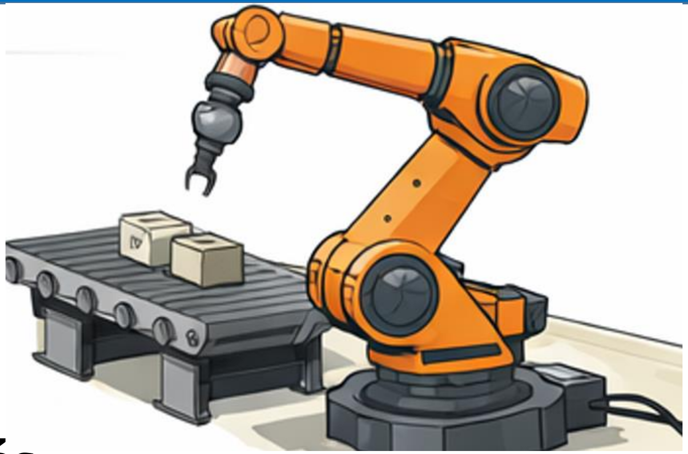
Robotique



Master en ingénierie des systèmes embarqués
(MUS ISE)

Chapitre 1: General Introduction

Année universitaire 2025/2026

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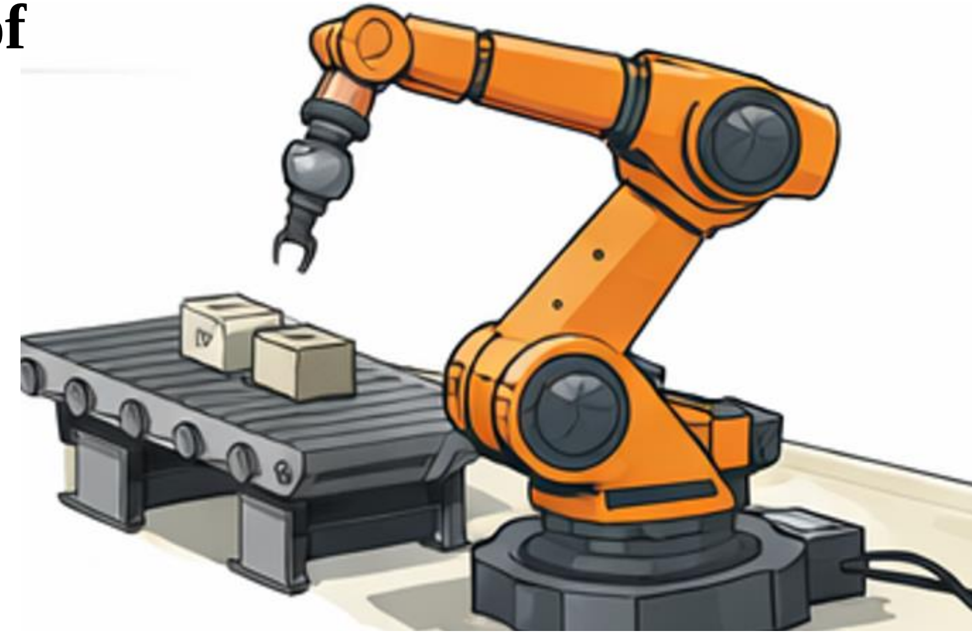
1.1 Definition of Robotics

Robotics is an interdisciplinary field concerned with the **design, modeling, control, perception, and application of robots**.

It integrates concepts from:

- ❑ Mechanical engineering
- ❑ Electrical and electronic engineering
- ❑ Control theory
- ❑ Computer science and artificial intelligence

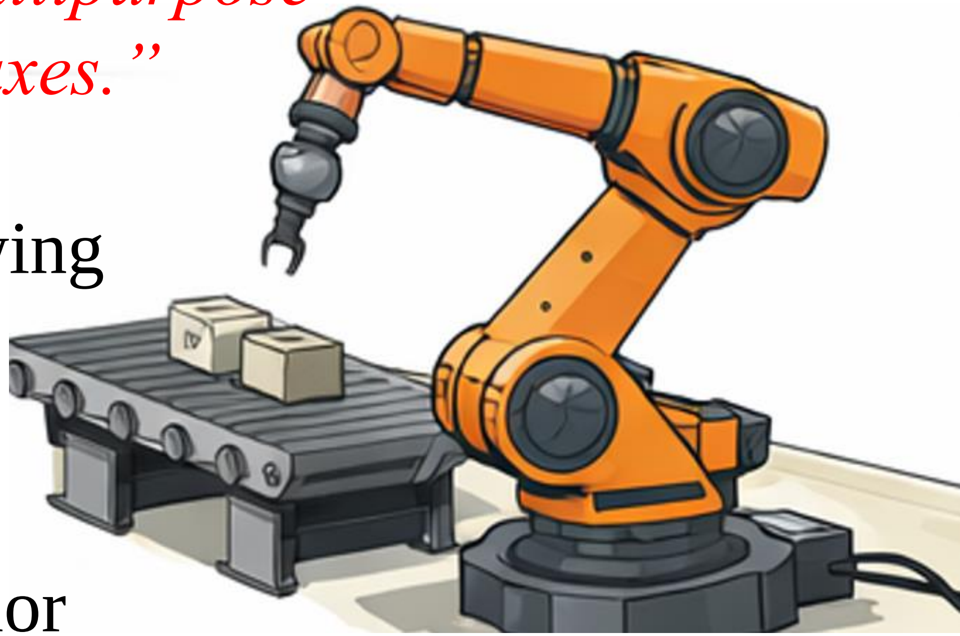


The goal of robotics is to create **autonomous or semi-autonomous systems** capable of performing tasks in structured or unstructured environments.

1.2 Definition of a Robot

According to ISO 8373, a robot is defined as:

“An automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes.”



From this definition, a robot must satisfy the following conditions:

- **Automatic control** (no continuous human intervention)
- **Reprogrammability** (software-based behavior modification)
- **Multi-functionality**
- **Physical interaction** with the environment

1.3 Key Characteristics of Robotic Systems

A robotic system is characterized by:

1.3.1 Autonomy

- Ability to perform tasks independently
- Levels: teleoperated, semi-autonomous, fully autonomous

1.3.2 Intelligence

- Decision-making capability
- Perception–action loop
- Adaptation to environment changes

1.3.3 Flexibility

- Capability to perform different tasks
- Reconfiguration through software and hardware

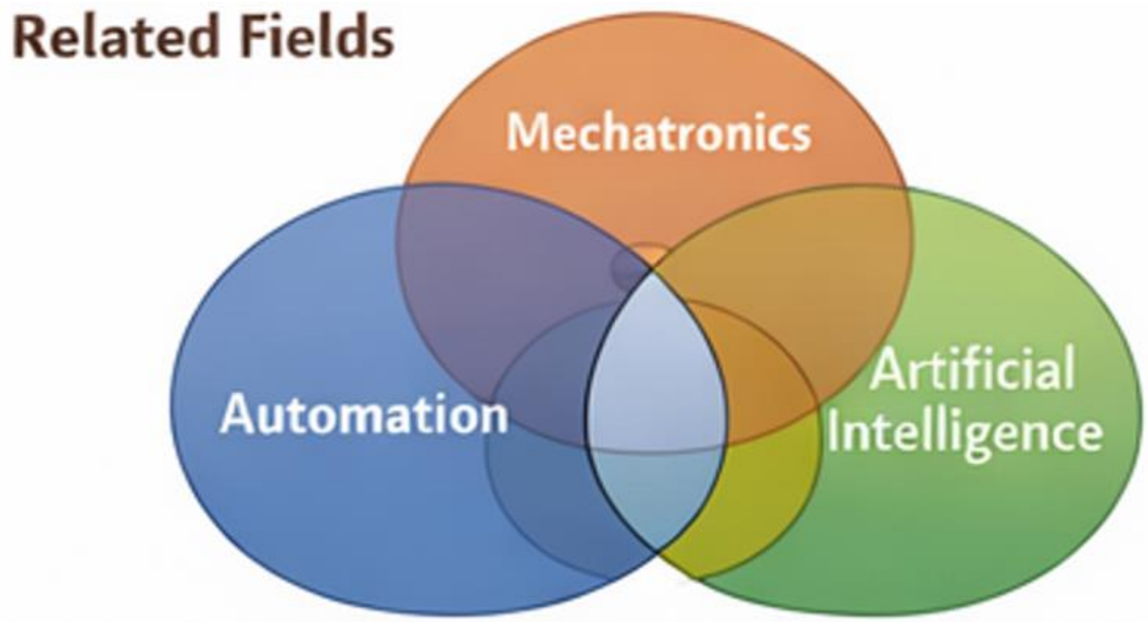
1.4 Robotics vs Related Disciplines

1.4.1 Automation

- Fixed-task systems
- Limited adaptability
- Example: conveyor-based production

1.4.2 Mechatronics

- Synergistic integration of mechanics, electronics, and control
- Robotics is an **advanced application** mechatronics



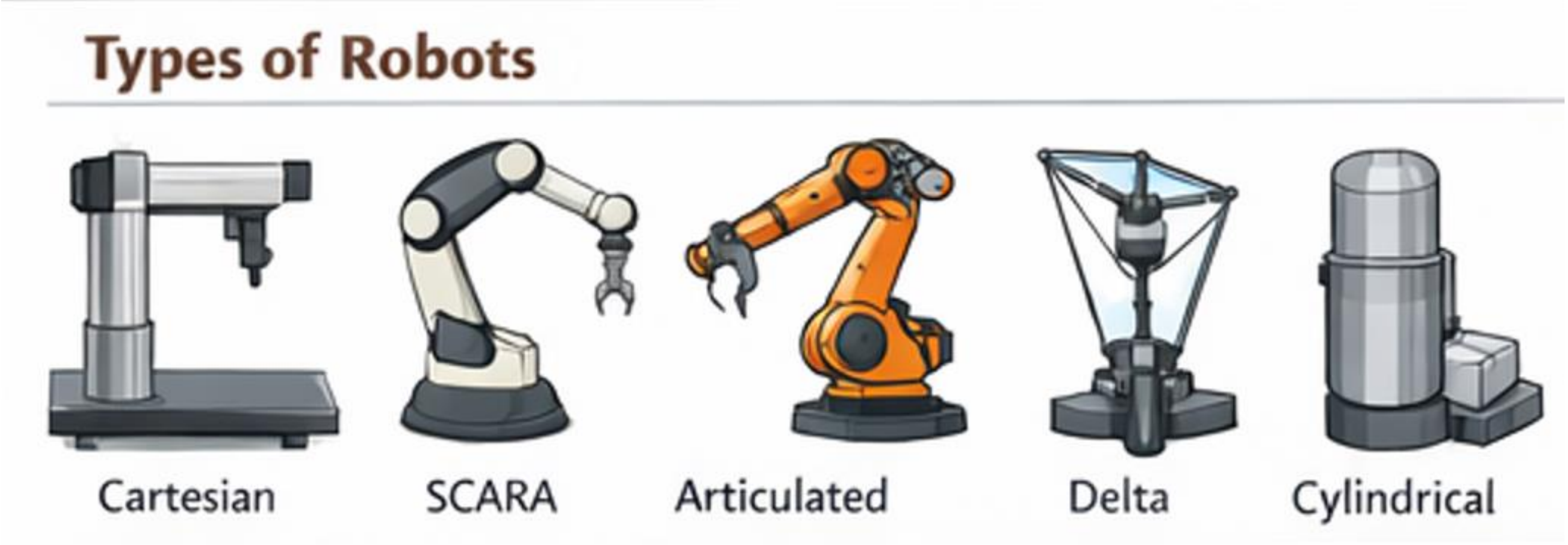
1.4.3 Artificial Intelligence

- Provides learning, perception, and planning
- Not all robots use AI

1.5 Classification of Robots

1.5.1 Classification by Structure

- **Cartesian robots** (PPP)
- **Cylindrical robots** (RPP)
- **SCARA robots**
- **Articulated robots** (RRR…)
- **Parallel robots** (Delta)



1.5 Classification of Robots

1.5.1 Classification by Structure

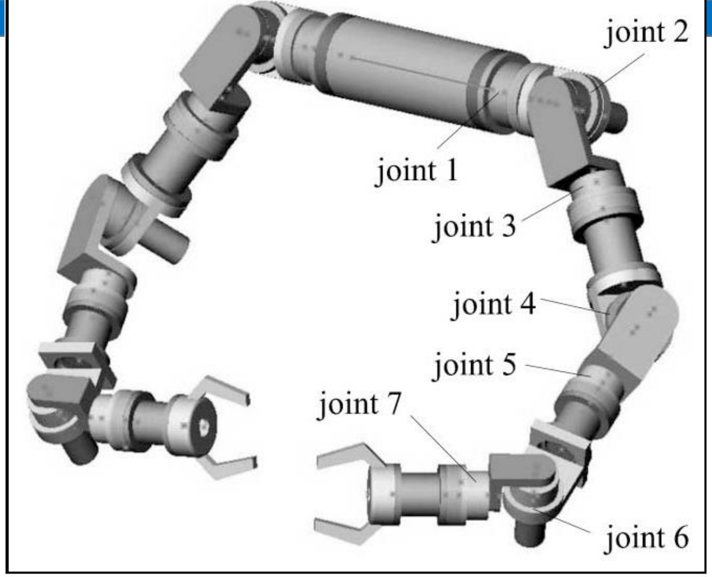


Figure 2: The two arm 2 × 7DoF humanoid manipulator

1. Formal Definition

A **joint** is a kinematic connection between two links that:

•Allows **relative motion** between them

•Restricts motion to **specific directions or axes**

•Defines the **degrees of freedom (DOF)** of the system

In robotics, joints are the **sources of motion** that determine how a robot can move.

2. Common Types of Joints in Robotics

❑ **Revolute Joint (R)**

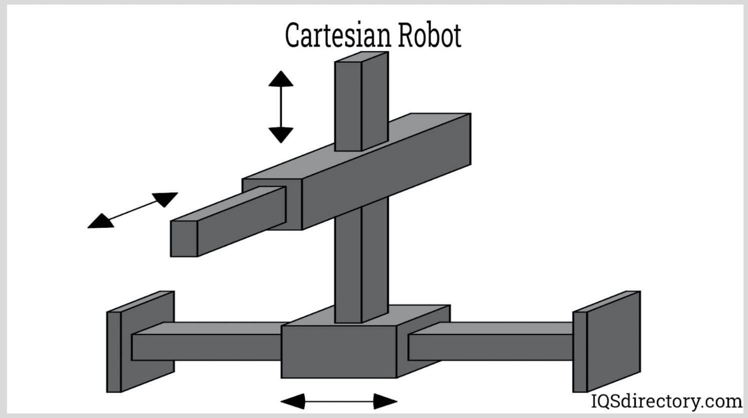
Definition

A revolute joint allows **rotation about a fixed axis**.

❑ **Prismatic Joint (P)**

Definition

A prismatic joint allows **linear translation along a fixed axis**.



3. Joint Variables

Each joint has an associated **joint variable**:

❑ Revolute joint → angle θ (rad or deg)

❑ Prismatic joint → displacement d (m or mm)

These variables define the robot's configuration.

1.5 Classification of Robots

1.5.1 Classification by Structure

❑ **Cartesian robots** (PPP)

Definition:

A Cartesian robot is composed of **three orthogonal linear axes (X, Y, Z)**. Each joint is prismatic.

Structure:

PPP (Prismatic–Prismatic–Prismatic)

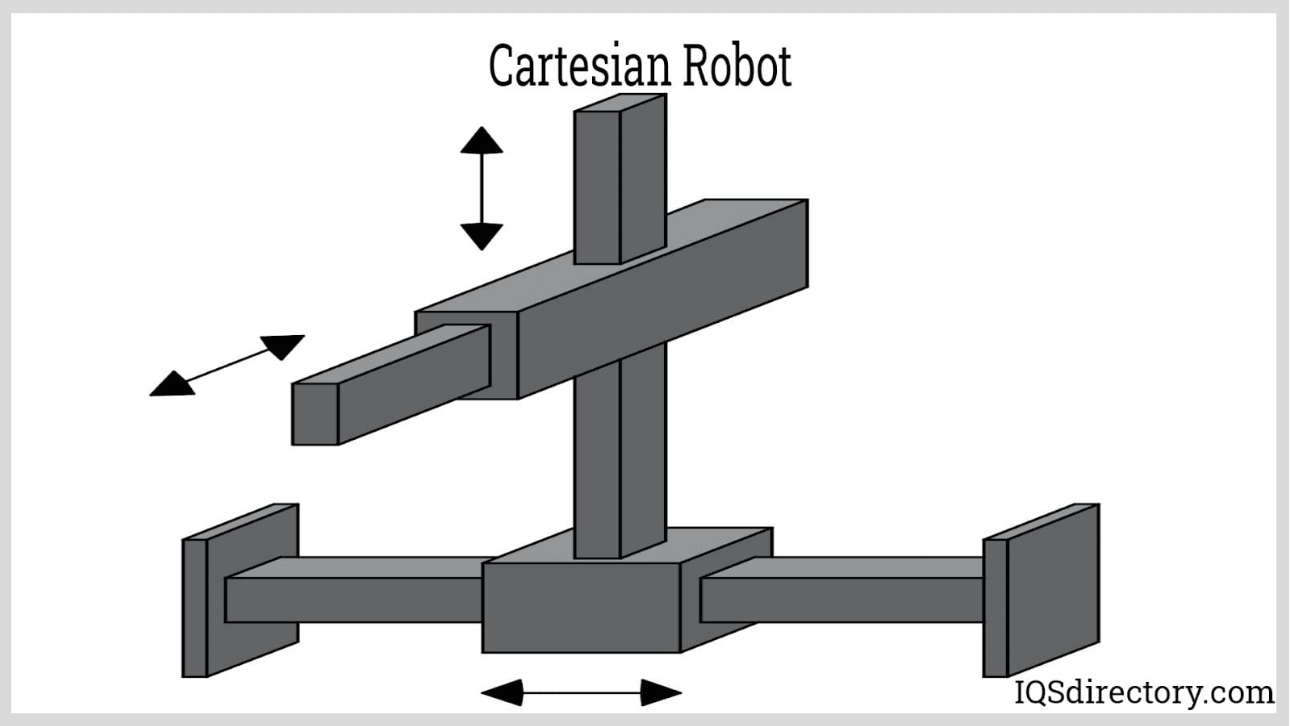
Characteristics:

•Simple kinematics

•High positioning accuracy

•Large workspace (rectangular)

Applications: CNC machines, 3D printers, pick-and-place.



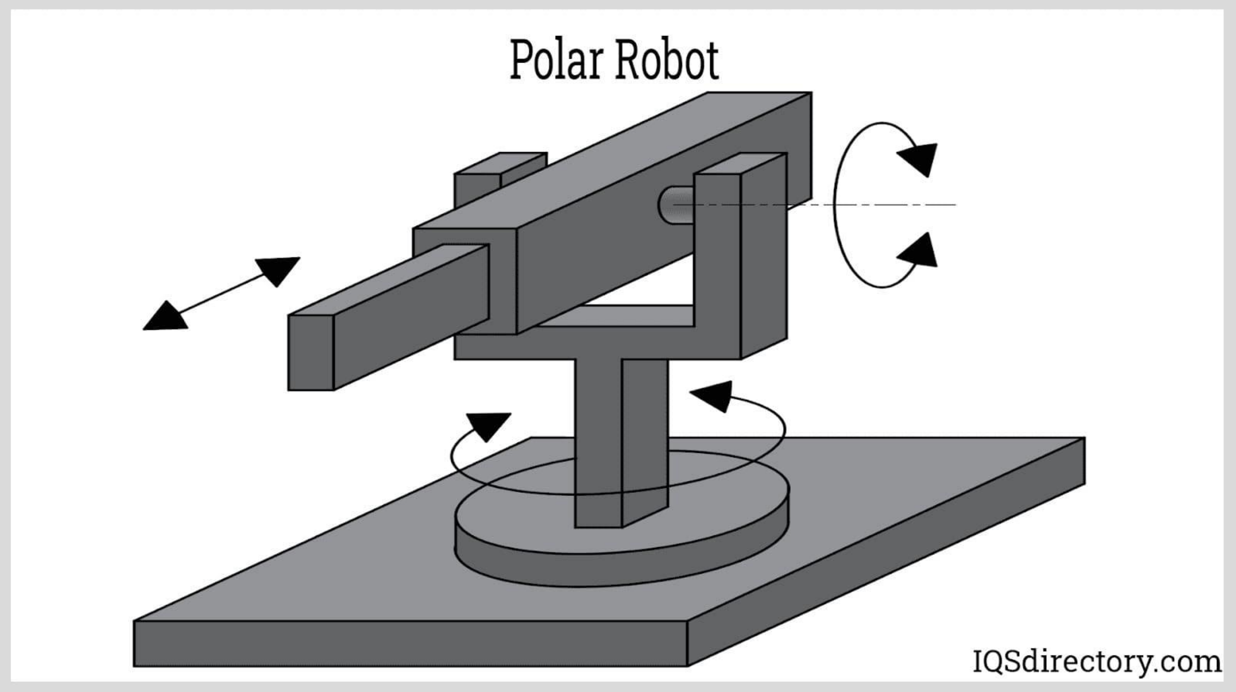
The name Cartesian is derived from the three-dimensional Cartesian coordinate system, which consists of X, Y, and Z axes. Cartesian robots are the simplest robotic system since their operation may only involve translational movements. They are suitable for applications that only require movement at right angles without the need for angular translations.

1.5 Classification of Robots

1.5.1 Classification by Structure

❑ POLAR ROBOT (RRP)

Polar Robot: Polar robots, also known as spherical robots as the work place is spherical



In the polar configuration, the robot arm has the following movements:

•Linear movement that allows the arm to extend and retract because of one linear joint.

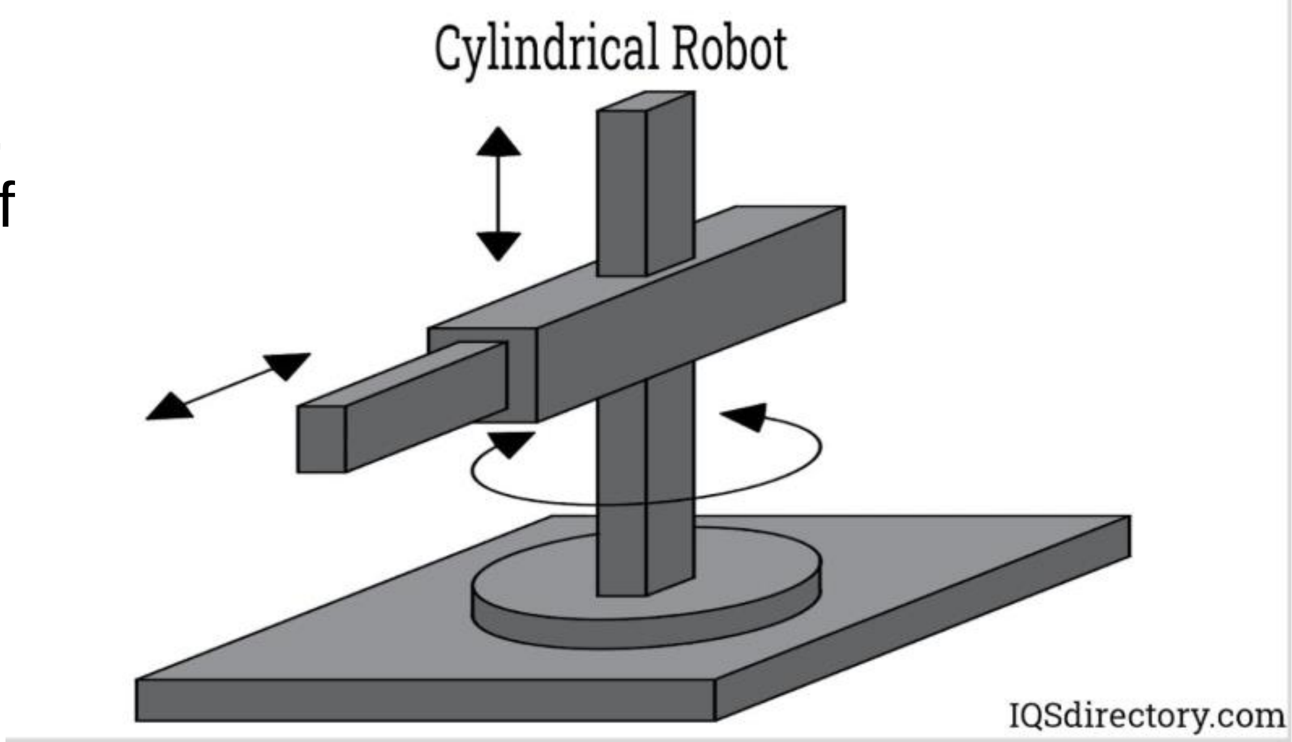
• two Rotary movement

1.5 Classification of Robots

1.5.1 Classification by Structure

- ❑ **CYLINDRICAL ROBOT (RPP)**

Cylindrical Robot: As the name suggests, a cylindrical robot has a cylindrical range of motion. This type consists of one revolute joint and two prismatic joints. The revolute joint is located at the arm's base, allowing the rotation of the links about the robot's axis. The two prismatic joints are used for adjusting the radius and height of the robot’s cylindrical work envelope.

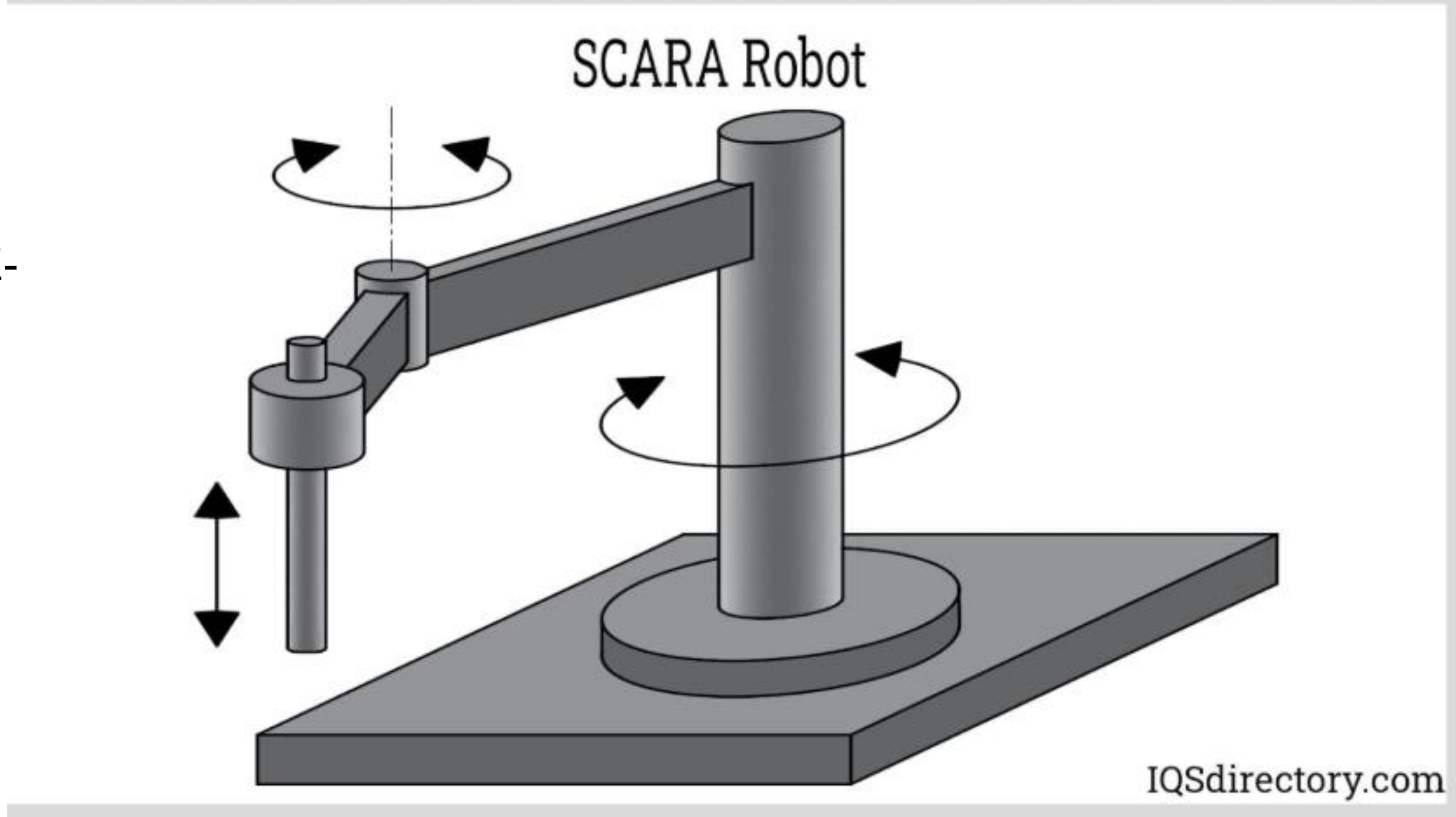


1.5 Classification of Robots

1.5.1 Classification by Structure

- SCARA ROBOT

Selective Compliant Articulated Robot Arm (SCARA): A SCARA is a type of robot with an arm that is compliant or flexible in the horizontal or XY-plane but rigid in the vertical direction or Z-axis. Its translational movement on a single plane describes its "Selective Compliant" characteristic. A SCARA has two links, two revolute joints, and a single prismatic joint.

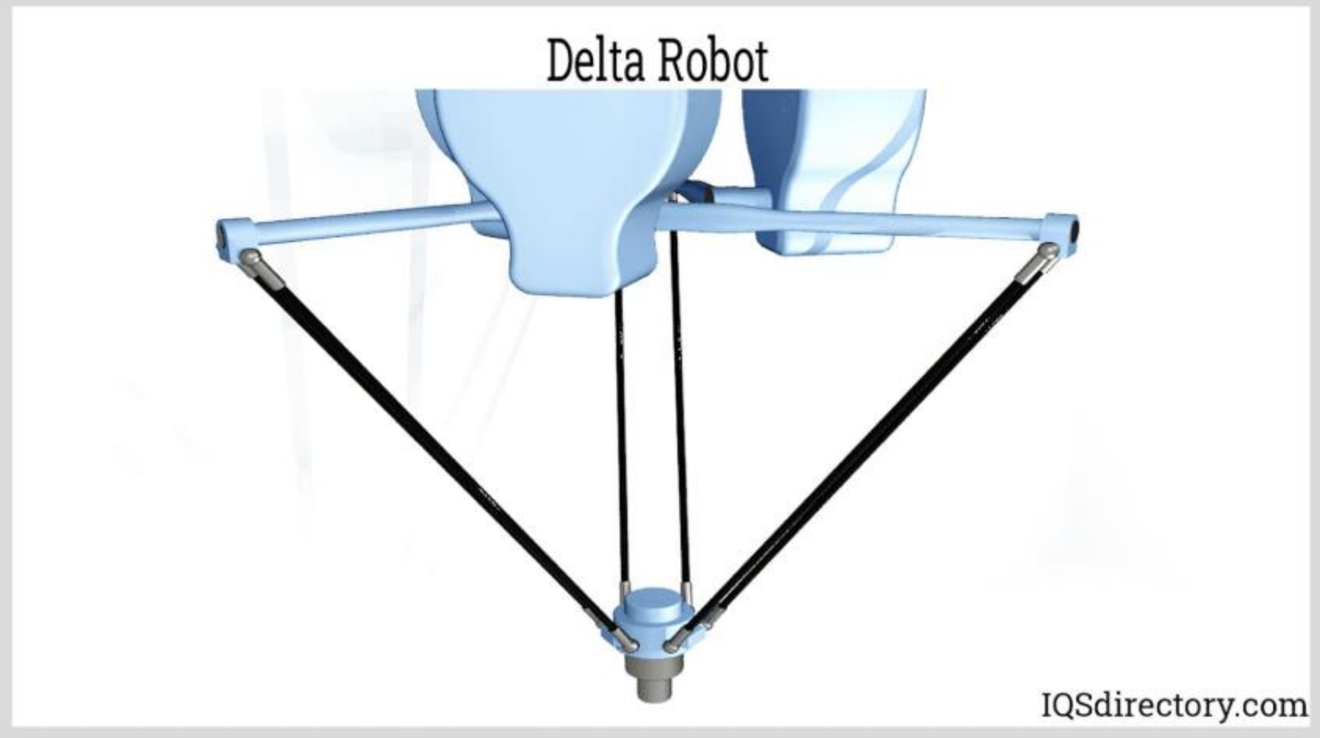


1.5 Classification of Robots

1.5.1 Classification by Structure

❑ DELTA ROBOT

Delta Robot: A delta robot consists of at least three links connected to an EOAT and a common base. The EOAT is connected to the links by three universal joints. On the other hand, the base is connected by either three prismatic or revolute-driven joints. The driven joints work together to allow the EOAT to have multiple degrees of freedom.



End-Of-Arm Tooling (EOAT) refers to **any device or tool mounted at the robot's wrist or flange**, whose purpose is to **interact with the environment or the workpiece**. It is the interface between the robot manipulator and the task to be performed.

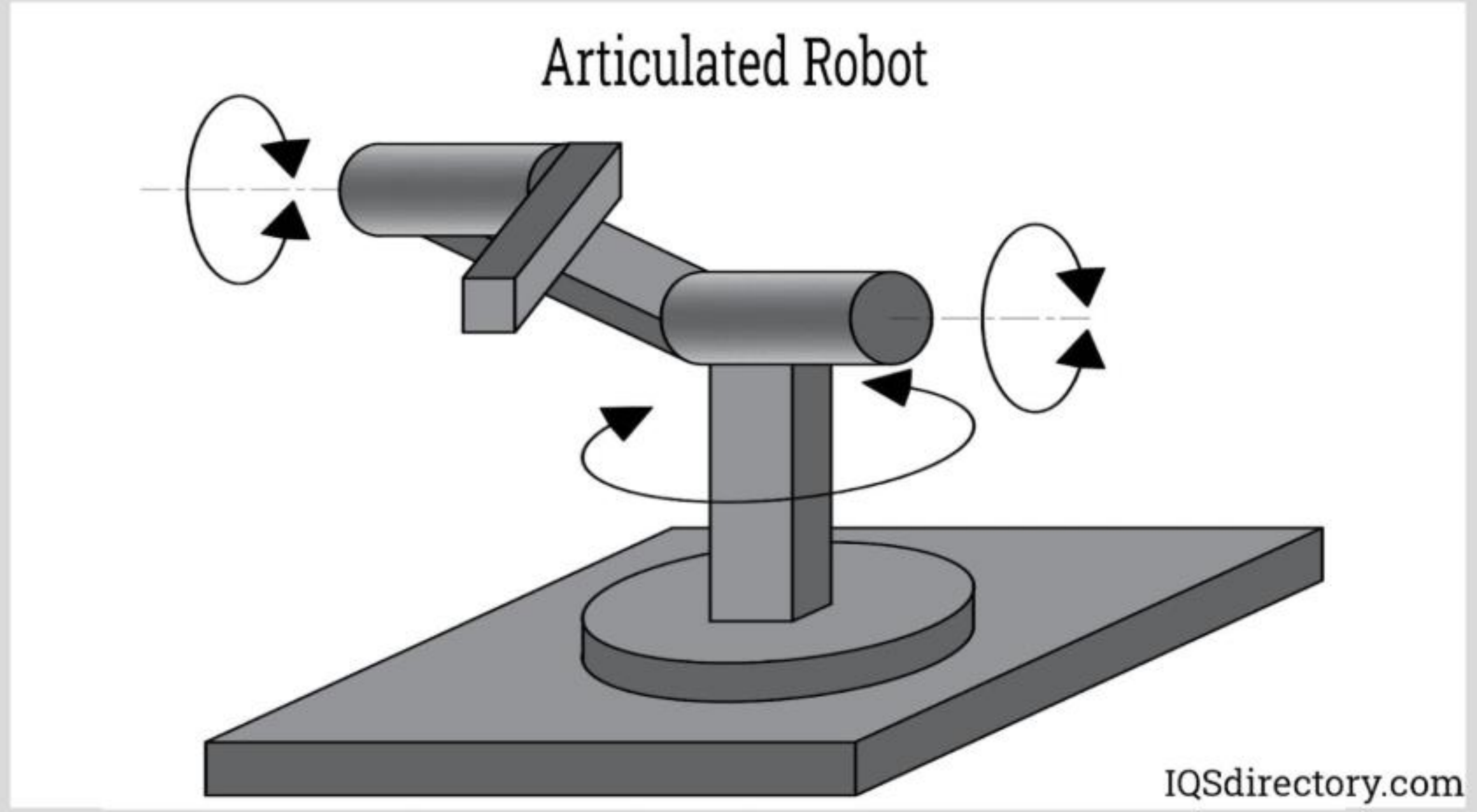
End-effector: General term for the device at the end of the robot arm

1.5 Classification of Robots

1.5.1 Classification by Structure

- ❑ **ARTICULATED ROBOT**

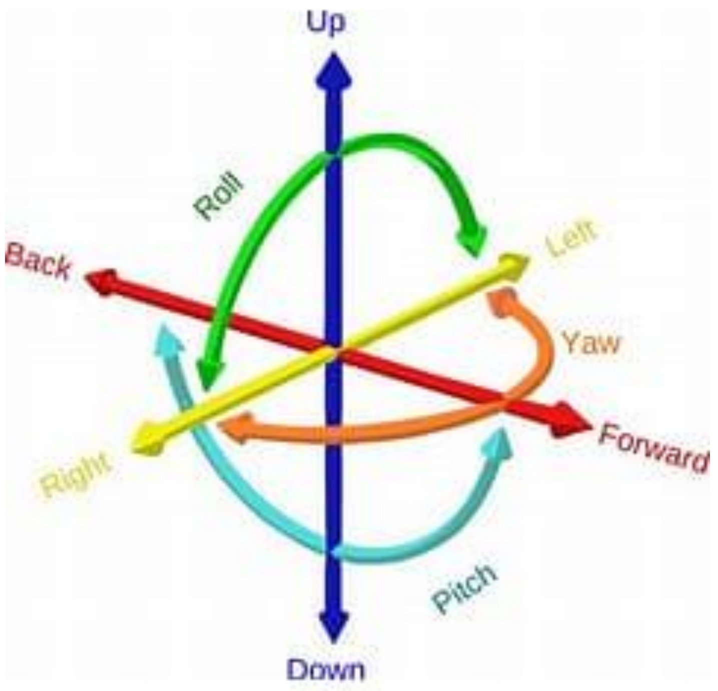
Articulated Robot: Articulated robots are the most common robots used in manufacturing processes. They perform more complex operations such as welding, product assembly, and machining. EOATs mounted on articulated robots are designed to have a full six degrees of freedom. The robot arm consists of at least three revolute joints. A fourth revolute joint can be added to the wrist of the arm for rotating the EOAT.



1.5 Classification of Robots

1.5.1 Classification by Structure

❑ ARTICULATED ROBOT



Definition of Six Degrees of Freedom

Six degrees of freedom describe the freedom of movement of a rigid body in three-dimensional space. This concept is crucial in various fields, including robotics, virtu al reality, gaming, and aviation. The six degrees of freedom can be categorized into two groups: **translational movements** and **rotational movements**.

Translational degrees of freedom (3DoF):
Translational degrees of freedom represent the ability to move in different directions. These include:

- **X-axis translation:** Movement along the horizontal axis, often referred to as left-right or side-to-side motion
- **Y-axis translation:** Movement along the vertical axis, often referred to as forward-backward or front-to-back motion
- **Z-axis translation:** Movement along the depth axis, often referred to as up-down or vertical motion

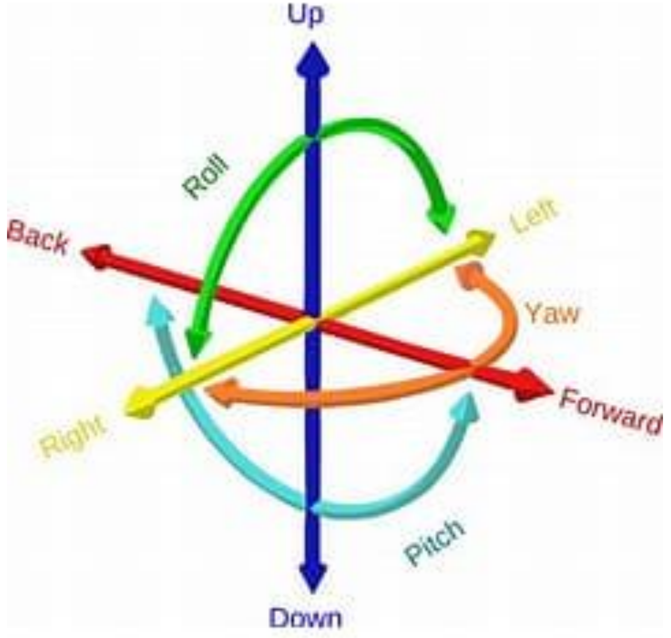
Rotational degrees of freedom (3DoF):
Rotational degrees of freedom represent the ability to rotate or change orientation. These include:

- **Pitch (rotation about X-axis):** Tilting forward or backward
- **Yaw (rotation about Y-axis):** Turning left or right
- **Roll (rotation about Z-axis):** Tilting sideways

1.5 Classification of Robots

1.5.1 Classification by Structure

❑ ARTICULATED ROBOT



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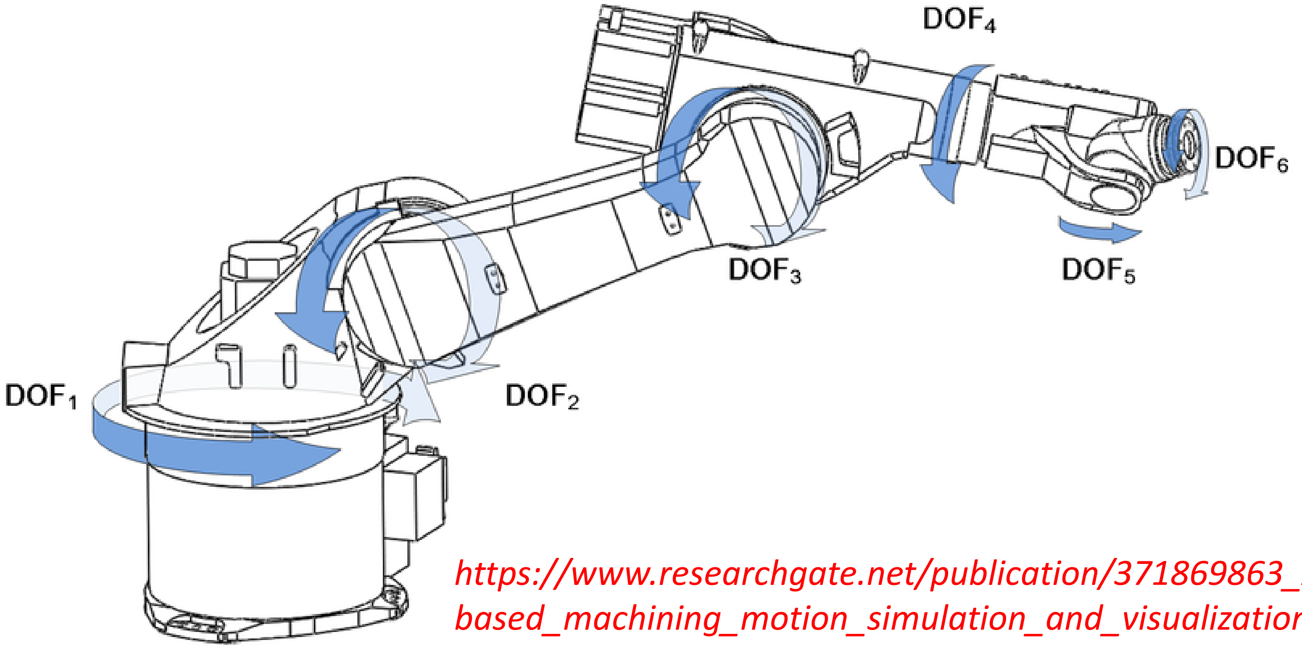
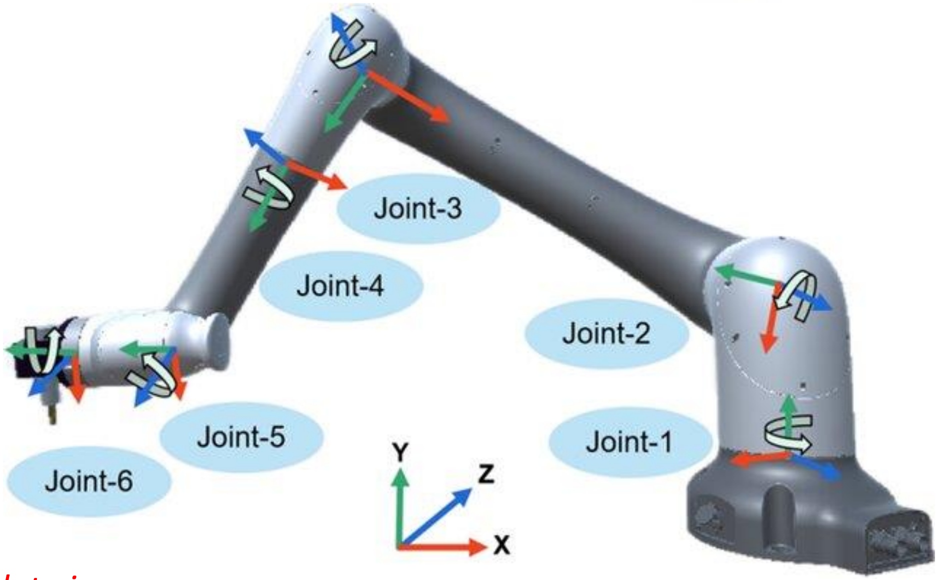




https://www.researchgate.net/publication/371869863_A_digital_twin-based_machining_motion_simulation_and_visualization_monitoring_system_for_milling_robot/figures?lo=1

1.5 Classification of Robots

1.5.2 Classification by Mobility

- Fixed-base robots:
- Mobile robots (wheeled, tracked, legged)
- Aerial robots (UAVs)

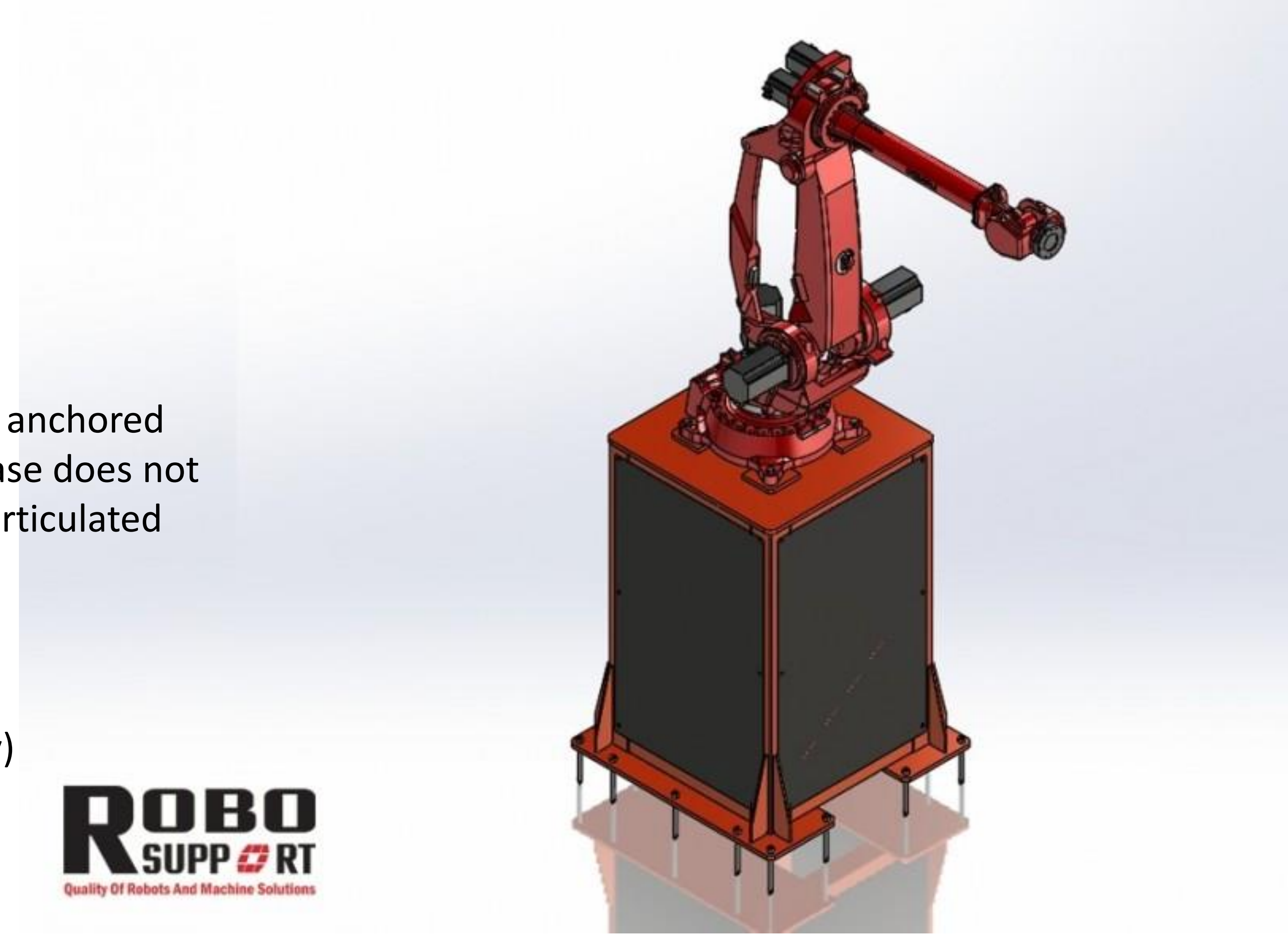
1.5 Classification of Robots

1.5.2 Classification by Mobility

❑ Fixed-base robots:

1. Fixed-Base Robots
Definition
Fixed-base robots are robotic systems mechanically anchored to a fixed support (floor, wall, ….), such that their base does not move during operation. All motion is produced by articulated links and joints connected to this stationary base.

Common applications
•Industrial automation (welding, painting, assembly)
•Pick-and-place operations
•Machining and precision manufacturing



https://www.thaisupport.co.th/17265531/base-robot

1.5 Classification of Robots

1.5.2 Classification by Mobility

- ❑ **Mobile robots (wheeled, tracked, legged)**

https://www.expo21xx.com/automation21xx/18488_st3_mobile-robots/default.htm

2. Mobile Robots

Definition

Mobile robots are robotic systems capable of autonomous or semi-autonomous movement within their environment. Unlike fixed-base robots, their entire body can translate and/or rotate in space to reach different locations.

https://www.robotshop.com/products/dr-robot-jaguar-v6-tracked-mobile-platform-arm

https://humanoidroboticstechnology.com/articles/legged-robot-basics-introduction/

1.5 Classification of Robots

1.5.2 Classification by Mobility

❑ Aerial robots (UAVs)

Definition

Aerial robots, commonly known as Unmanned Aerial Vehicles (UAVs), are robotic systems capable of sustained flight within the atmosphere.

Key characteristics

•Operate in three-dimensional space
•High mobility and wide area coverage
•Limited payload and flight time due to energy constraints

Common applications

•Surveillance and mapping
•Environmental monitoring
•Infrastructure inspection and delivery

https://robohub.org/autonomous-exploration-planning-using-aerial-robots/

https://www.survtechsolutions.com/uav-unmanned-aerial-vehicles

1.5 Classification of Robots

1.5.3 Classification by Application

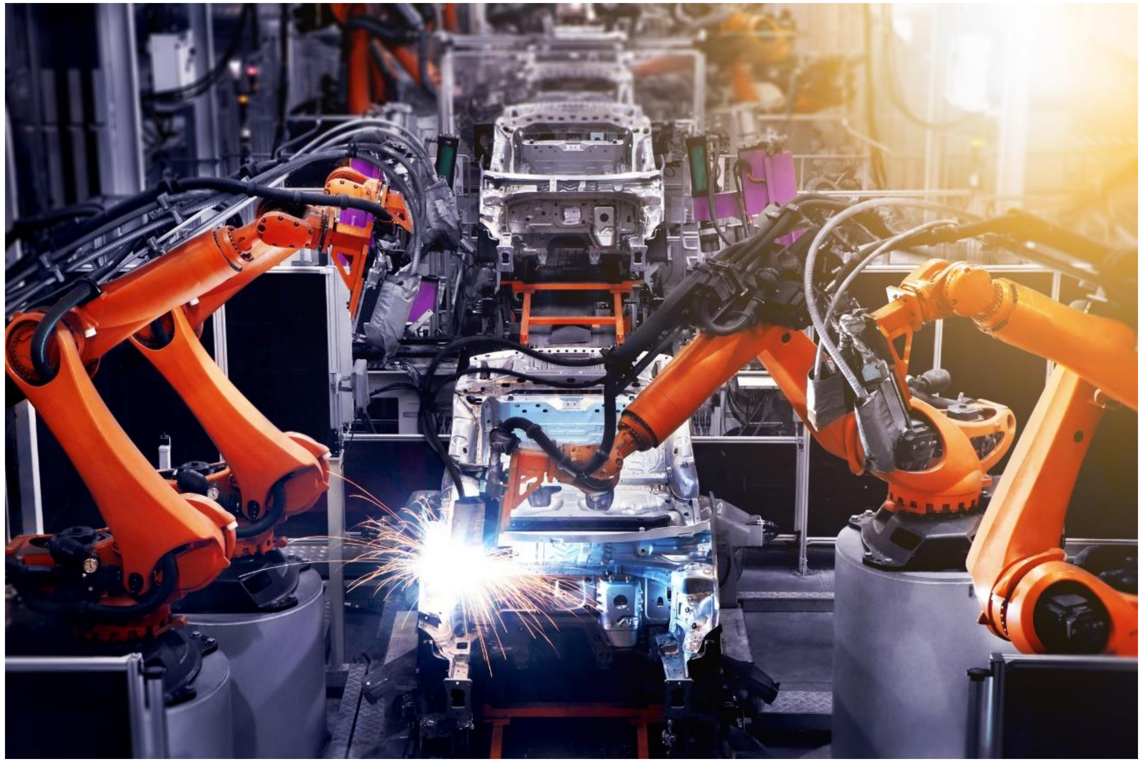
- Industrial robots
- Service robots
- Medical robots
- Agricultural robots
- Military and exploration robots

1.5 Classification of Robots

1.5.3 Classification by Application

❑ Industrial robots

Industrial robots are automated machines used in manufacturing to perform tasks such as welding, painting, assembly, and material handling with hig h precision and speed.



https://robodk.com/blog/industrial-robot-applications/

1.5 Classification of Robots

1.5.3 Classification by Application

❑ Service robots

Definition and Purpose

Service robots are defined as robots that perform useful tasks for humans or equipment, excluding industrial automation applications. They are typically autonomous or semi-autonomous, meaning they can operate independently or with minimal human intervention. The primary goal of service robots is to assist in tasks that are dirty, dull, distant, dangerous, or repetitive

https://suburbanrobotics.com/service-robots/

Service robots are designed to interact with people and perform tasks for them. They are typically smaller and less powerful than industrial robots, and they are often designed to be more user-friendly and easier to interact with.

1.5 Classification of Robots

1.5.3 Classification by Application

❑ Medical robots

A medical robot is a programmable electromechanical device designed to assist with or perform tasks within healthcare environments. These robots can perform various medical tasks, such as surgery, disease screening, and rehabilitation, often integrating artificial intelligence (AI) and advanced sensors to enhance their functionality. They are built to assist healthcare professionals, improving precision and efficiency in medical procedures.

https://www.practical-patient-care.com/analysis/medical-robots/

1.5 Classification of Robots

1.5.3 Classification by Application

❑ Agricultural robots

An agricultural robot, also known as an agribot, is a robot designed for use in the agriculture industry. These robots automate tasks for farmers, such as planting seeds, watering plants, harvesting crops, and controlling pests, thereby boosting production efficiency and reducing reliance on manual labor.

https://www.agricultural-robotics.com/news/naio-technologies-goes-global

1.5 Classification of Robots

1.5.3 Classification by Application

❑ Military and exploration robots

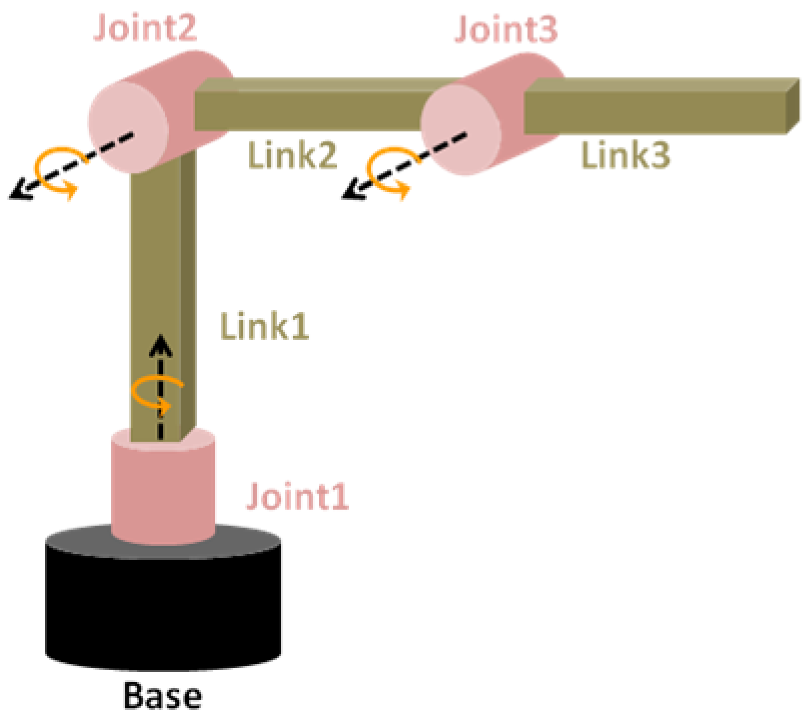
Military robots **support missions that keep soldiers safer and improve battlefield precision**. These machines handle reconnaissance, bomb disposal, logistics, and, in some cases, autonomous targeting.

1.6 Main Subsystems of a Robot

1.6.1 Mechanical Subsystem

- ❑ Links
- ❑ Joints
- ❑ End-effectors

Defines the robot’s geometry and workspace.

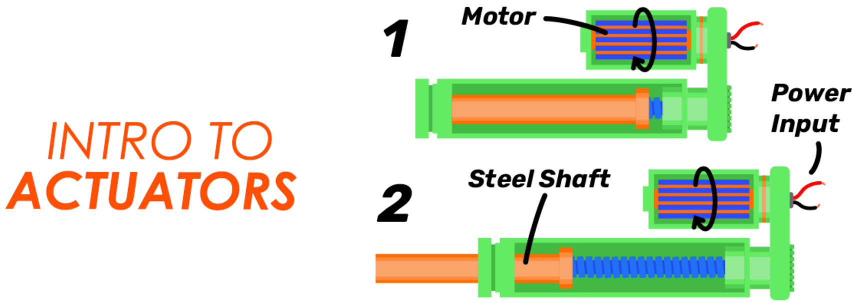


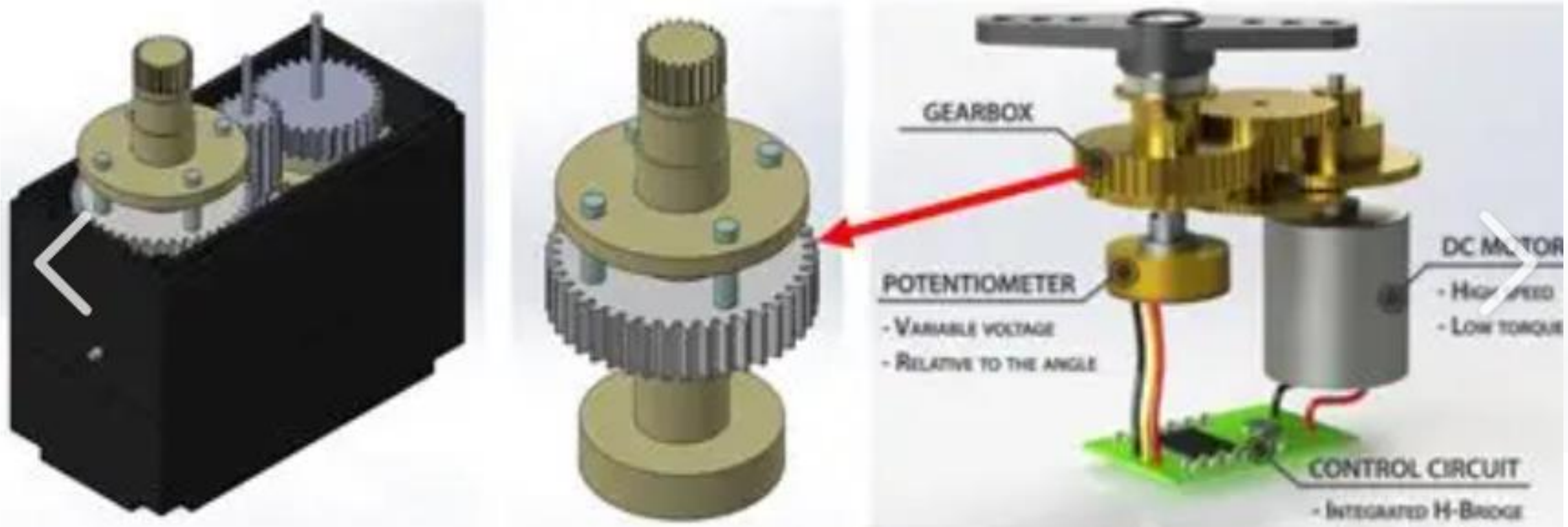
1.6 Main Subsystems of a Robot

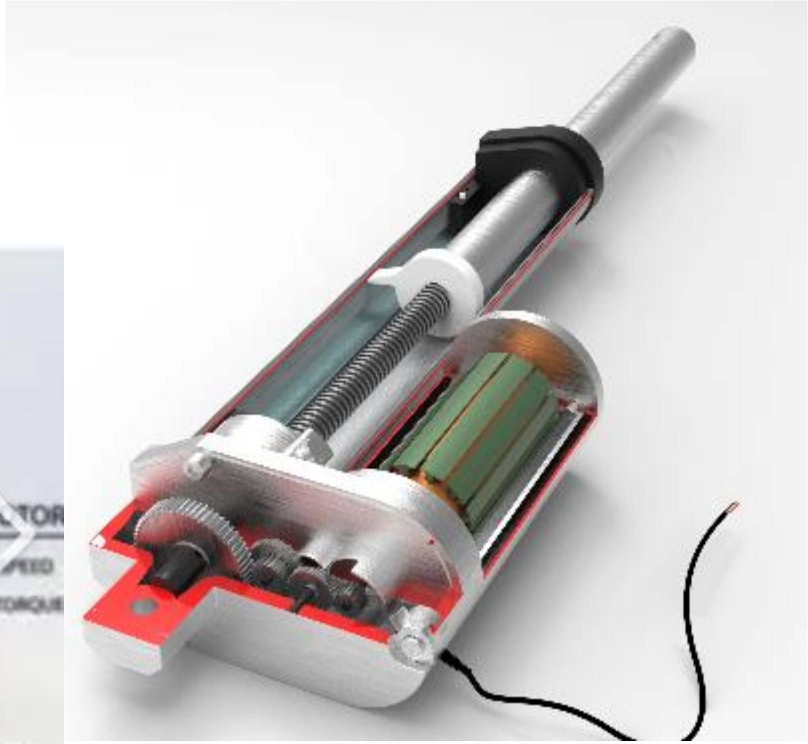
1.6.2 Actuation Subsystem

- Electric actuators (DC, BLDC, servo)
- Hydraulic actuators
- Pneumatic actuators

Selection depends on torque, speed, accuracy, and environment.







1.6 Main Subsystems of a Robot

1.6.3 Sensor Subsystem

Internal Sensors (Proprioceptive)

- Encoders
- Sensors
- ....

External Sensors (Exteroceptive)

- Proximity sensors
- Force/torque sensors
- Vision sensors (cameras, LiDAR)

1.6 Main Subsystems of a Robot

1.6.4 Control and Computing Subsystem

- ❑ Microcontrollers
- ❑ Embedded processors
- ❑ Industrial PCs

Executes control algorithms and decision logic.