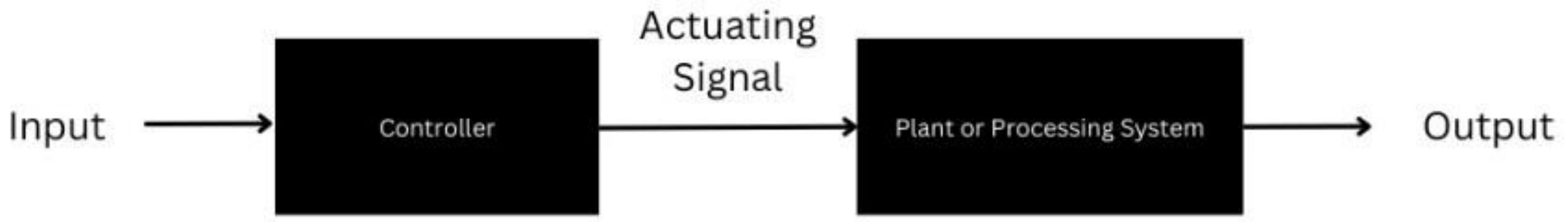
Open-loop control systems

Open-loop control systems are characterized by their **lack of feedback**, meaning that the robot's movements are determined solely by the input commands provided by the controller.

In an open-loop system, the controller sends a series of commands to the robot's actuators, which then execute the movements without any feedback on the actual position or performance of the robot.



Open Loop System

Open-loop control systems

Advantages:
- simplicity,
- reduced system complexity,
- lower costs

Disadvantages:
- system cannot compensate for errors or disturbances that may occur during operation,
- reduced accuracy and repeatability

→ typically used in applications where the required level of precision and accuracy is relatively low, and the risk of errors or disturbances is minimal

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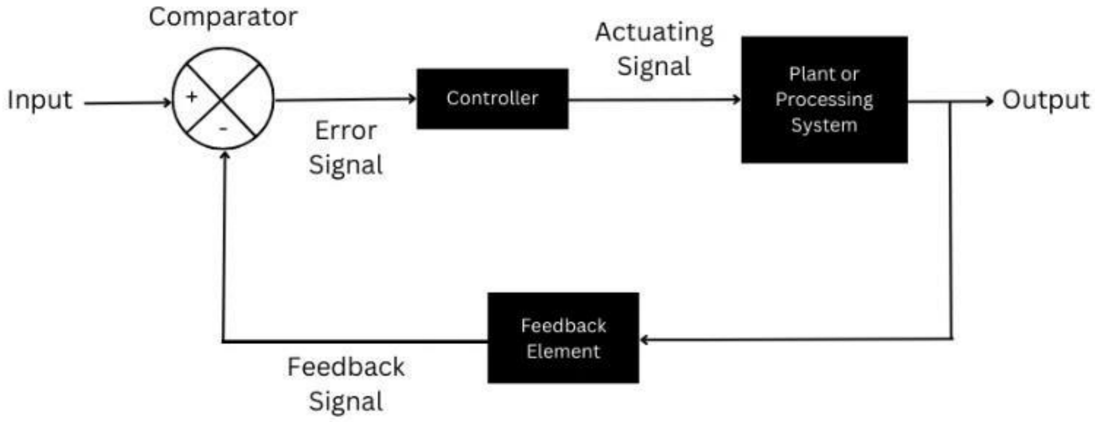
Closed-loop control systems

Closed-loop control systems, in contrast to open-loop systems, incorporate **feedback** mechanisms and more complex algorithms to monitor and adjust the robot's movements in real-time.

The controller sends commands to the robot's actuators, while sensors continuously measure the robot's actual position and performance. This feedback is then used by the controller to adjust the commands, ensuring that the robot's movements closely match the desired position and trajectory.



Closed Loop System

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Closed-loop control systems

Advantages:

- compensate for errors and disturbances that may occur during operation
- accuracy and repeatability.

Disadvantages:

- more complex hardware and software,
- increased costs and system complexity

→ typically used in applications where high precision and accuracy are required, such as assembly, inspection, or machining tasks.

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Control Method

Many industrial manipulators are servo-controlled. Thus, each joint actuator is operated under closed-loop control, allowing the joint to be positioned accurately anywhere within its range of movement.

Cheaper and less sophisticated, end of market are pick-and-place or bang-bang robots. These have non servo-controlled actuators which will only stop moving when they reach a mechanical end-stop, or are turned off.

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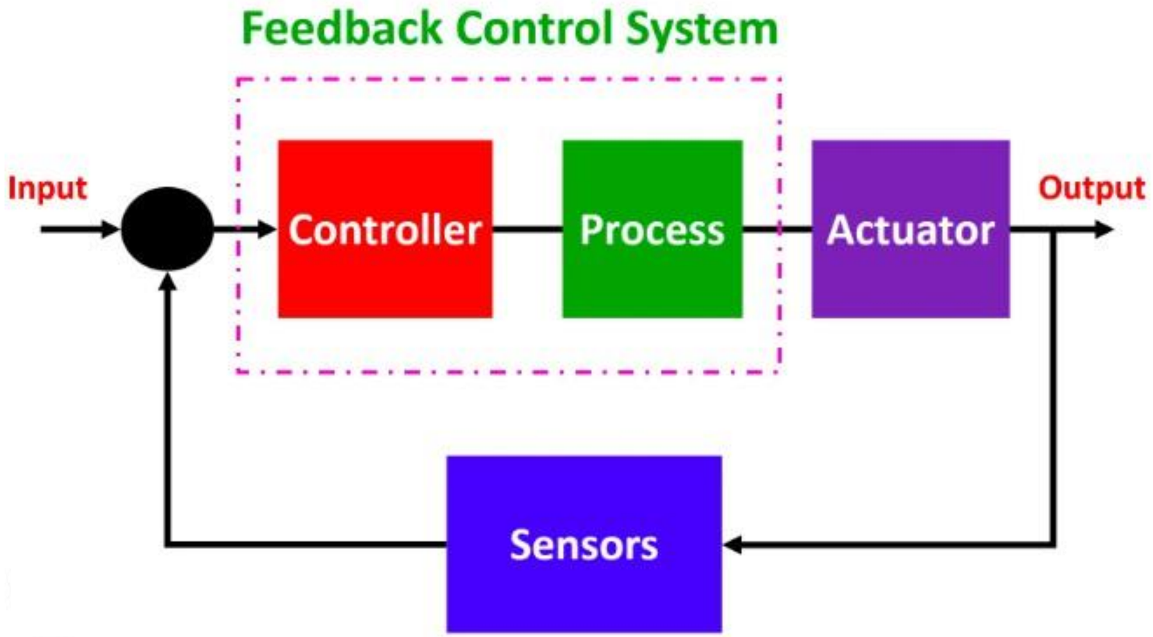
Robot controller

The controller takes feedback from sensors, controlling the outputs of the actuators so the robot moves sequentially to accomplish its task.

- The sensors and actuators are interfaced with the controller through hardware interfaces.
- The controllers can also have a user interface for reprogramming or human inputs.



Controller types

1. Proportional controllers - resist error by applying an opposing influence that is proportional to the error.
2. Integral controllers - detect and correct trends in error over time.
3. Derivative controllers - detect and resist abrupt changes in the system.

1. Proportional and integral controllers (PI)
2. Proportional and derivative controllers (PD)
3. Proportional integral derivative control (PID)

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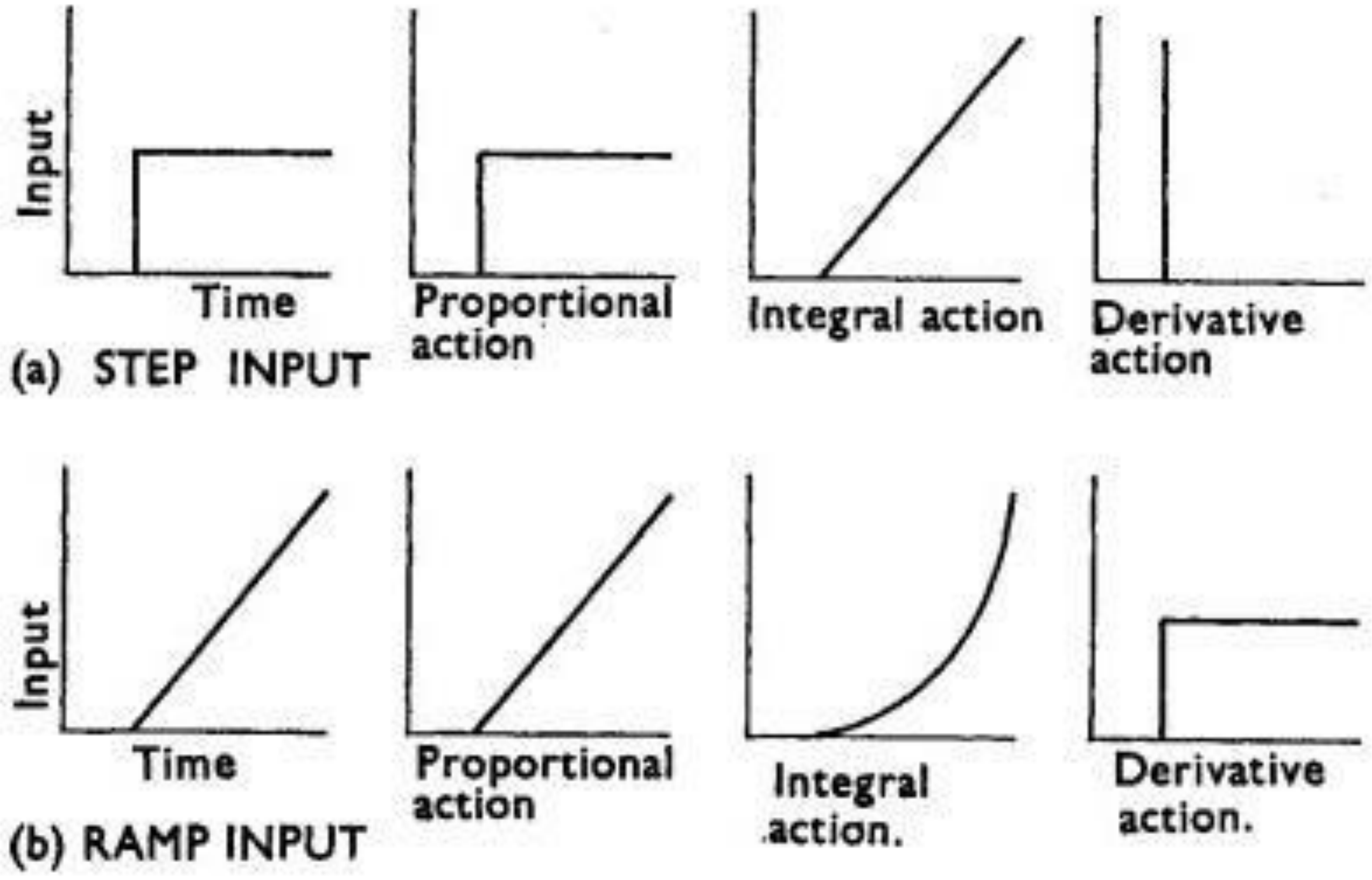
Controller types



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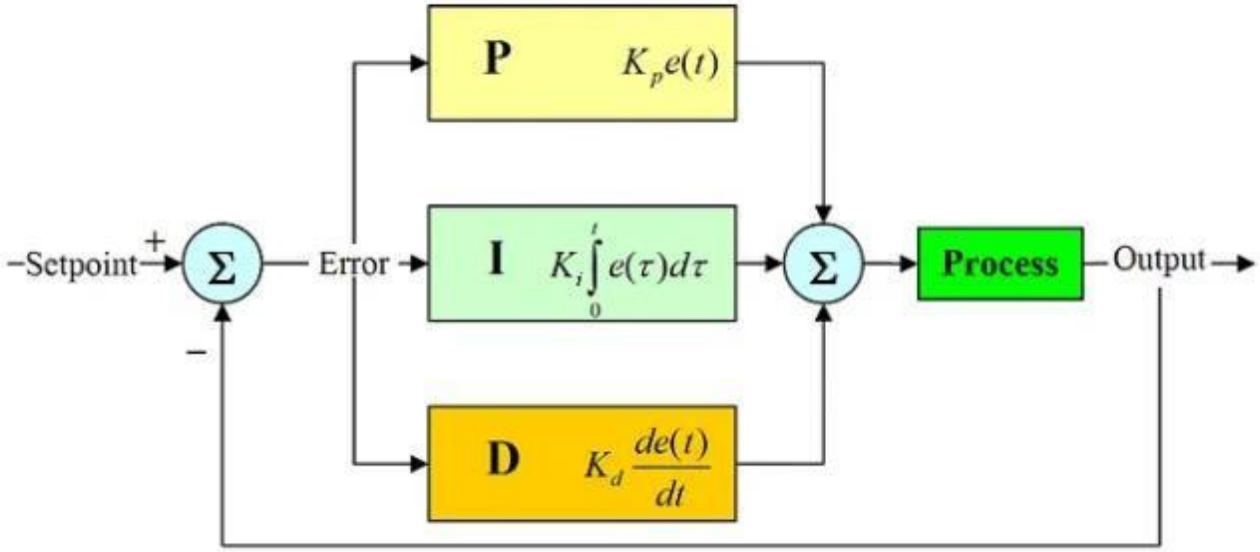
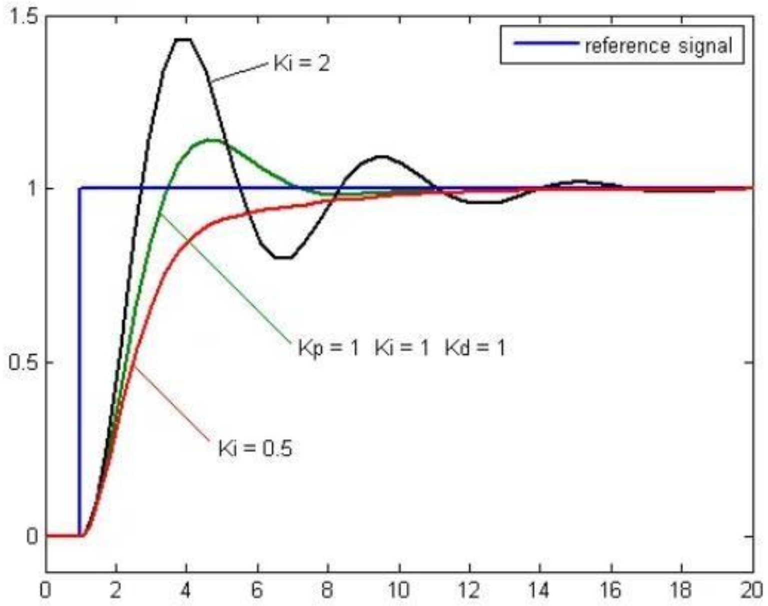
PID controllers

The basic idea behind a PID controller is to read a sensor, and then compute the desired actuator output by calculating proportional, integral, and derivative responses and summing those three components to compute the output.

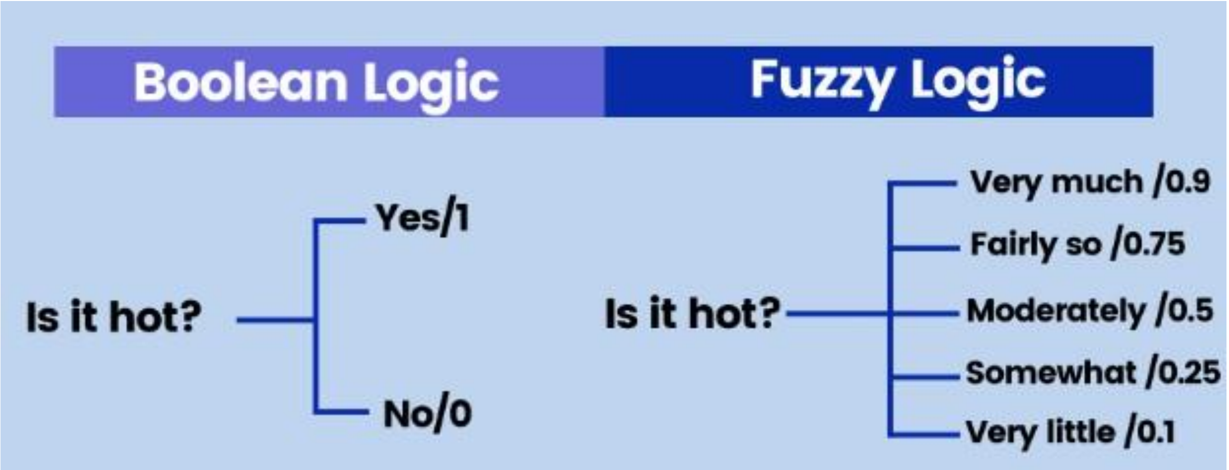




Fuzzy logic

- Fuzzy – “not clear, distinct, or precise; blurred”

- Fuzzy logic is an approach to variable processing that allows for multiple possible truth values to be processed through the same variable.



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Typical Energy Sources

Electric Batteries:

- Rechargeable battery types like lithium-ion, nickel-metal hydride, and lead-acid.
- Non-rechargeable battery types such as alkaline and lithium primary cells.

Power Adapters and Cords:

- Direct current (DC) power from a wall outlet through an adapter.
- Alternating current (AC) directly from power outlets for larger industrial robots.

Solar Power:

- Solar panels that convert light energy into electrical energy, suitable for autonomous outdoor robots.

Wireless Energy Transfer:

- Inductive charging systems for automated and self-charging robots.
- Electromagnetic fields to transfer energy between two coils, a transmitter, and a receiver.

Pneumatic and Hydraulic Power:

- Compressed air or fluids to power robotic actuators, common in industrial automation.

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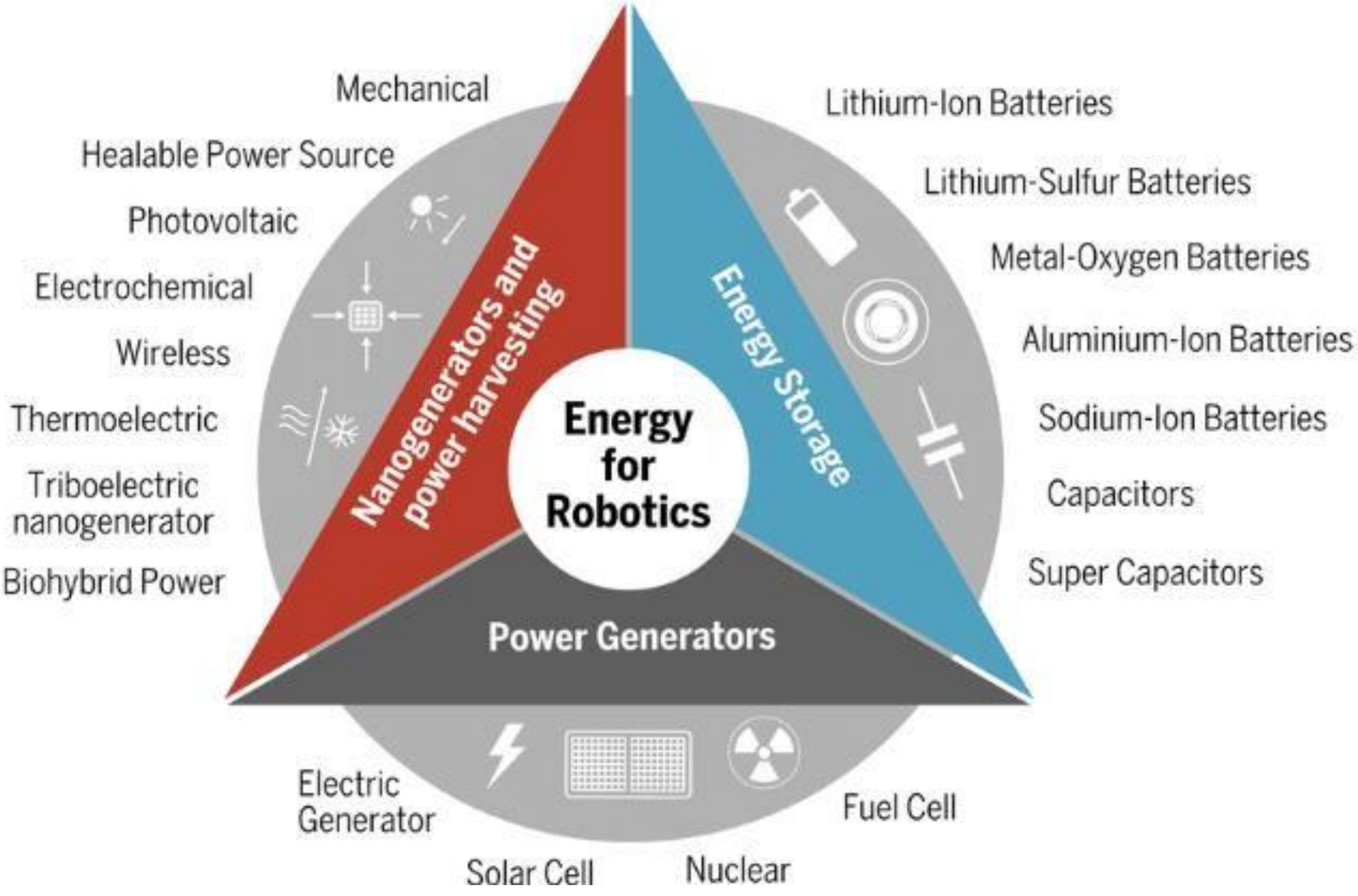
Typical Energy Sources



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PROGRAMMING AND SIMULATIONS

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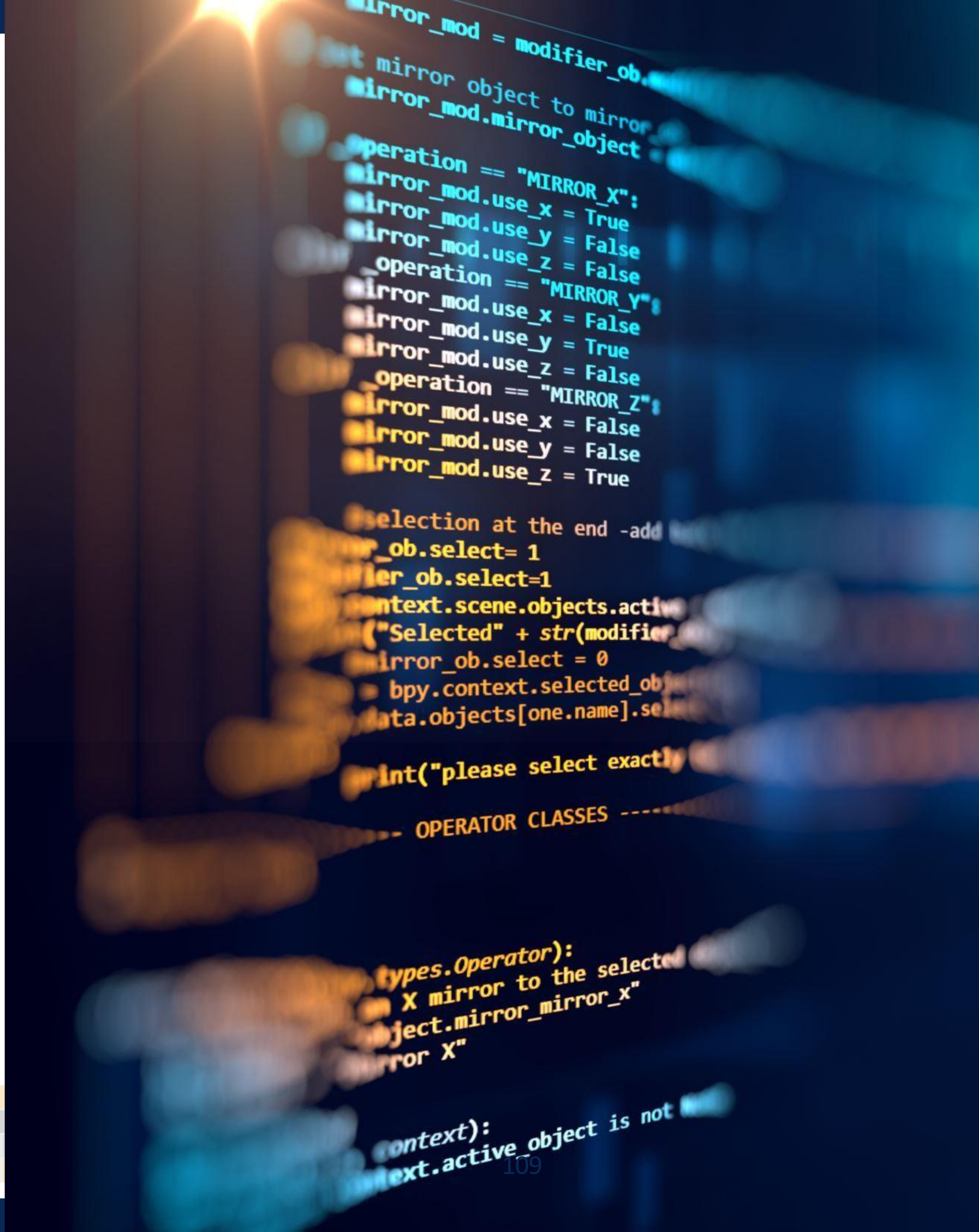
Programming robots

Languages :

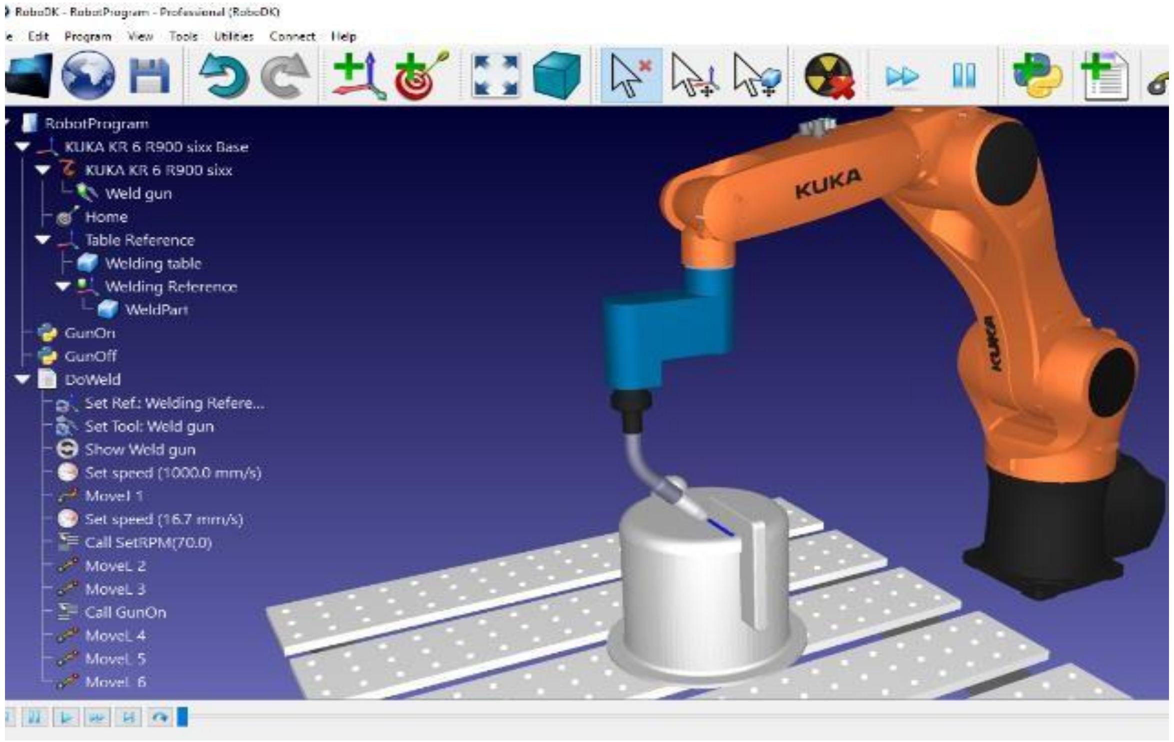
- C/C++
- Python
- Java
- Scratch
- MatLab

Programming environments:

- Arduino IDE
- LabVIEW
- RoboDK
- ROS



RoboDK is an offline programming and simulation software for industrial robots. The simulation software can be used for many manufacturing projects including welding, pick and place, packaging and labelling etc.



ROS

The Robot Operating System (ROS) is an open-source, meta-operating system for robots. It provides the services expected from an operating system, including hardware abstraction, low-level device control, implementation of commonly-used functionality, message-passing between processes, and package management. Designed to encourage collaborative robotics software development, ROS provides tools and libraries for obtaining, building, writing, and running code across multiple computers.

Open-Source Framework: ROS is freely available for use and contribution, fostering an open community of developers.
Modularity: The system consists of a large number of independent packages or modules, allowing for a plug-and-play architecture.
Tools and Libraries: It offers numerous tools and libraries that aid in the development of robot applications.
Language-Independent: The ROS framework is compatible with several programming languages, though most common ROS tools are written in Python and C++.
Distributed Computing: ROS has a peer-to-peer architecture, allowing processes to run on different machines and communicate with each other.

Hardware Abstraction: It provides a way to access underlying hardware without needing to write hardware-specific code.
Device Drivers: ROS includes sets of drivers for controlling a wide variety of sensors and actuators.
Package Management: ROS has a package management system to help with installing, managing, and updating software components.
Simulation Capabilities: ROS is integrated with simulation tools like Gazebo, which allows for testing of software in a virtual environment before deploying it on a real robot.
Community and Support: ROS has a large and active community, providing extensive resources, documentation, and support for developers.

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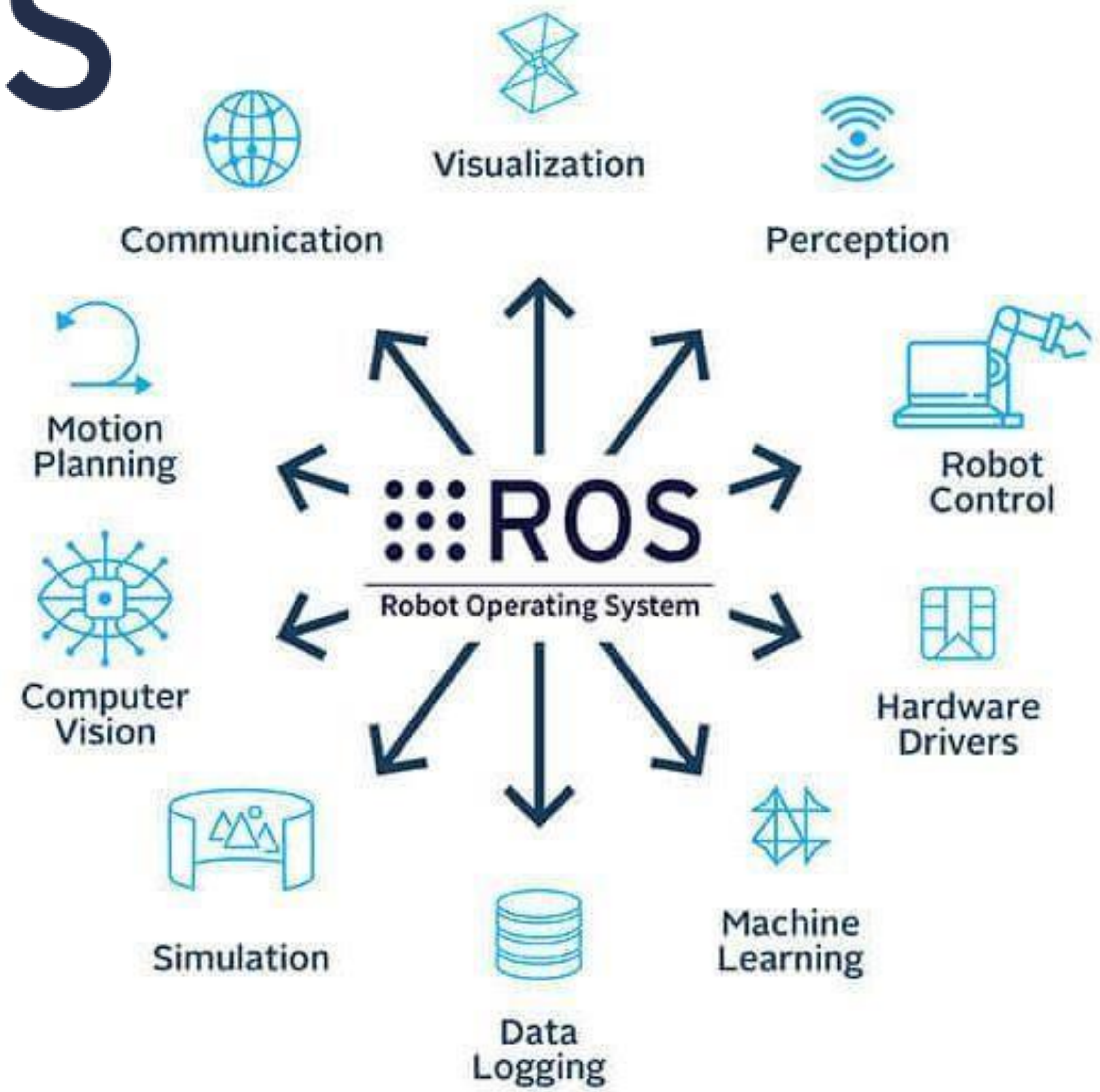
ROS



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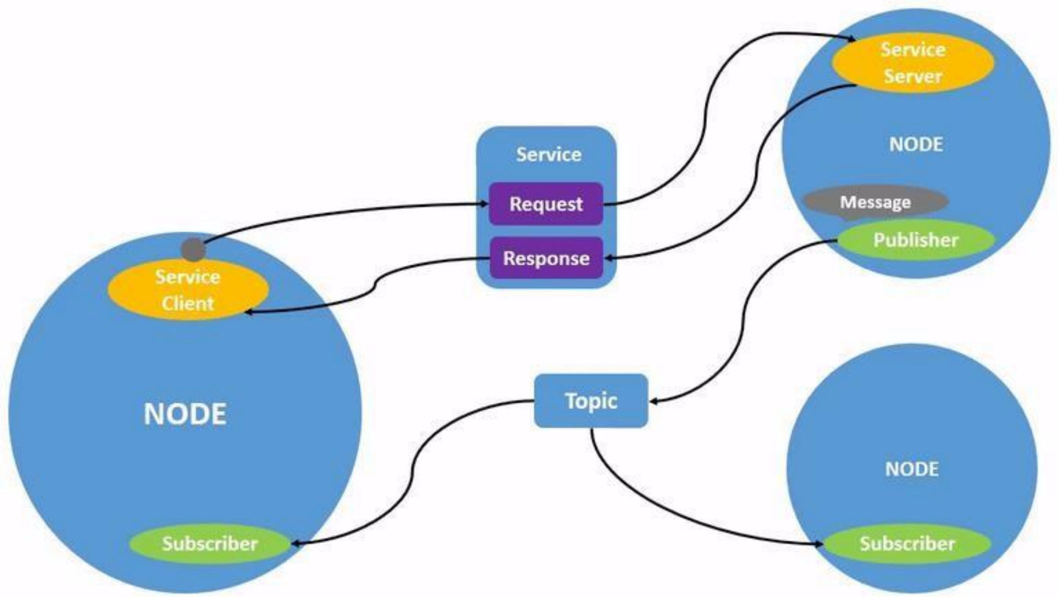
ROS

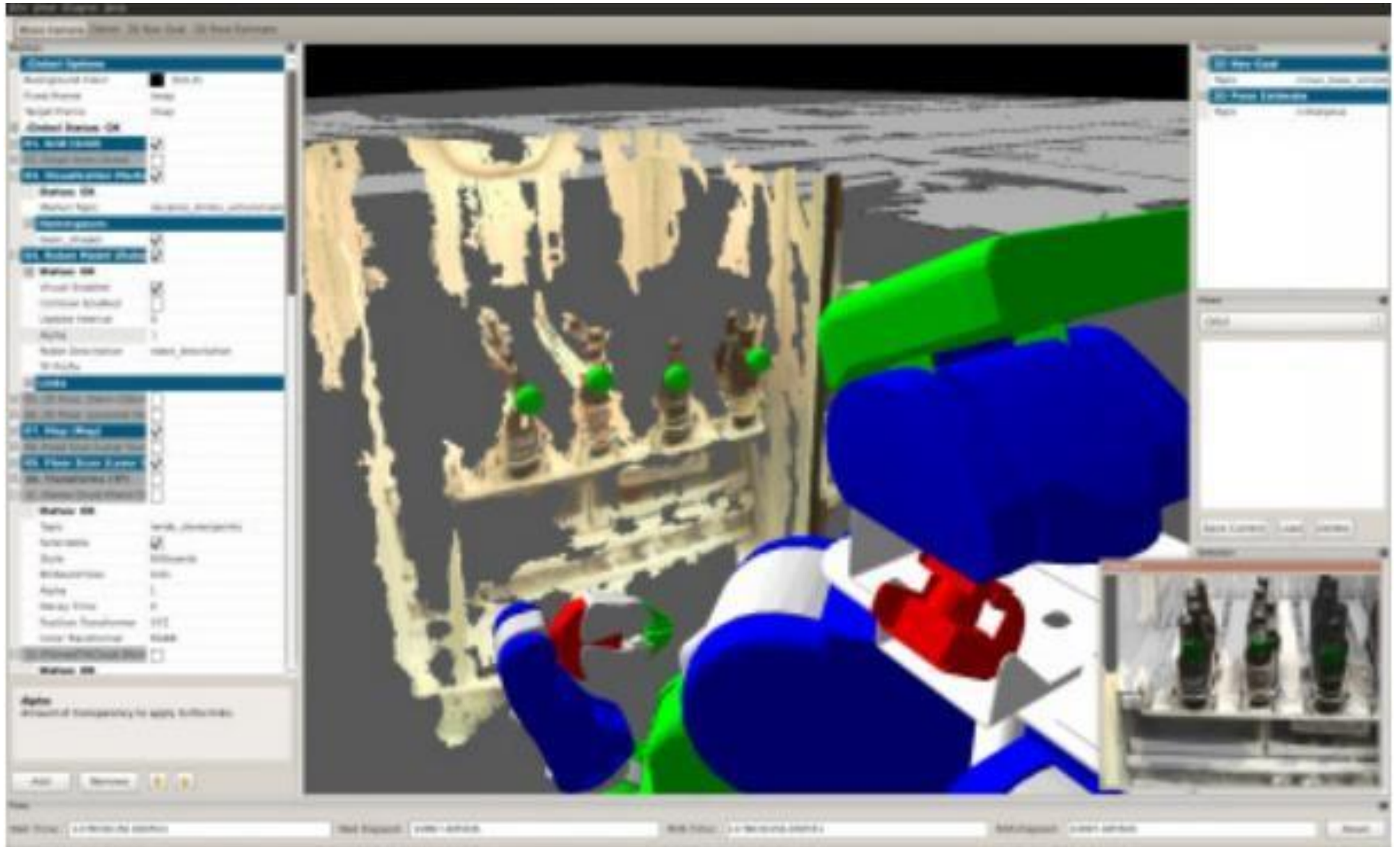
- **Nodes:** In ROS, the primary abstraction is the node. A node is an executable that uses ROS to communicate with other nodes. Nodes can publish or subscribe to a topic or provide or use a service.
- **Messages:** Nodes communicate with each other by passing messages. A message is a simple data structure, comprising typed fields. Standard primitive types (integer, floating-point, boolean, etc.) are supported, as are arrays of primitive types and constants.
- **Topics:** Communication on topics happens via publish/subscribe semantics. When nodes publish or subscribe to a topic, they are announcing to the rest of the network that they are publishing data to be shared (publish) or they are looking for data that other nodes are sharing (subscribe).
- **Services:** The service server responds to requests from service clients. The service server and service client communicate with each other through service names, and the communication is done via a pair of message types: a request and a response.
- **Master:** The ROS master provides name registration and lookup to the rest of the nodes. Without the master, nodes wouldn't be able to find each other, exchange messages, or invoke services.



Funded by the Erasmus+ Programme of the European Union

ROS

- RVIZ is the 3D visualization tool in ROS



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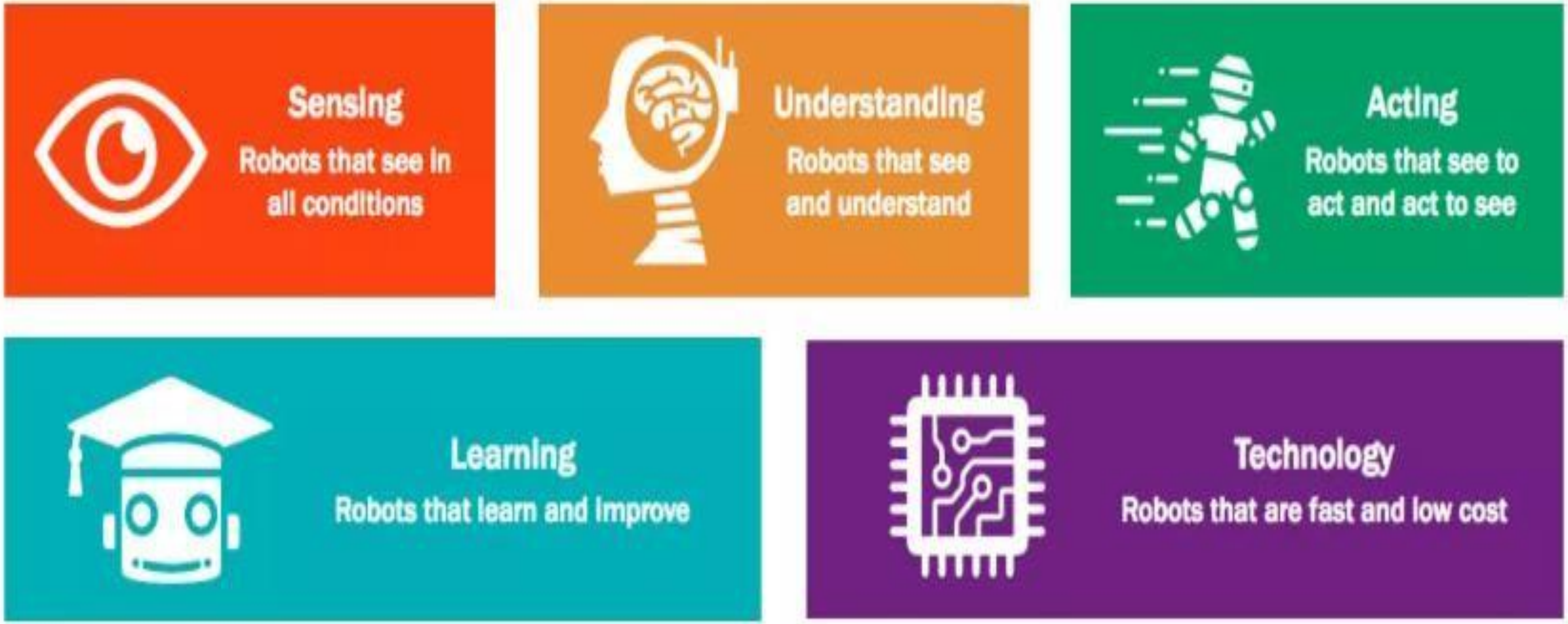
Integration



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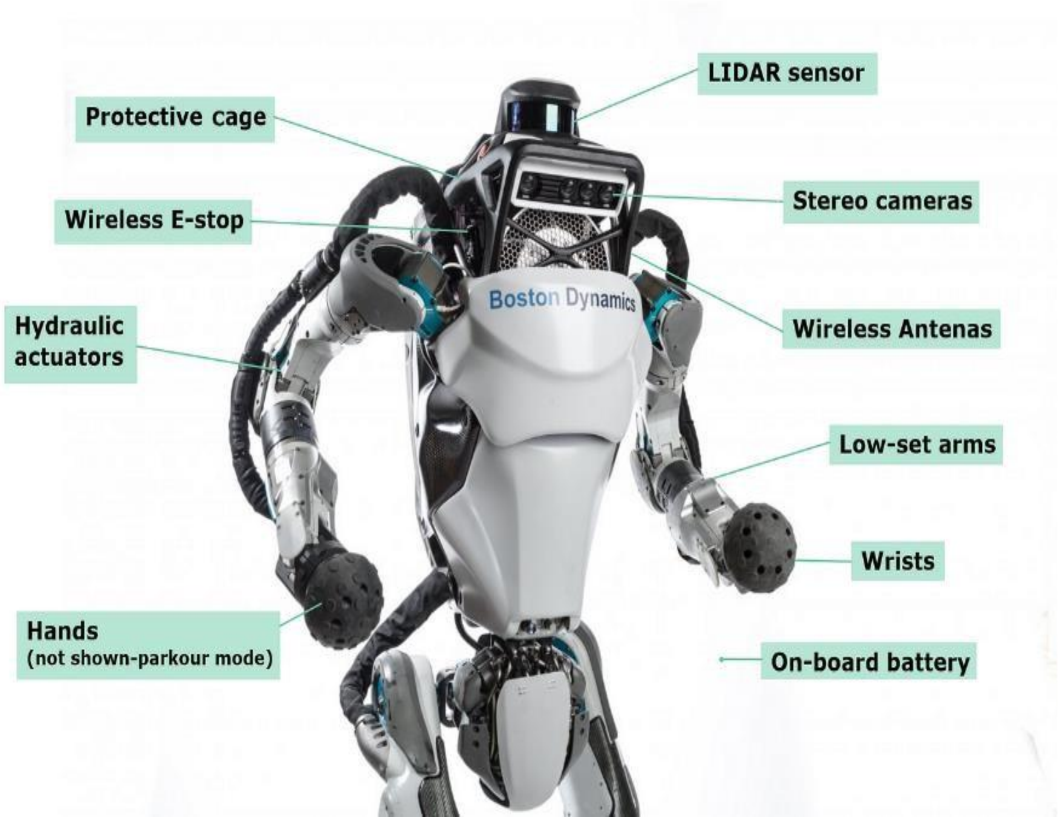
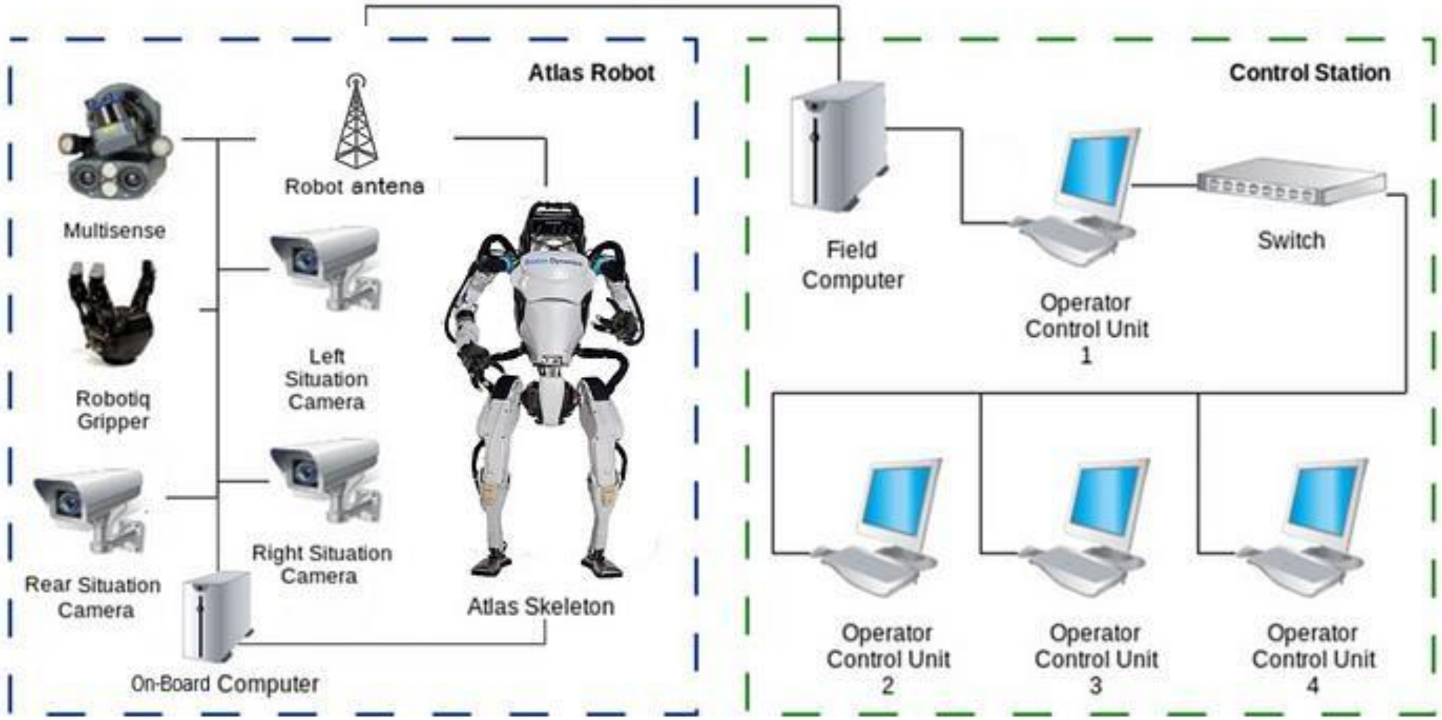
ATLAS robot


LIDAR sensor
Protective cage
Stereo cameras
Wireless E-stop
Boston Dynamics
Wireless Antenas
Hydraulic actuators
Low-set arms
Wrists
Hands
(not shown-parkour mode)
On-board battery

ATLAS robot

- Atlas requires **rapid behavior and dynamic locomotion.**
- It needs connections between perception and control for on-the-fly adaptation.
- **Two computers** are essential for operating Atlas to meet these requirements.
- Atlas features a **wireless communication** link for sending sensor data to the operator.
- When the signal is strong, the operator can send commands back to the robot.
- The control unit operator addresses issues from robot sensors and commands.
- **An onboard computer** in Atlas runs basic functions, including motor control and sensor management.



ARTIFICIAL INTELLIGENCE

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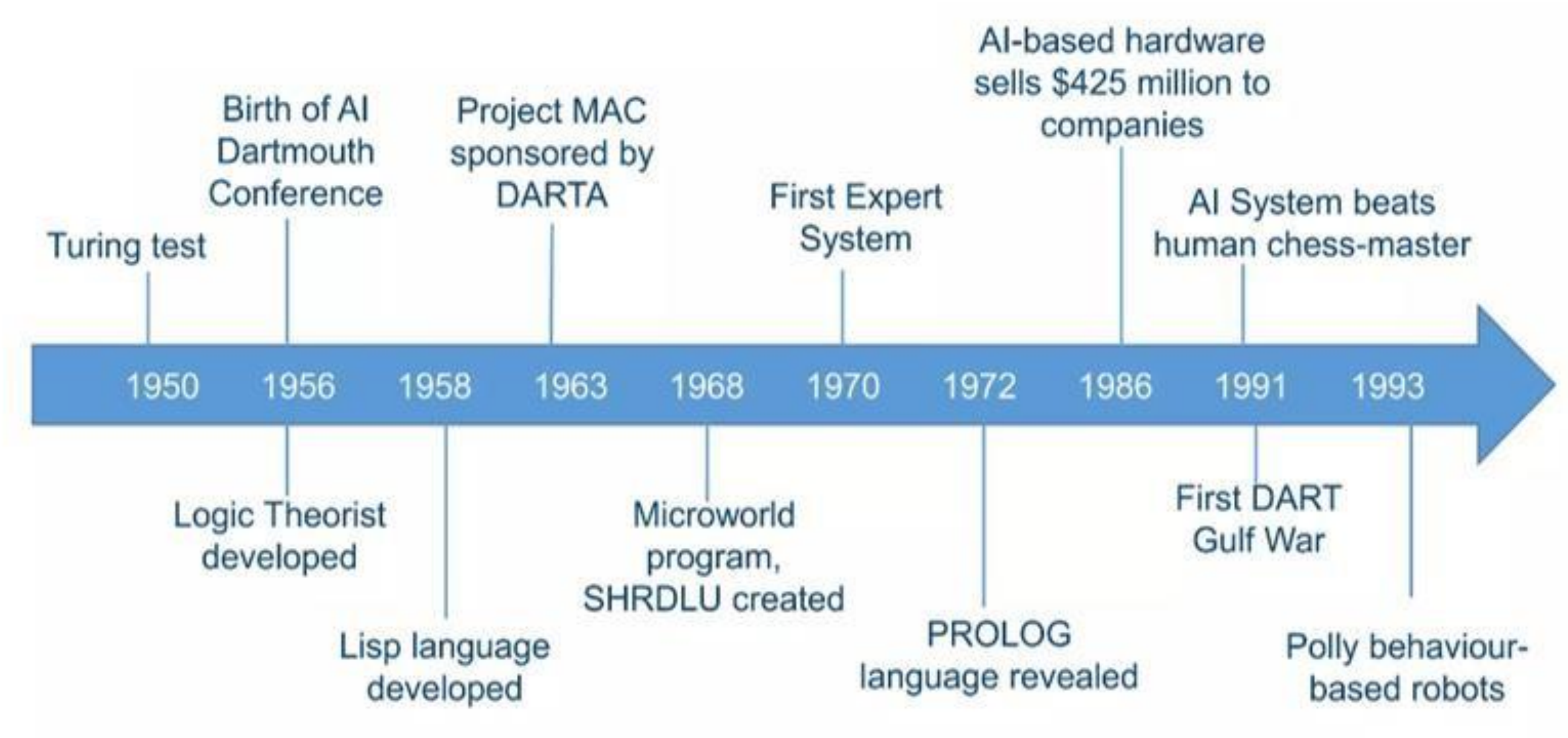
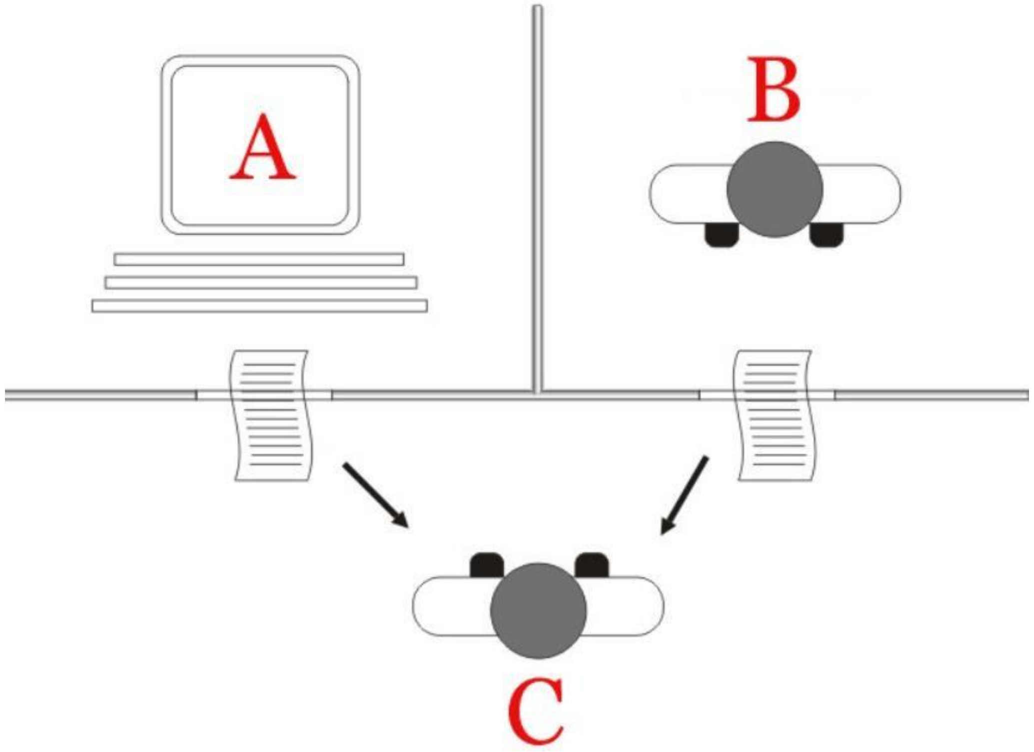
History of AI



Turing Test

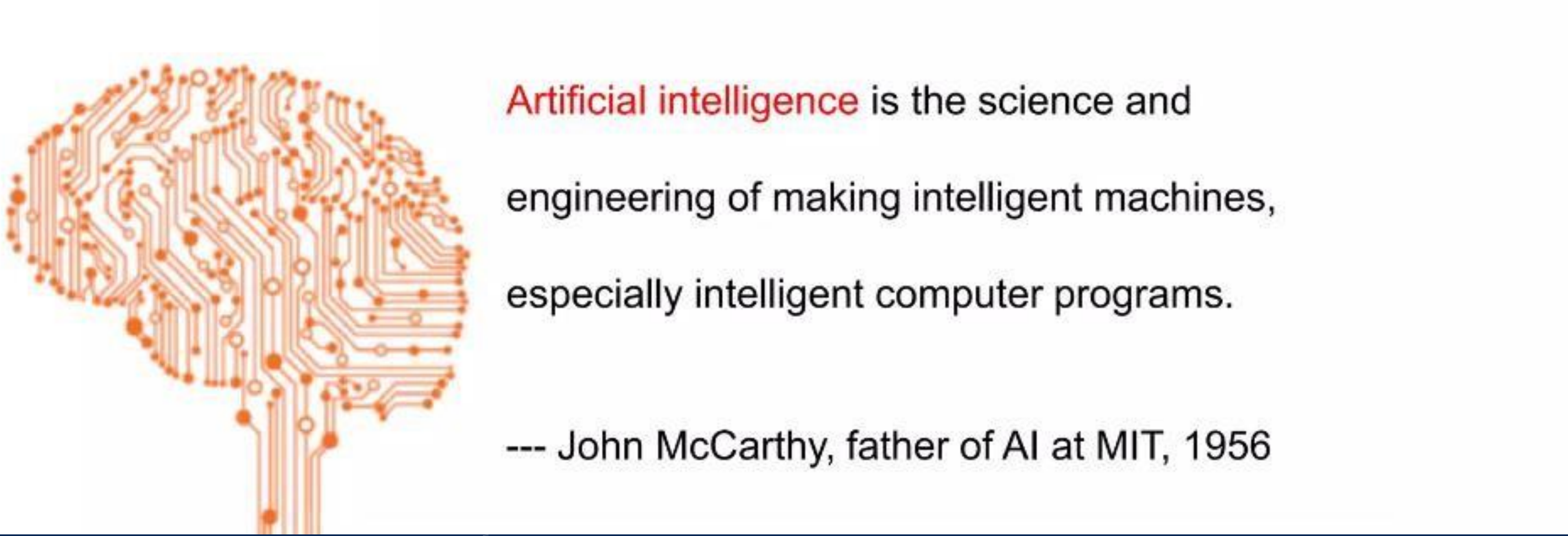
- 1950: **Alan Turing** introduced the **Turing Test** in his 1950 paper called "Computing Machinery and Intelligence" while at the University of Manchester.

- Turing test: a machine's ability to exhibit intelligent behavior equivalent to, or indistinguishable from, that of a human.



Introduction of AI

- 1956: **John McCarthy** a computer scientist, started the **first AI research program** at Dartmouth College. He is often referred to as the "Father of AI" for his contributions to the field.



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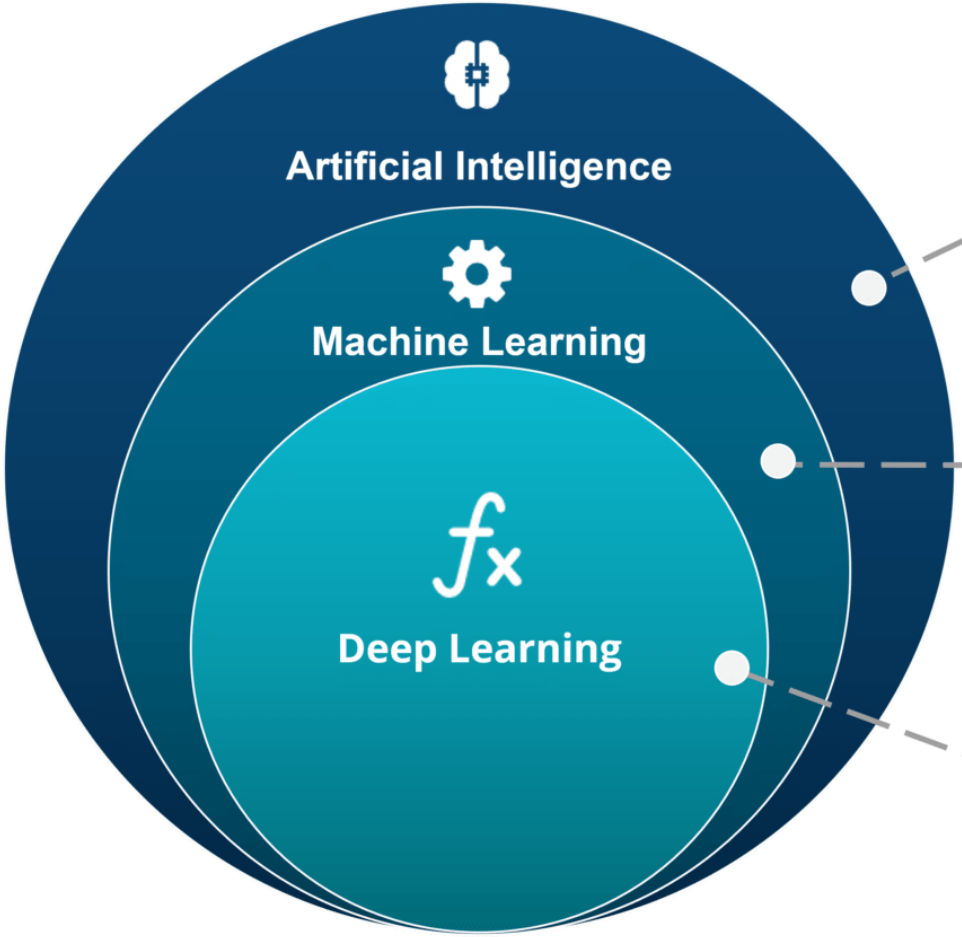
Artificial Intelligence

An interdisciplinary field, usually regarded as a branch of computer science, dealing with **models and systems** for the performance of functions generally associated with **human intelligence**, such as reasoning and learning.

(ISO 2383)

AI subsets



ARTIFICIAL INTELLIGENCE
A technique which enables machines to mimic human behaviour

MACHINE LEARNING
Subset of AI technique which use statistical methods to enable machines to improve with experience

DEEP LEARNING
Subset of ML which make the computation of multi-layer neural network feasible

Machine learning (ML)

ML is a subset of AI that focuses on building systems that can learn from data and improve their performance over time without being explicitly programmed.

- ML algorithms enable computers to identify patterns, make predictions, and learn from experience by analyzing large datasets.
- Examples of machine learning techniques include linear regression, logistic regression, decision trees, support vector machines, and clustering algorithms.
- ML algorithms require labeled data for training (supervised learning), where the algorithm learns to make predictions by identifying patterns in the data.

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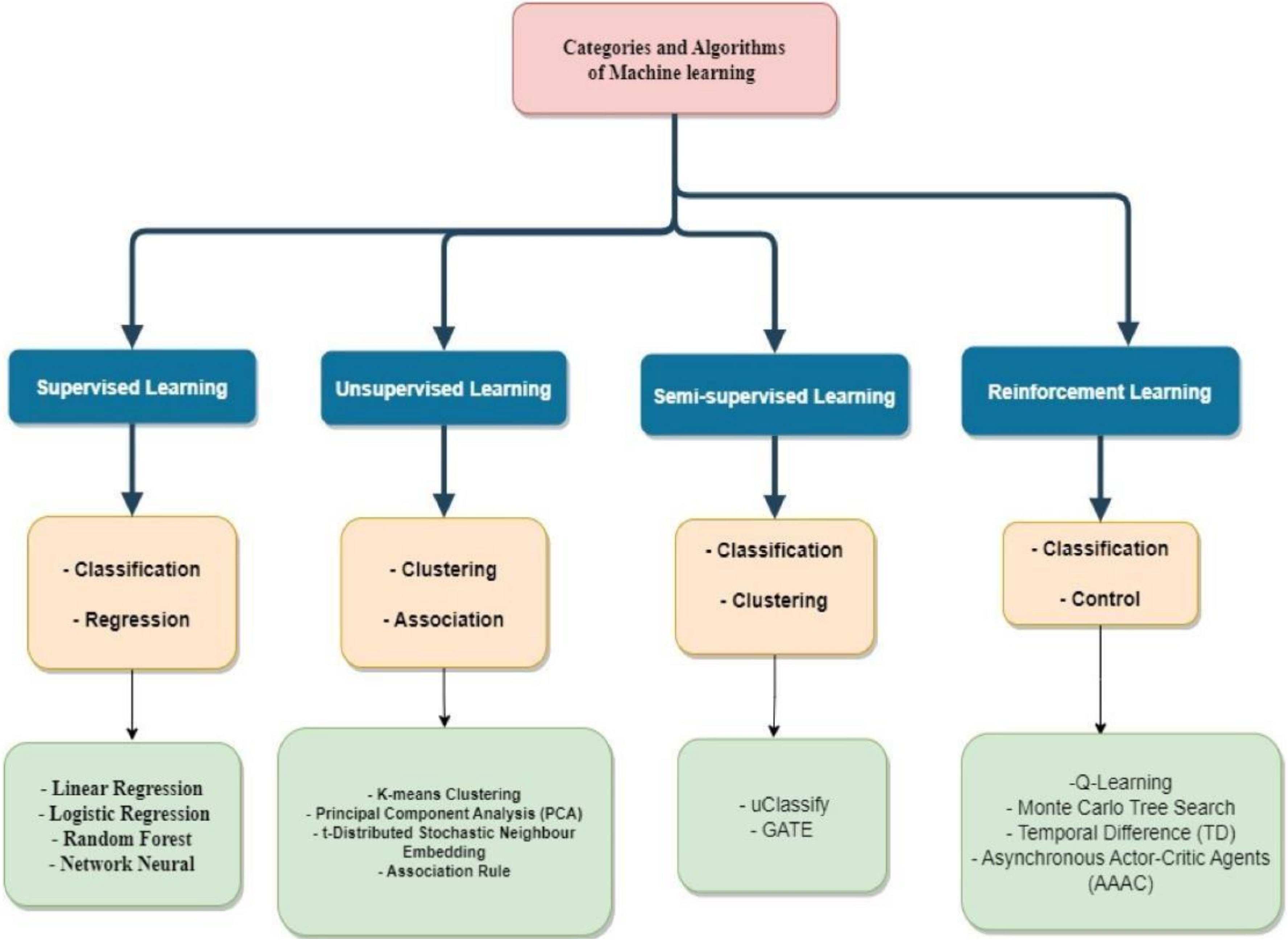
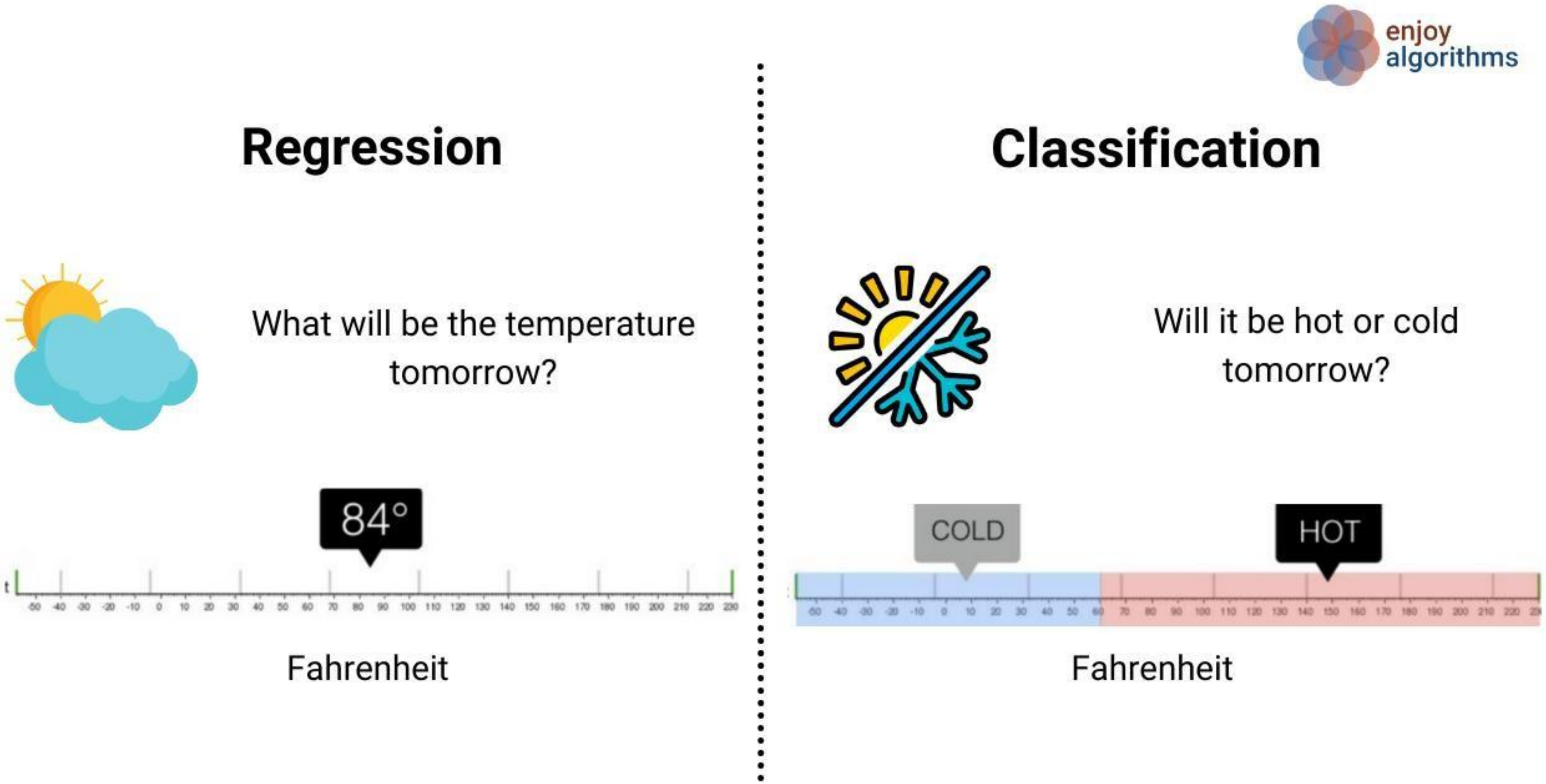

Categories and Algorithms
of Machine learning
Supervised Learning
Unsupervised Learning
Semi-supervised Learning
Reinforcement Learning
- Classification
- Regression
- Clustering
- Association
- Classification
- Clustering
- Classification
- Control
- Linear Regression
- Logistic Regression
- Random Forest
- Network Neural
- K-means Clustering
- Principal Component Analysis (PCA)
- t-Distributed Stochastic Neighbour Embedding
- Association Rule
- uClassify
- GATE
-Q-Learning
- Monte Carlo Tree Search
- Temporal Difference (TD)
- Asynchronous Actor-Critic Agents (AAAC)

Supervised learning



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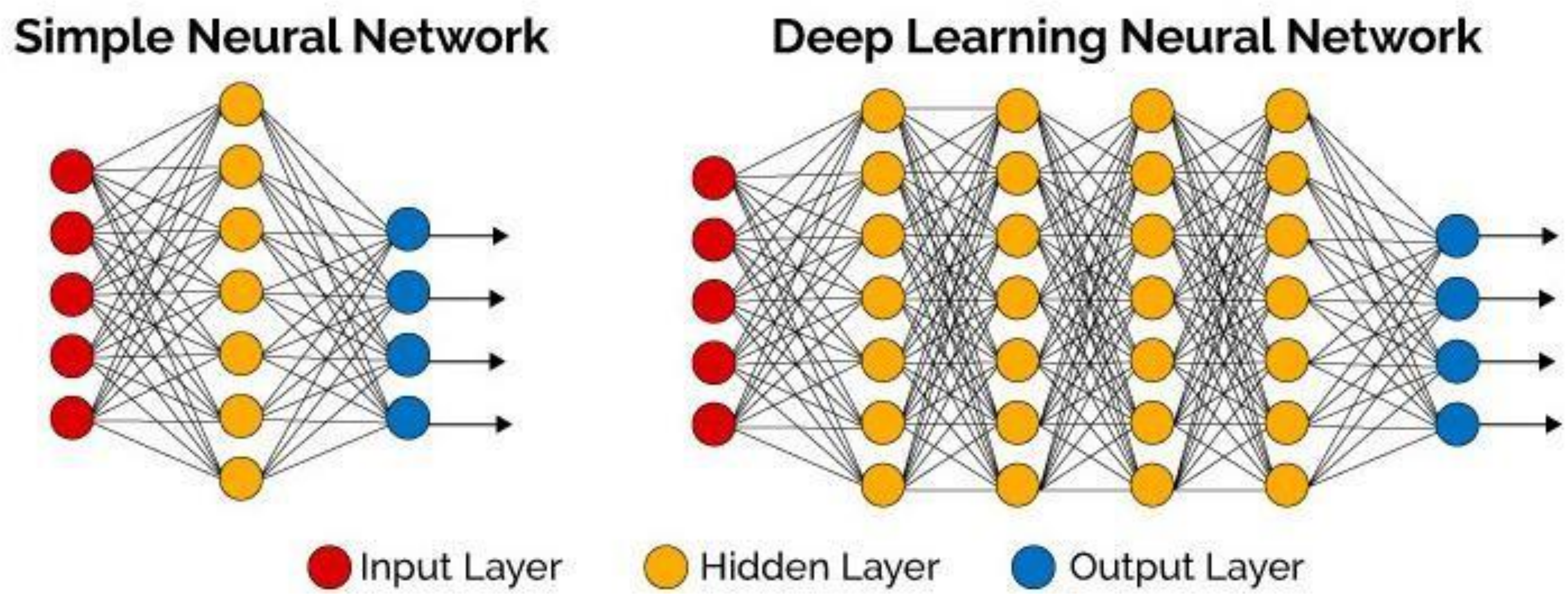
How to confuse machine learning!

Deep Learning (DL)

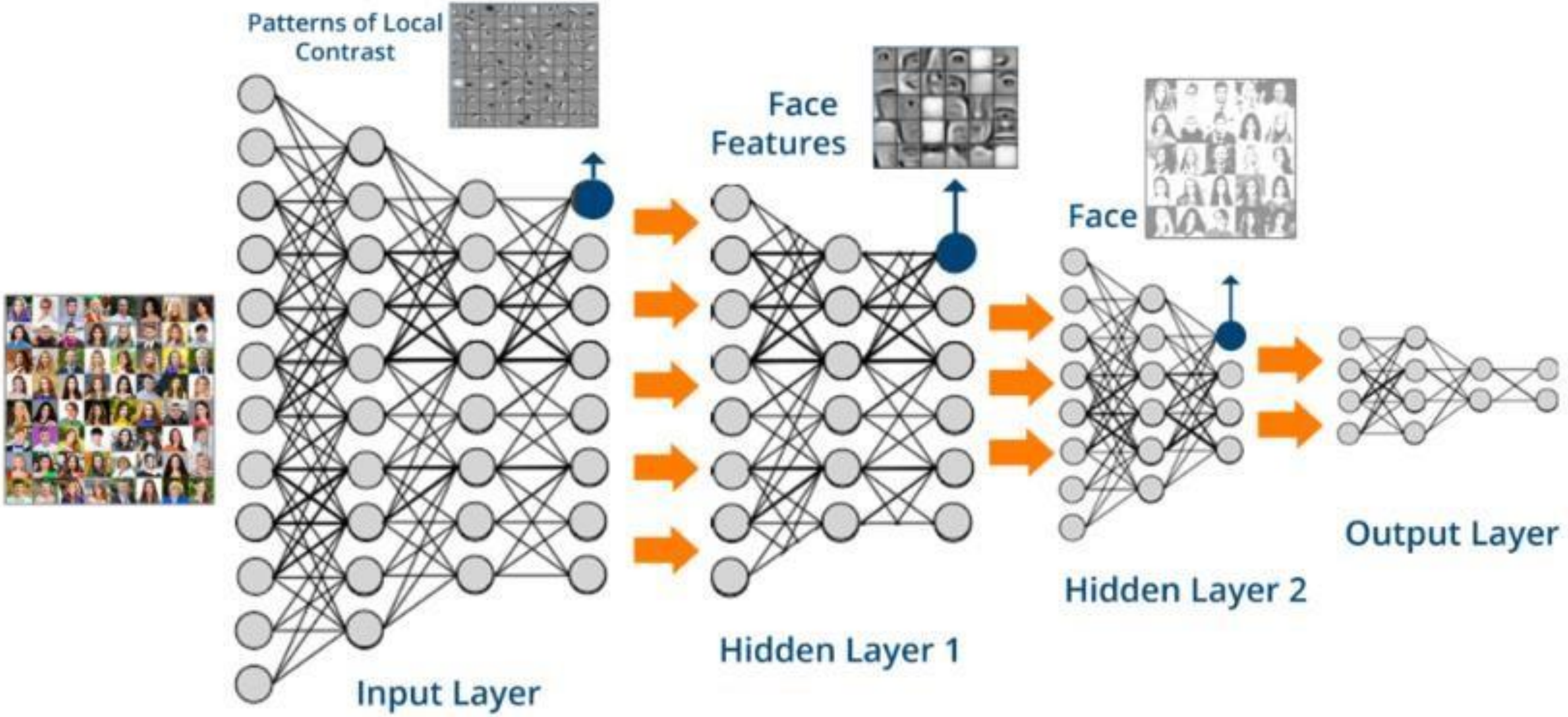
DL is a subset of machine learning that uses neural networks with many layers (deep neural networks) to learn complex patterns from data.

- DL algorithms are inspired by the structure and function of the human brain's neural networks, which consist of interconnected neurons.
- DL models can automatically discover and learn features from raw data, making them particularly effective for tasks such as image recognition, natural language processing, speech recognition, and autonomous driving.
- DL models require large amounts of data for training and significant computational resources for training deep neural networks.

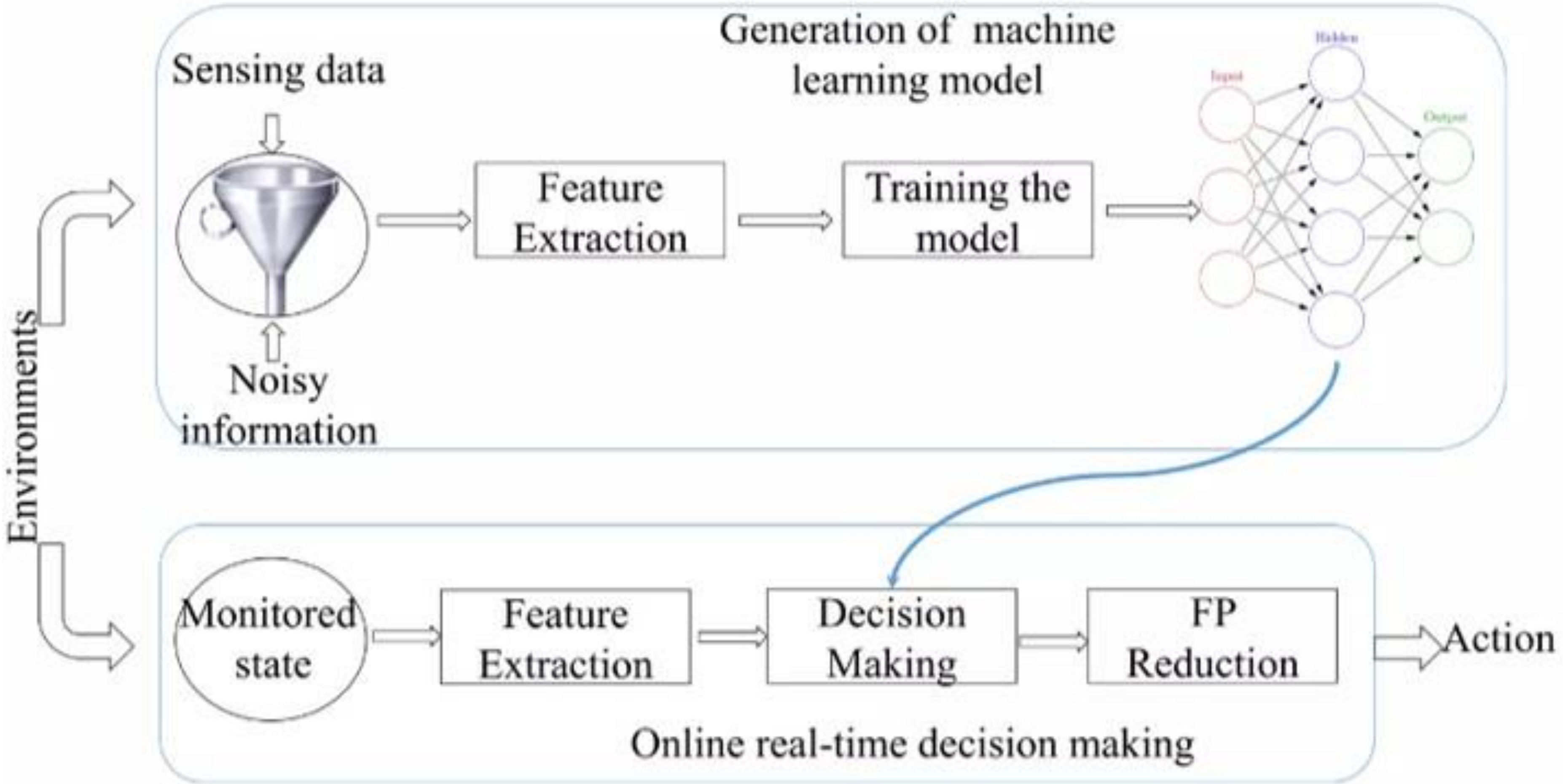
Neural Network (NN)



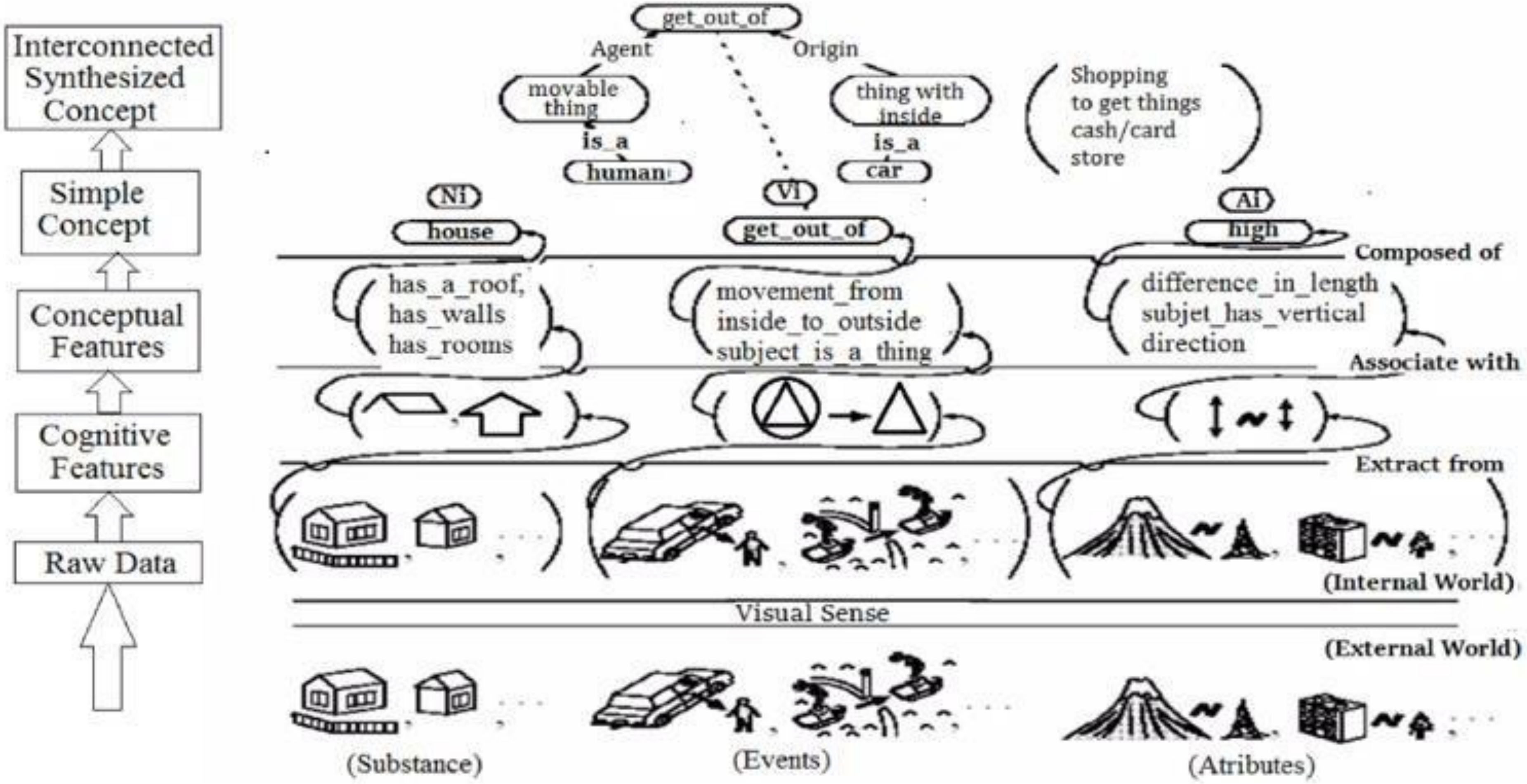
DL layers


Patterns of Local Contrast
Face Features
Face
Input Layer
Hidden Layer 1
Hidden Layer 2
Output Layer

Framework of perception



Information propagation



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ADVANCED ROBOTICS

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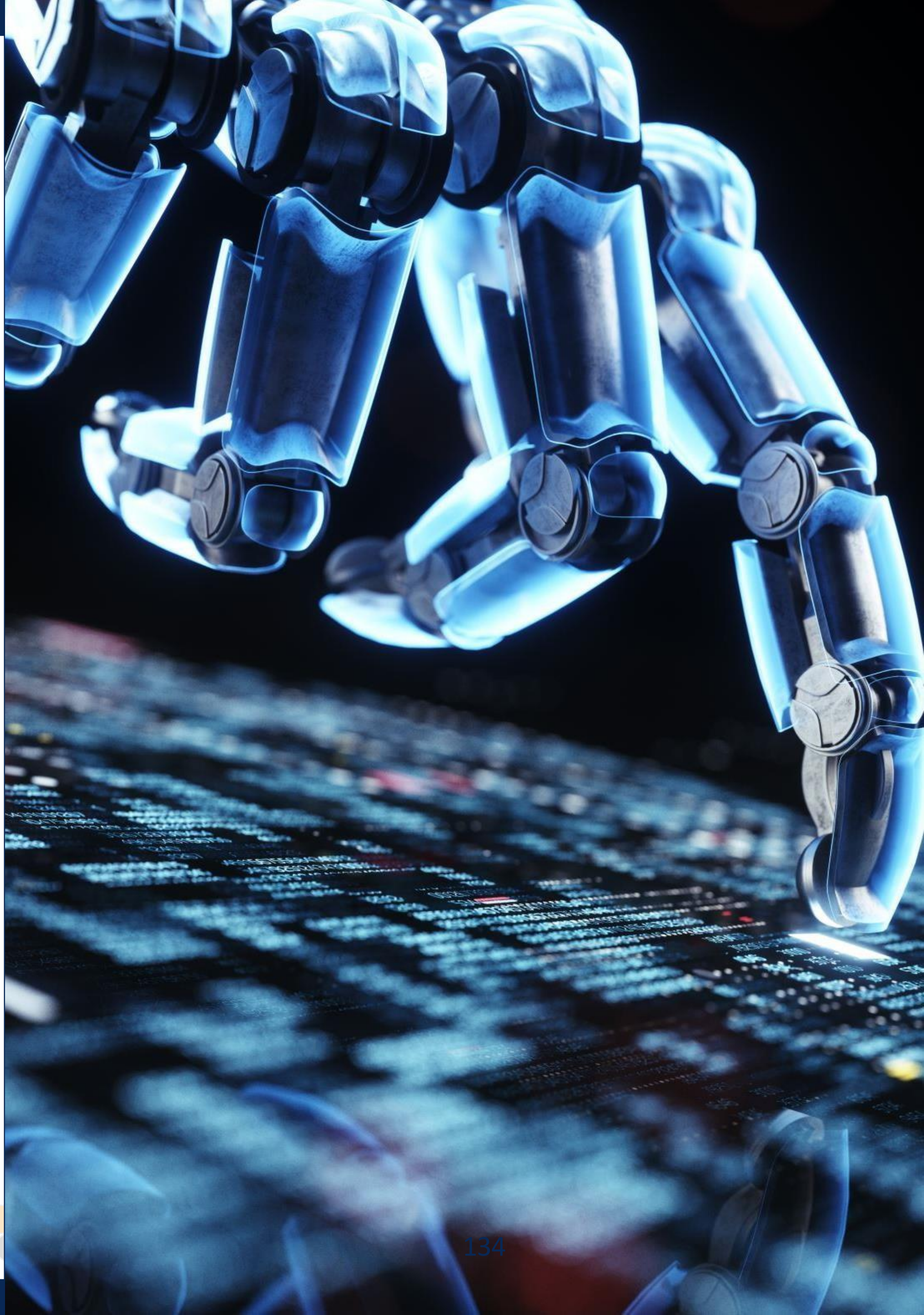
Advanced robotics

- Collaborative robotics
- Soft robots
- Micro/Nano
- Swarm robots
- Neuromorphic
- Exoskeleton-prosthetics
- etc



Funded by the
Erasmus+ Programme
of the European Union

Collaborative Robots

A cobot, or collaborative robot, is a robot intended for direct human-robot interaction within a shared space, or where humans and robots are in close proximity.

Co-funded by the European Union

Collaborative Robots

Collaborative Robots

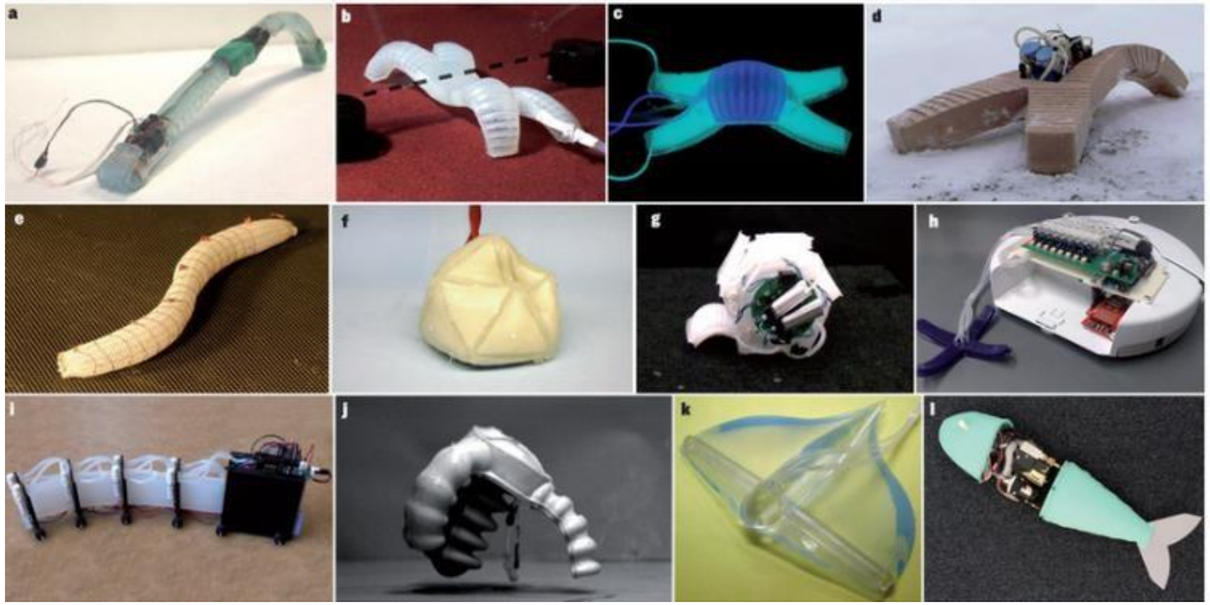
IERA AWARD.

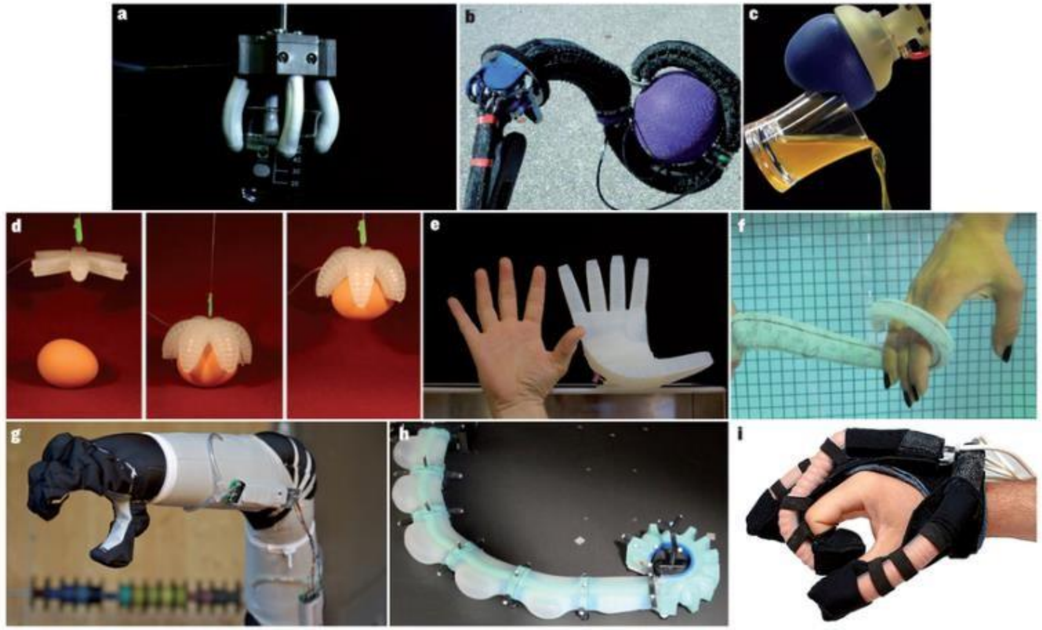
Innovation and Entrepreneurship in Robotics and Automation

KUKA Medical Robotics Team wins IERA Award 2018

Soft robotics

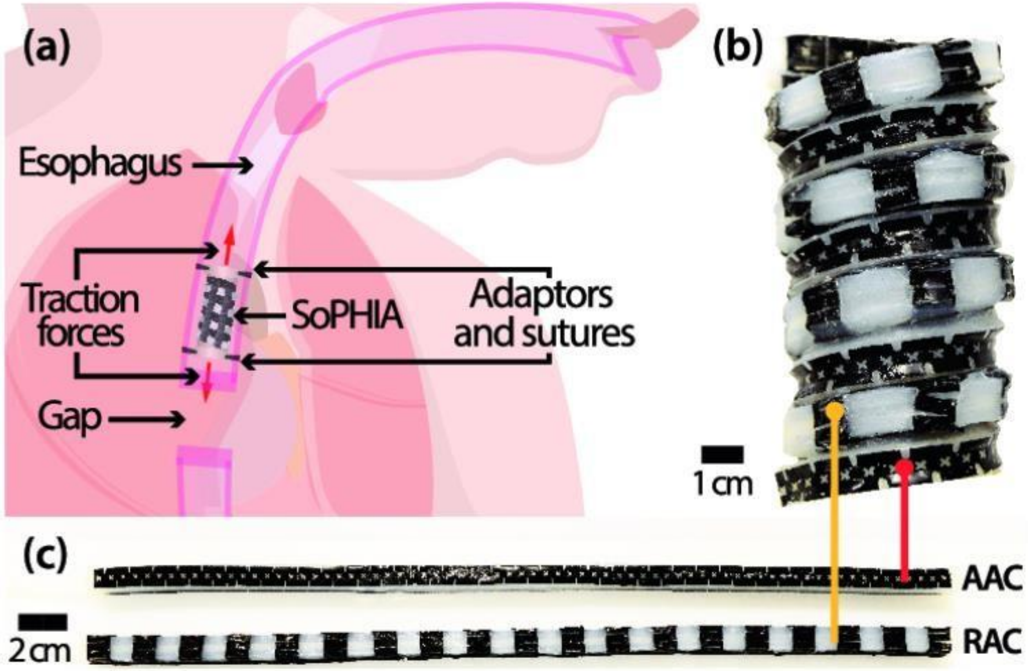
Soft robotics is a subfield of robotics that concerns the design, control, and fabrication of robots composed of compliant materials, instead of rigid links.

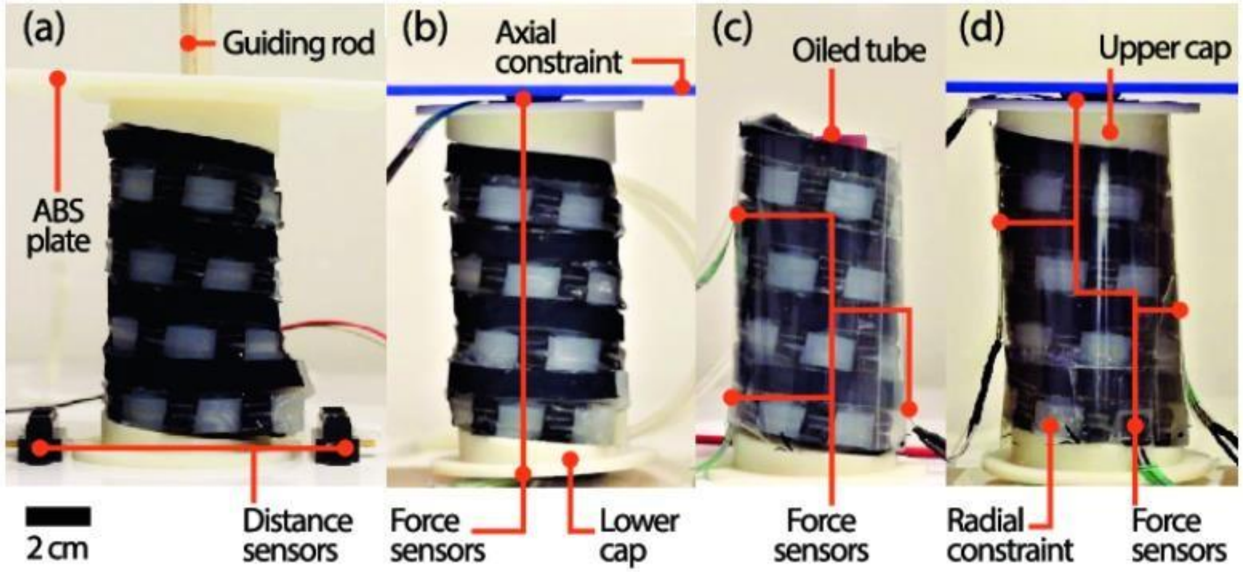




Soft robotics - Medicine

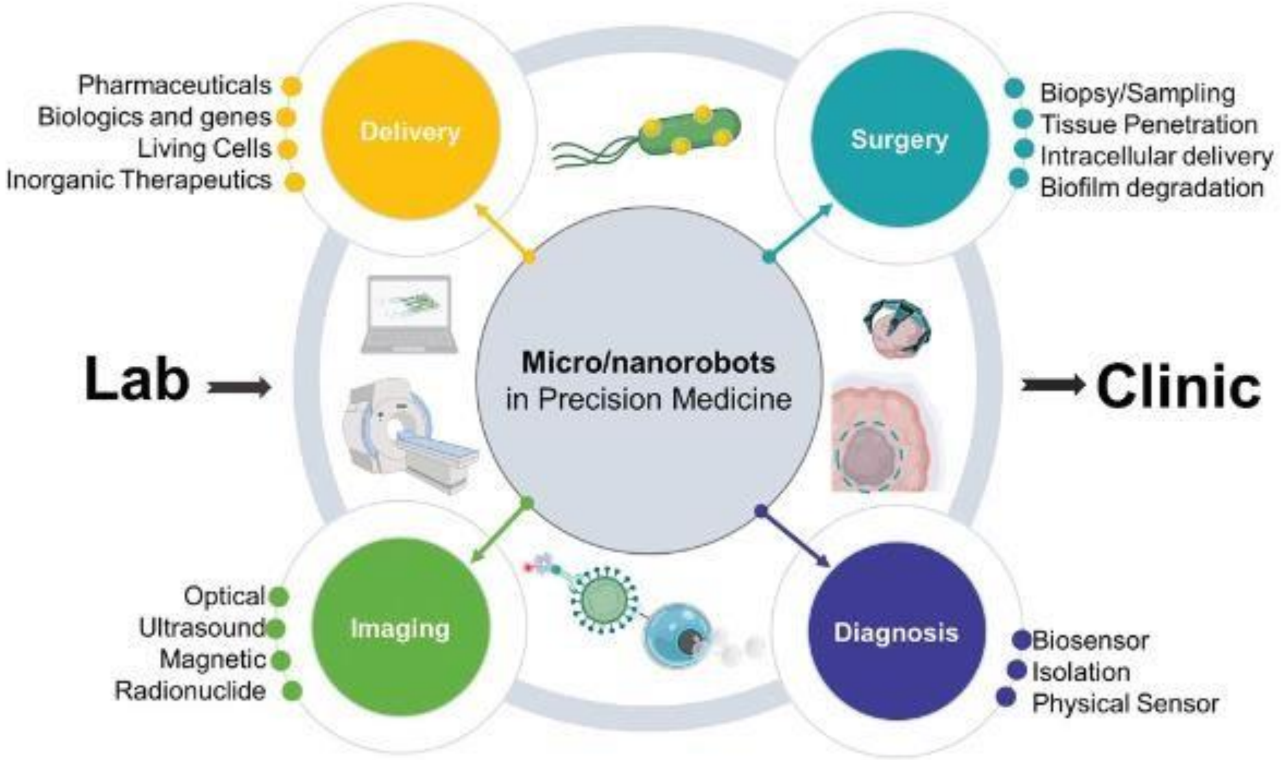
SoPHIA - Soft Pneumatic Helically-Interlayered Actuator



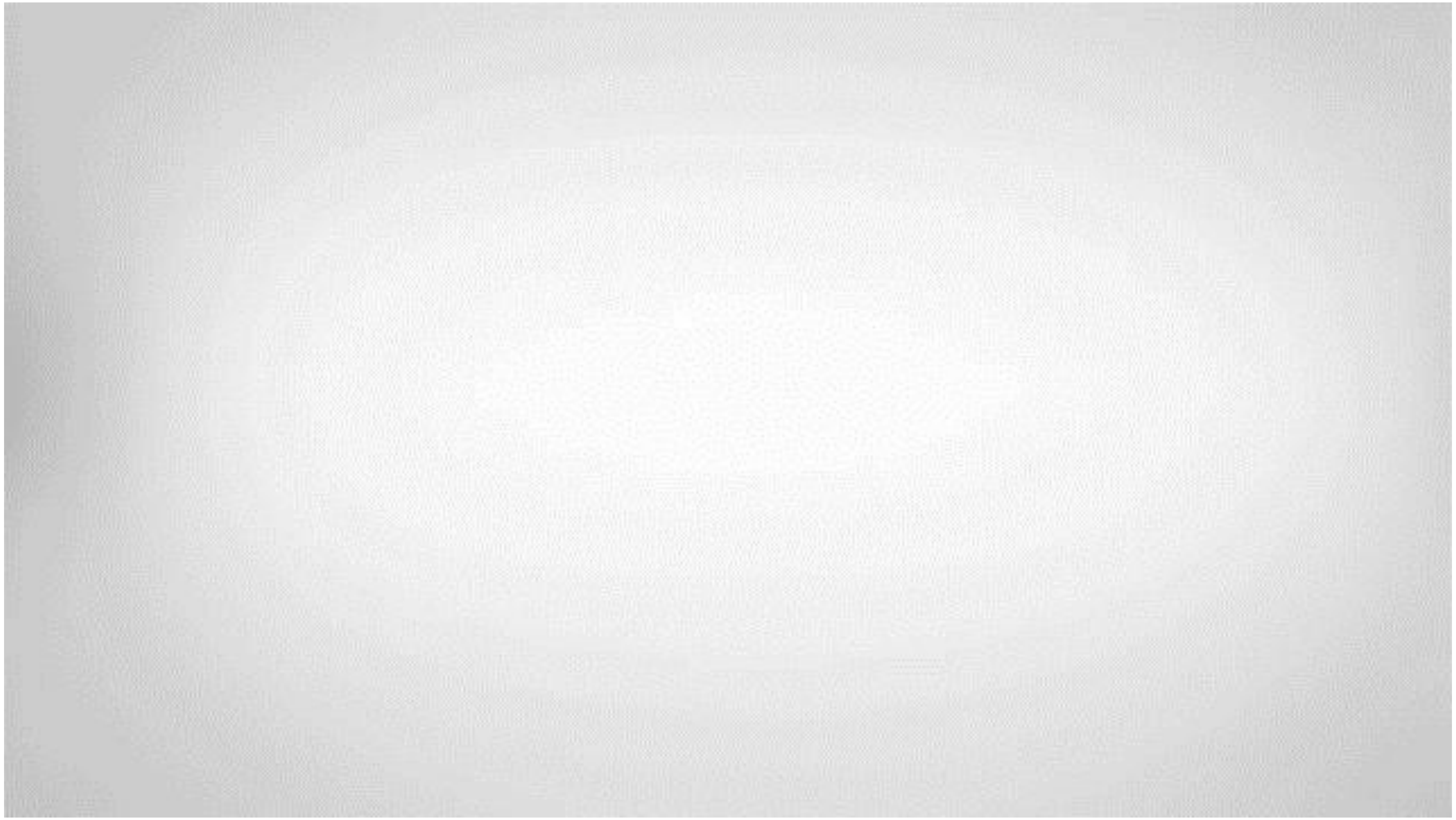


Microbots and Nanorobots

Micro and nano robots are small-scale manipulatable devices at the micrometer and nanometer scale which have found uses in several fields and have been noted to be of great interest in the biomedical field.

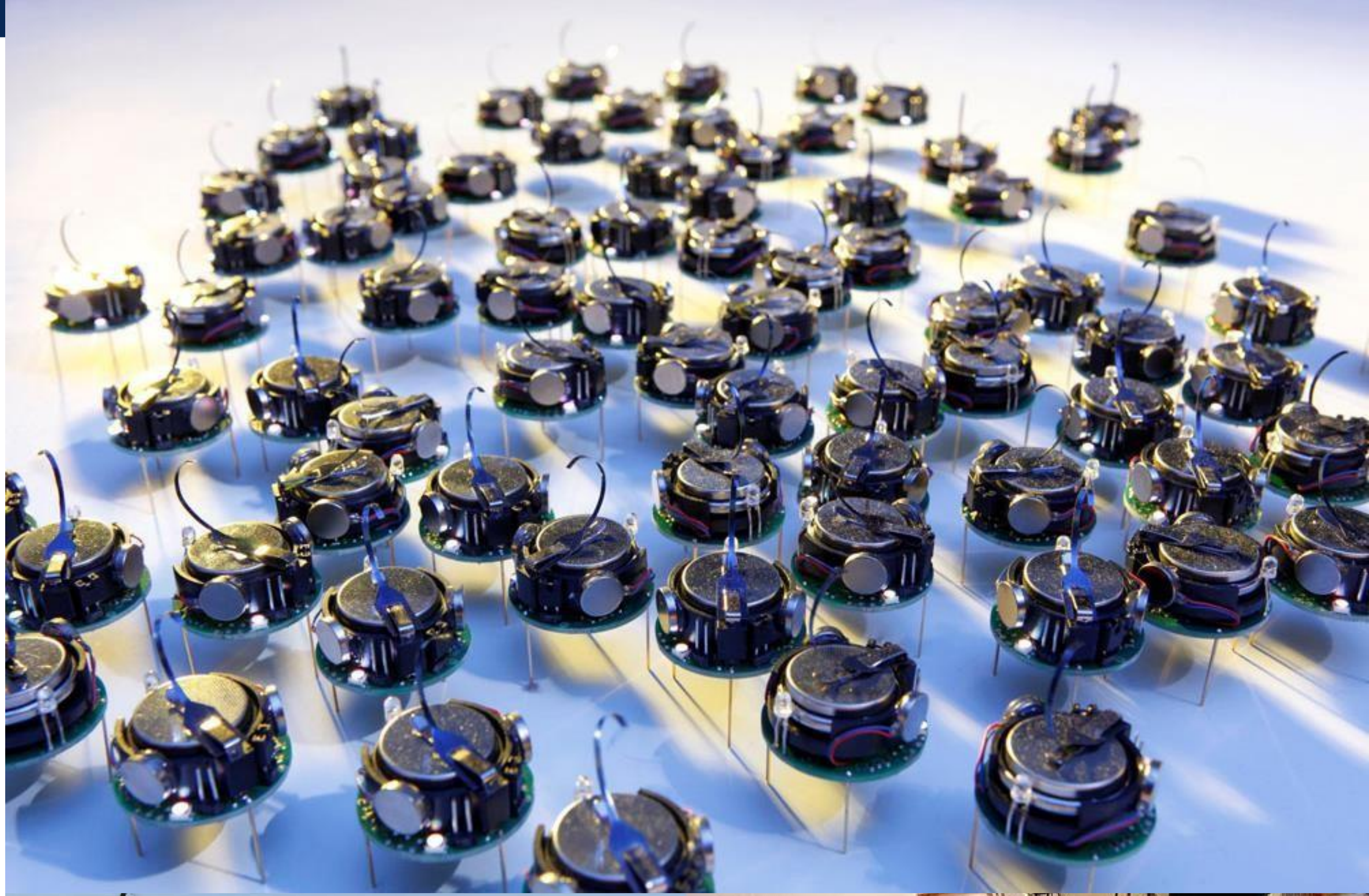


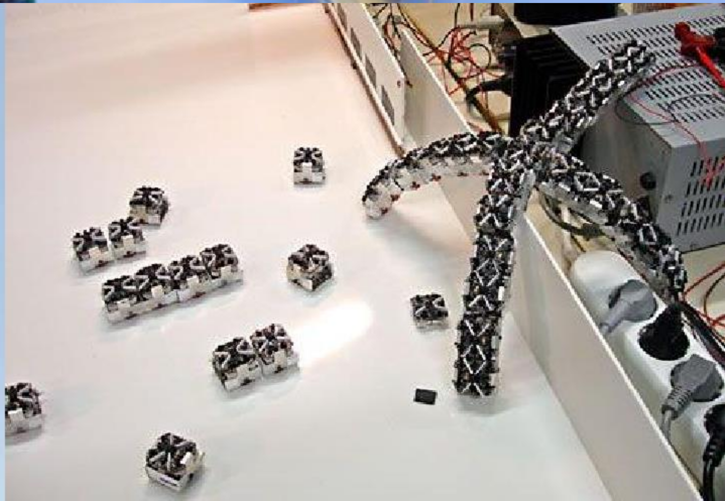
Origami robots



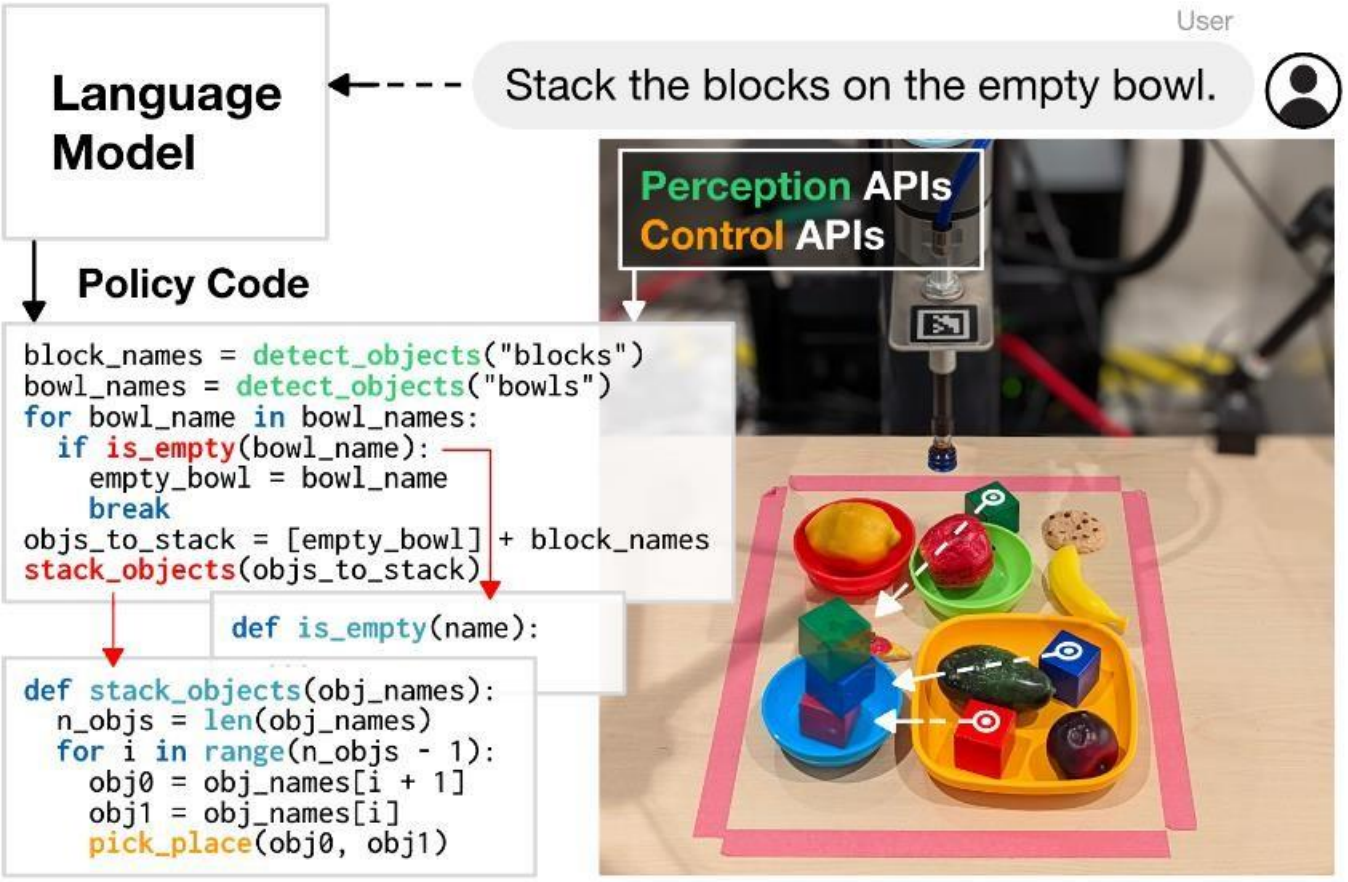
Swarm robotics

Swarm robotics is an approach to the coordination of multiple robots as a system that consists of large numbers of mostly simple physical robots.





Robots That Write Their Own Code



Multi robot smart platform solution(Ocado)

BETES

Discover Technologies, expand opportunities!

Thank you!

For more information:

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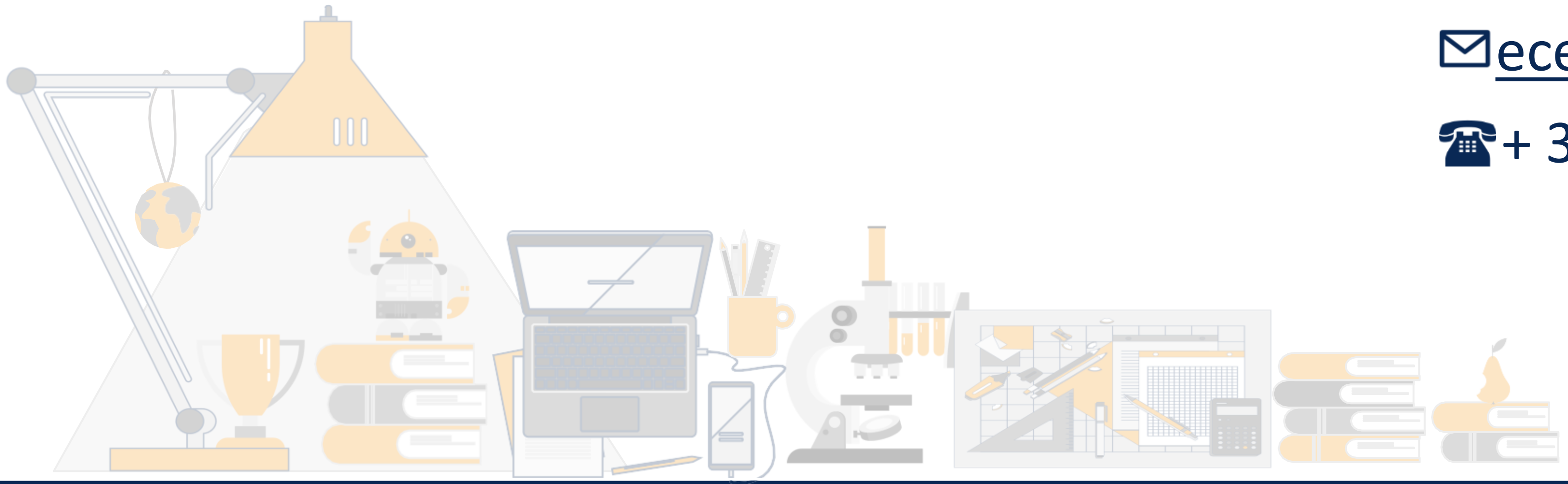
www.facebook.com/BETESproject

ecect.projects@gmail.com

+ 357 96520112 (Cyprus)



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