Introduction to Robotics

Chapter 1. Overviews and Fundamentals

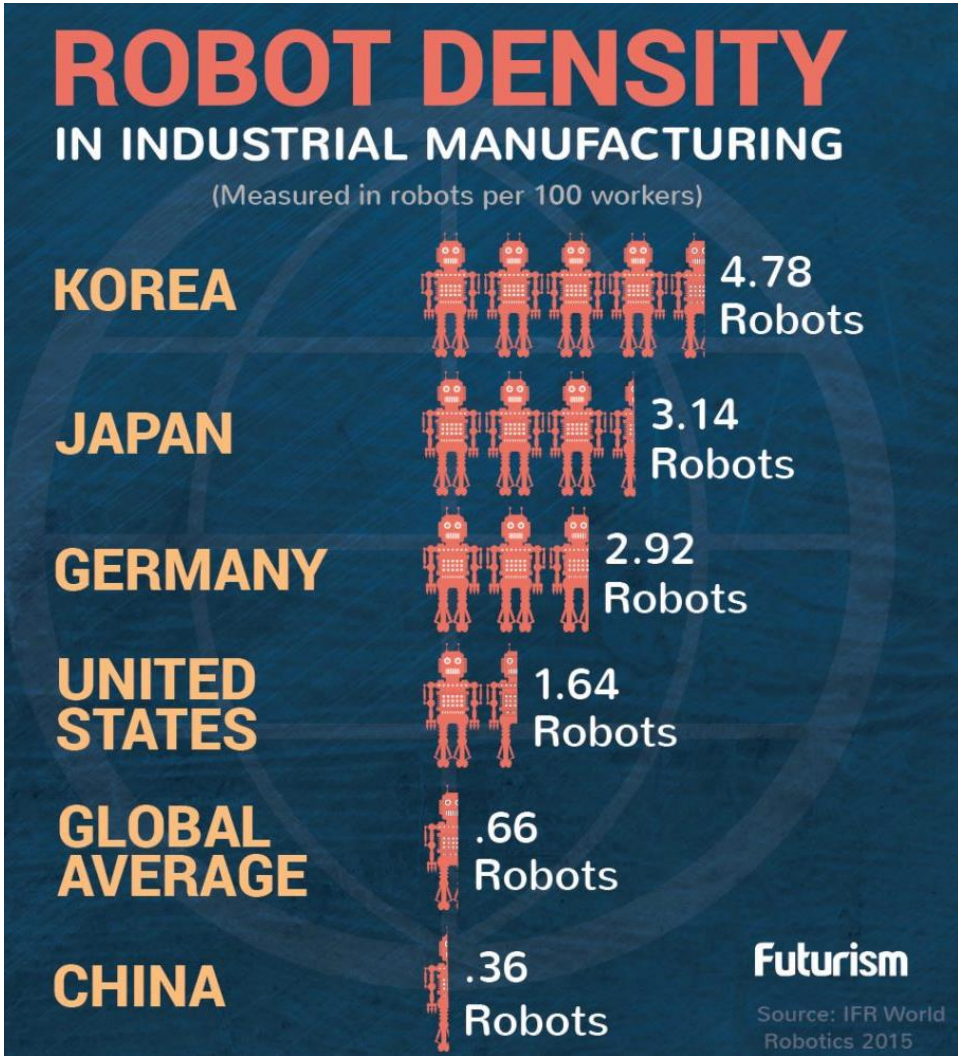
Dr. Tran Minh Thien

HCMUTE, Faculty of Mechanical Engineering

Department of Mechatronics

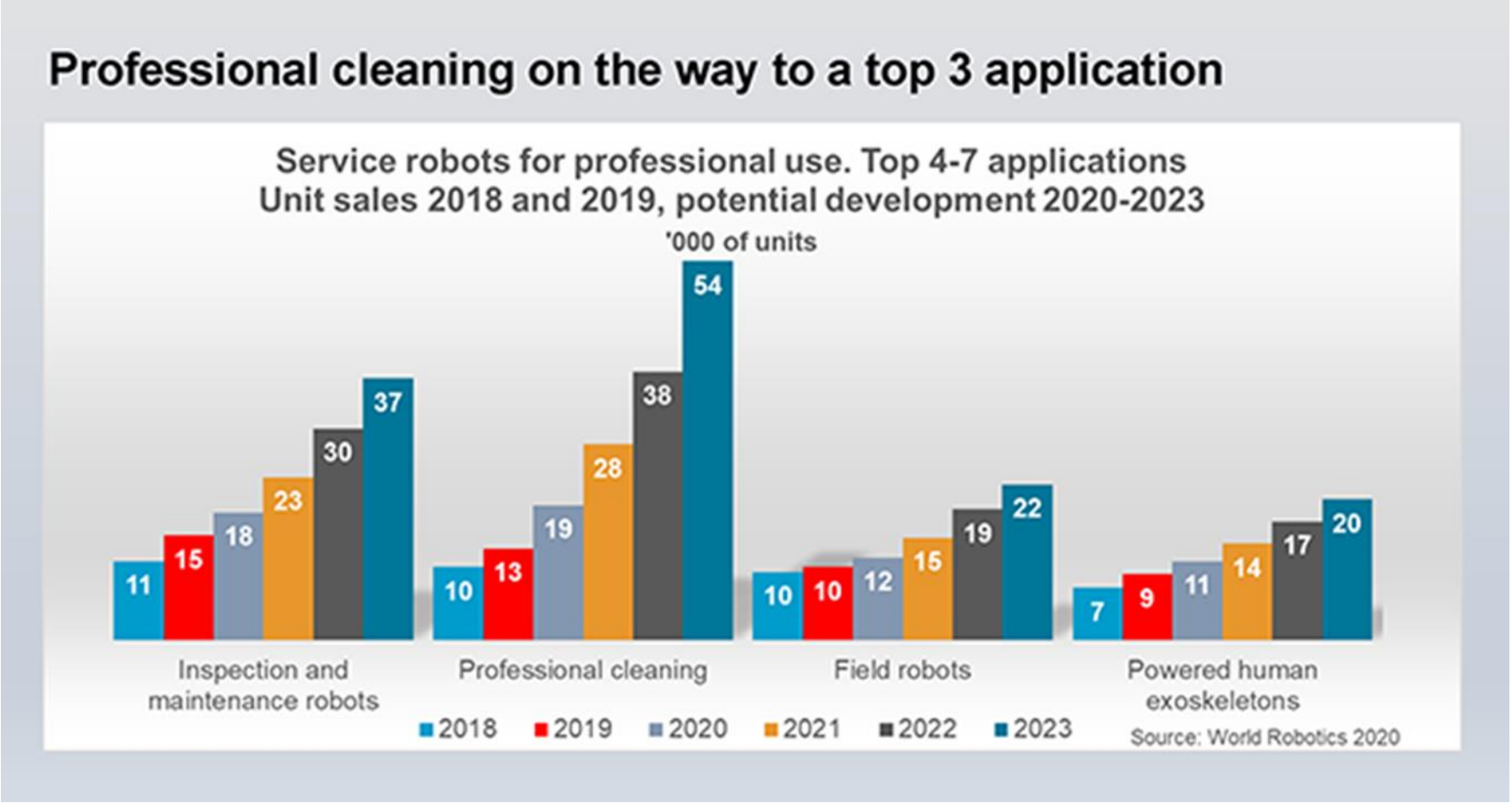
1.1. Introduction

Overviews of robots



1.1. Introduction

Overviews of robots



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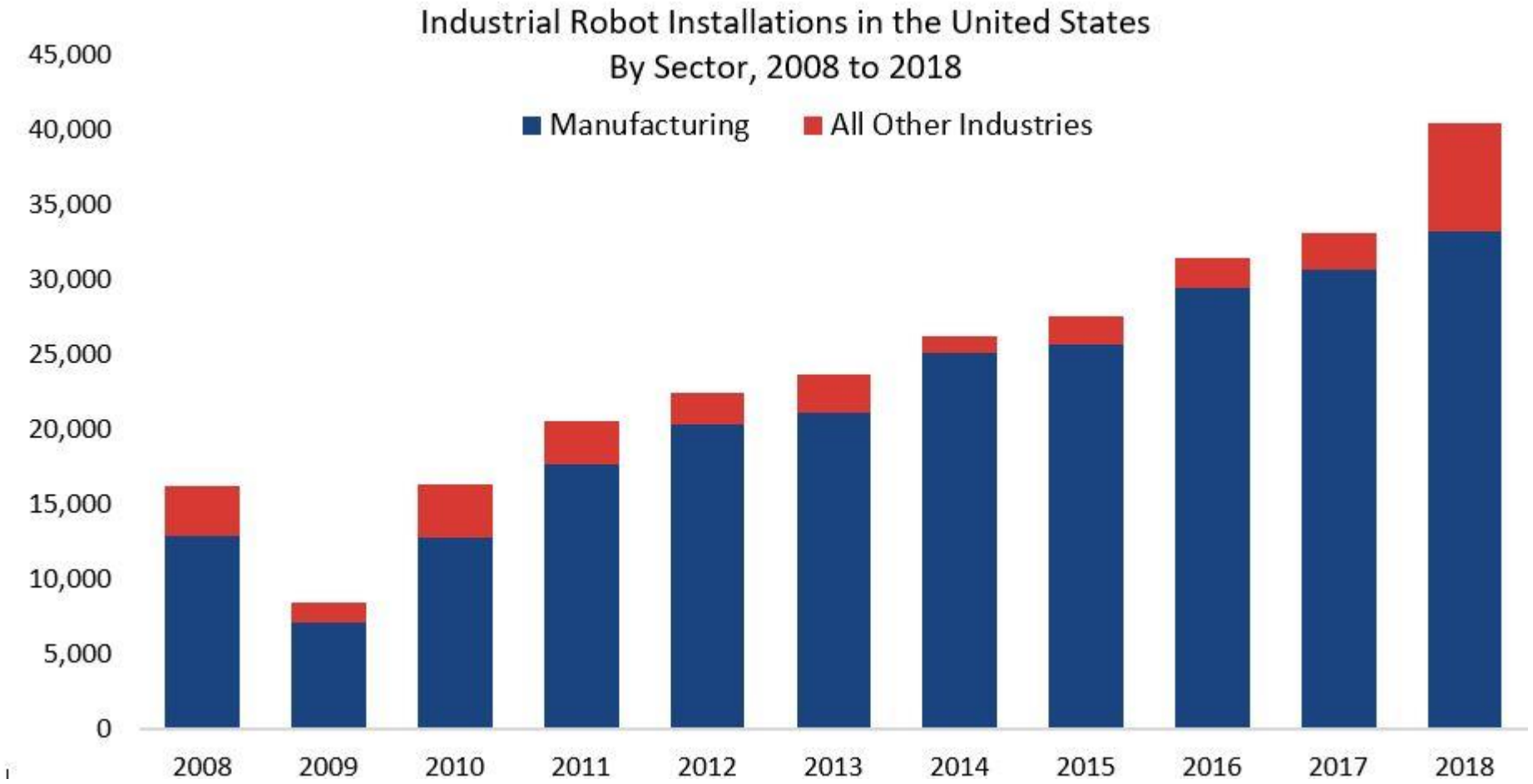
Overviews of robots



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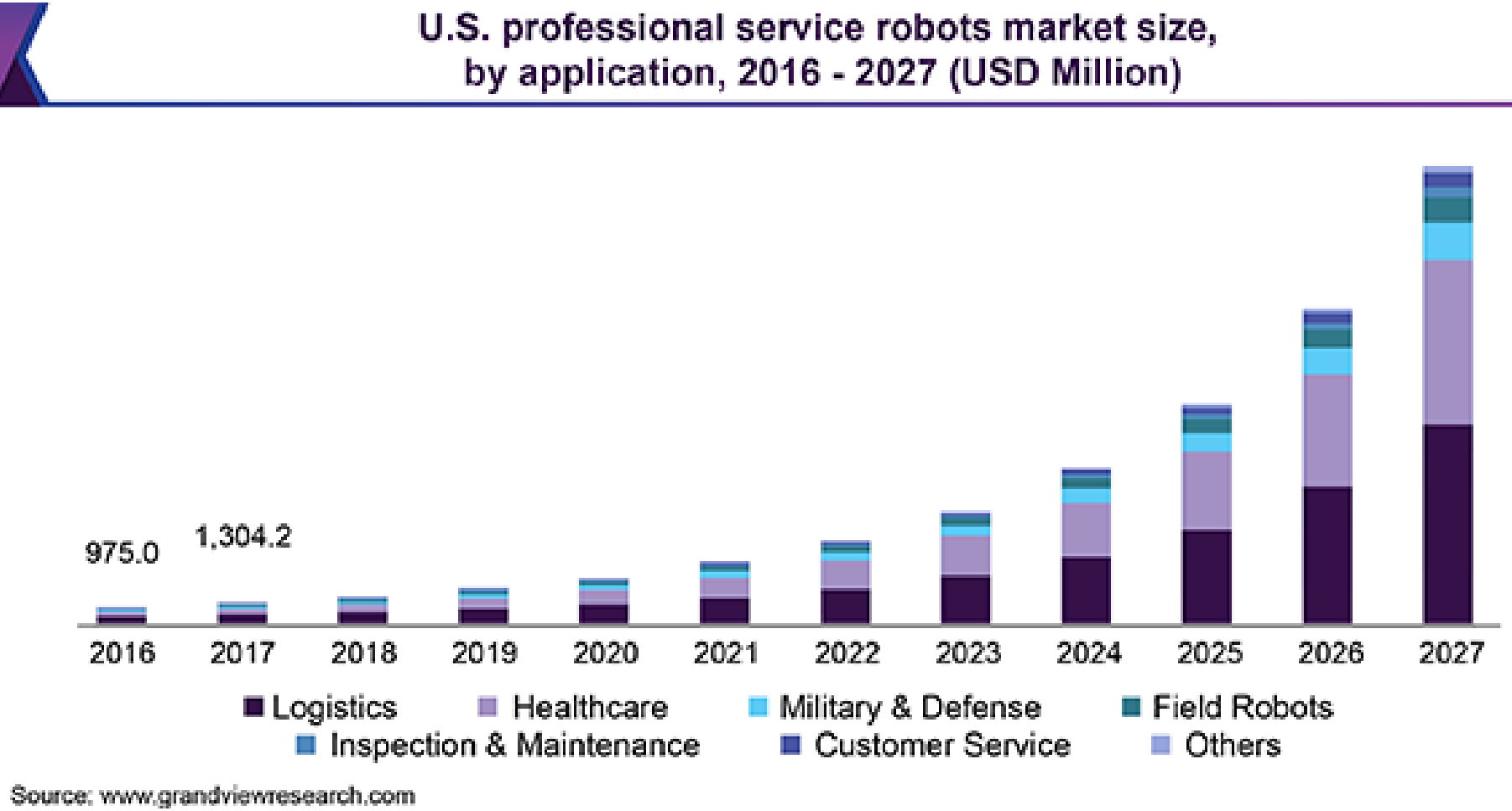
Overviews of robots



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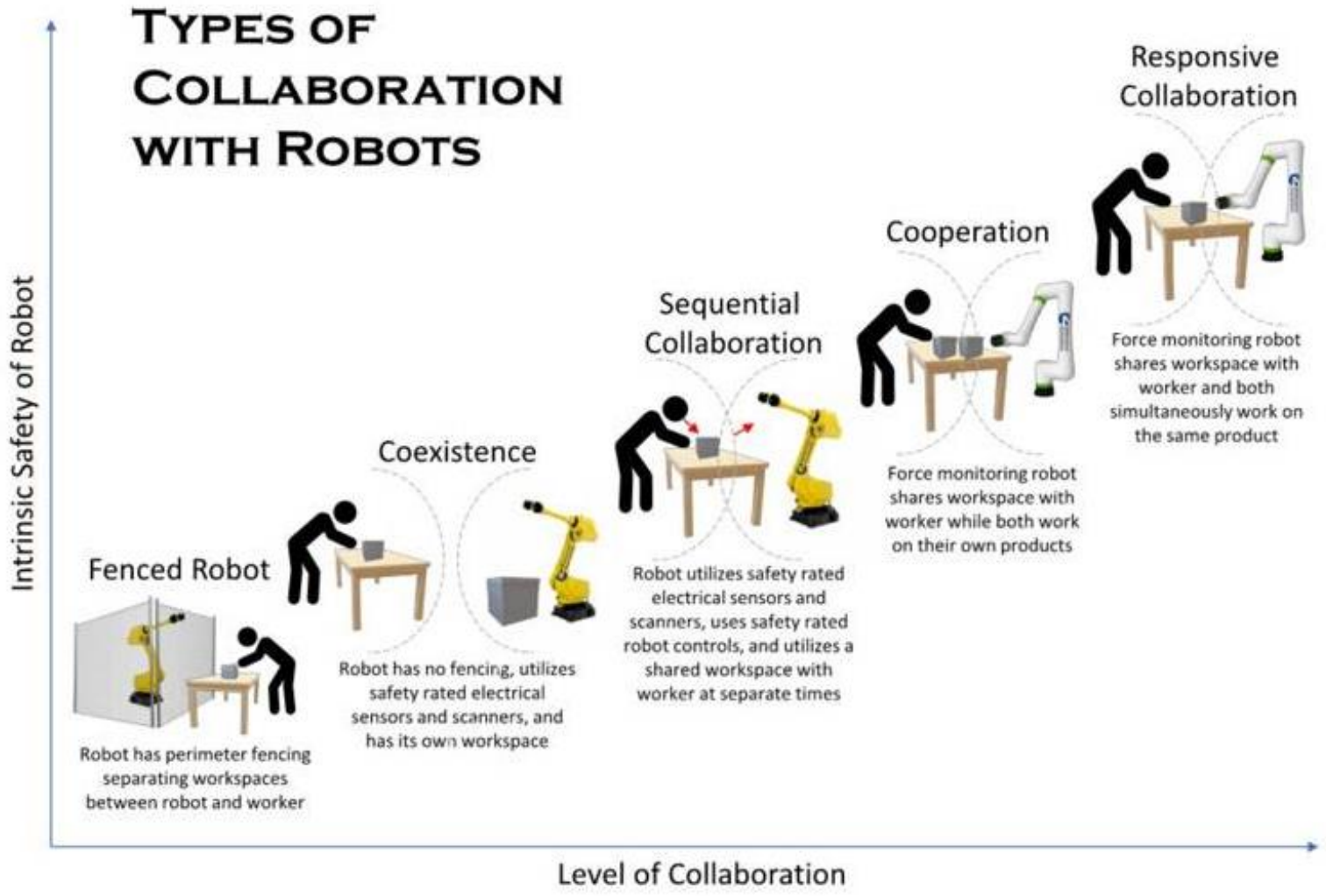
Overviews of robots



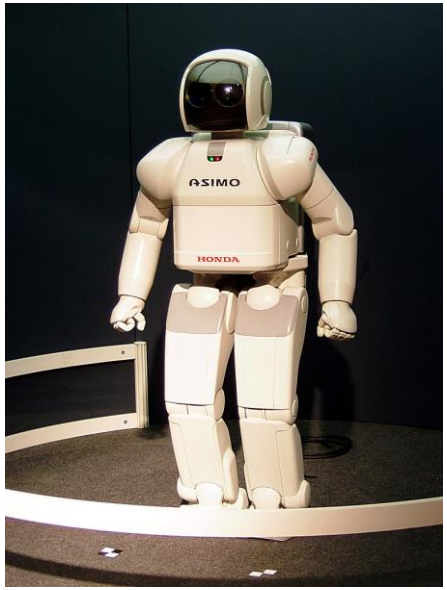
1.1. Introduction

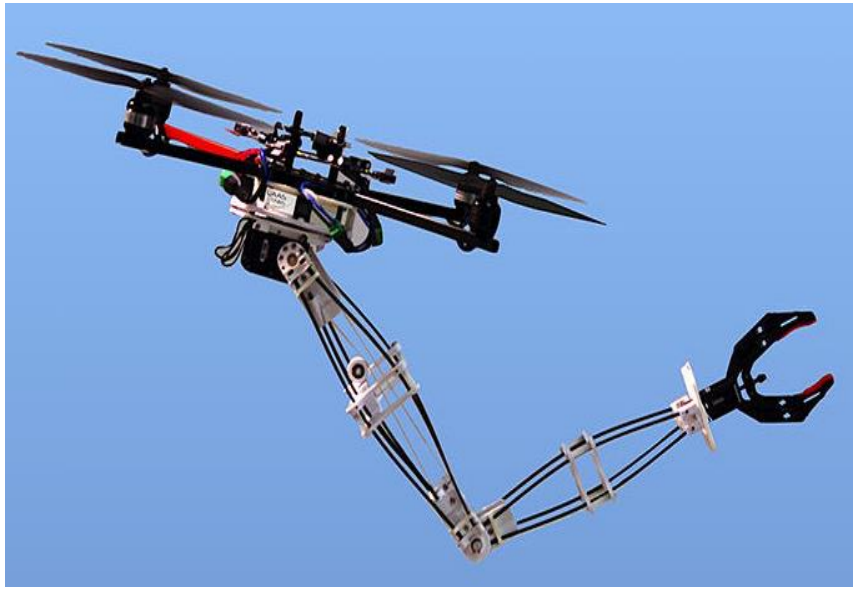
Overviews of robots

1.1. Introduction

What is a robot?

Robots are complex, versatile devices that contain a mechanical structure, a sensory system, and an automatic control system. **Robots** may be used in manufacturing environments, in underwater and space exploration, in researching human and animal behavior, for transportation and delivery, for military purposes, or even for fun.

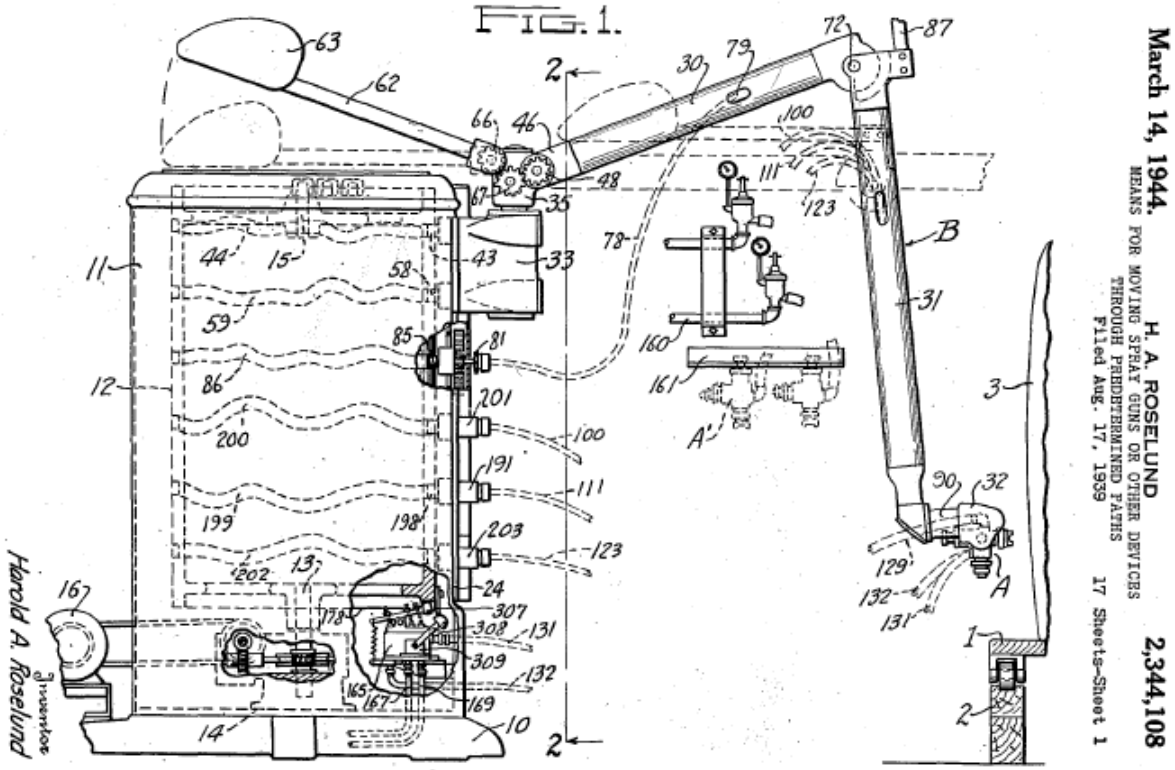




1.1. Introduction

Historical Development

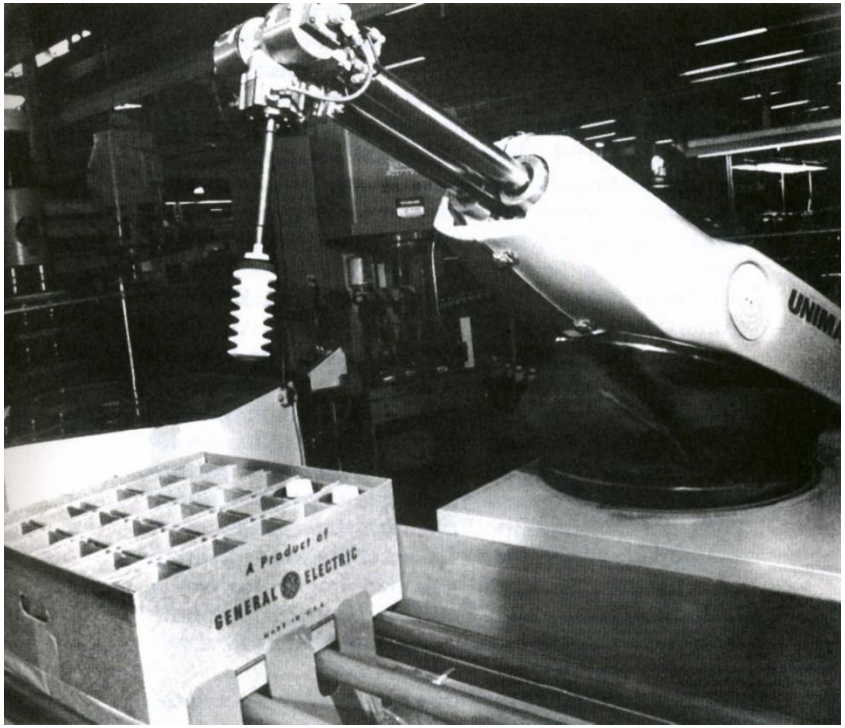
- The first position controlling apparatus was invented around 1938 for spray painting.

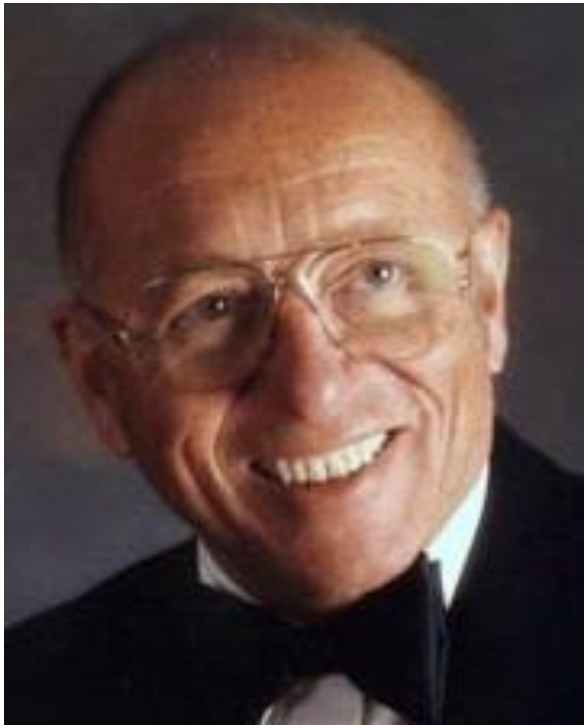


1.1. Introduction

Historical Development

- The first modern industrial Robot were the **Unimates**, made by Joseph Engelberger (1925–2015) in the early 1960s.
- **Engelberger** has been called the father of Robotics.





1.1. Introduction

Historical Development

Asimo Humanoid Robot Evolution, Honda

1.1. Introduction

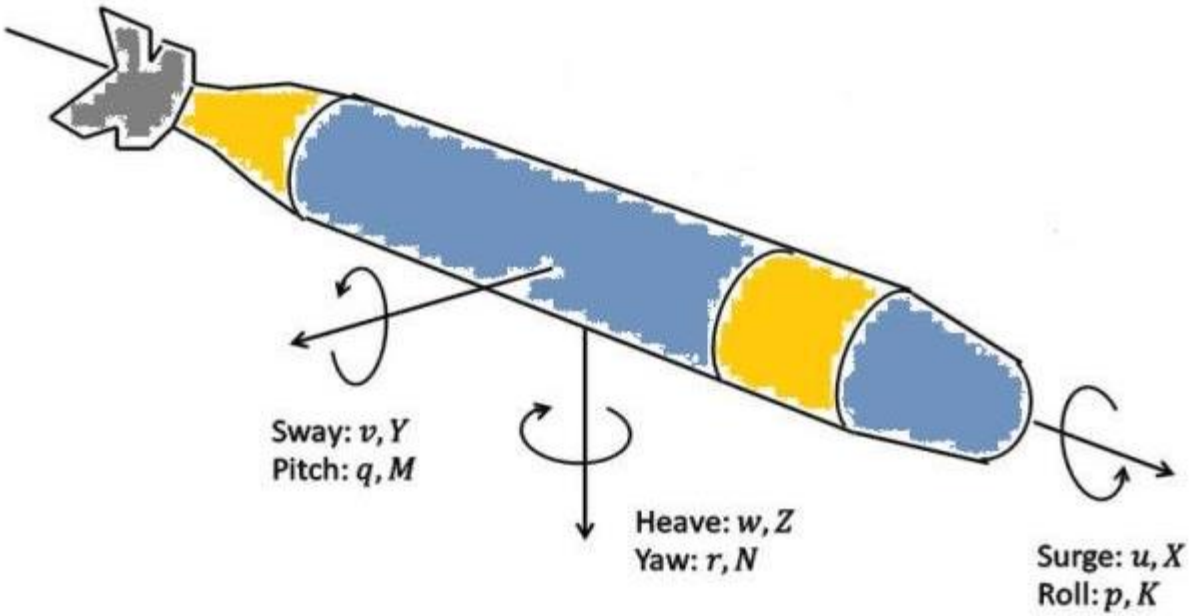
What is a Robotics?

Robotics is the art, knowledge base, and know-how of designing, applying, and using robots in human endeavors. Robotic systems consist of not just robots, but also other devices and systems that are used together with the robots.

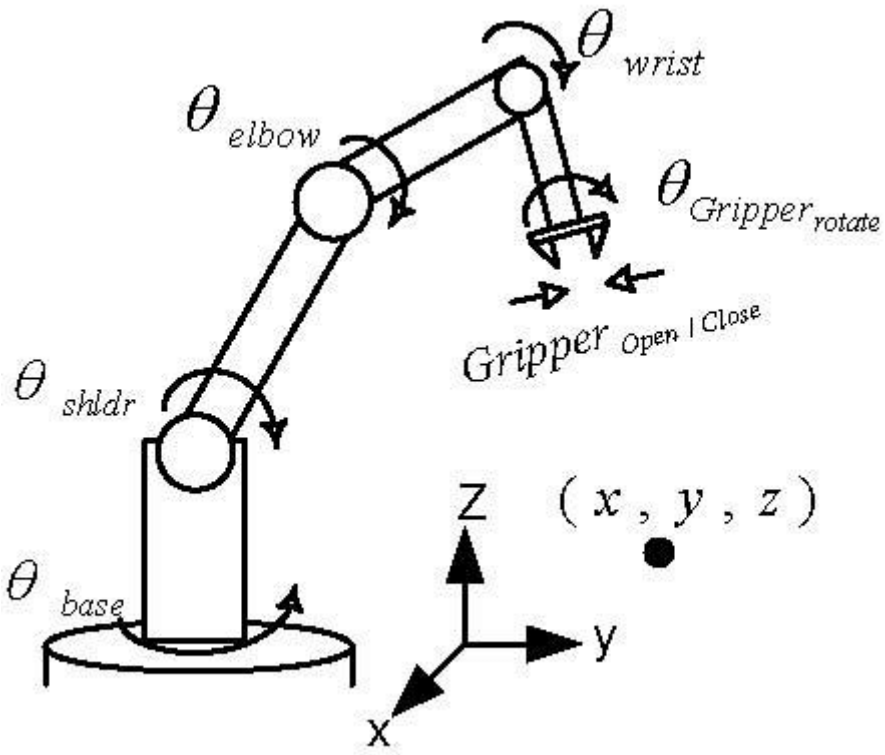
Robotics is an interdisciplinary subject that benefits from mechanical engineering, electrical and electronic engineering, computer science, cognitive sciences, biology, and many other disciplines.

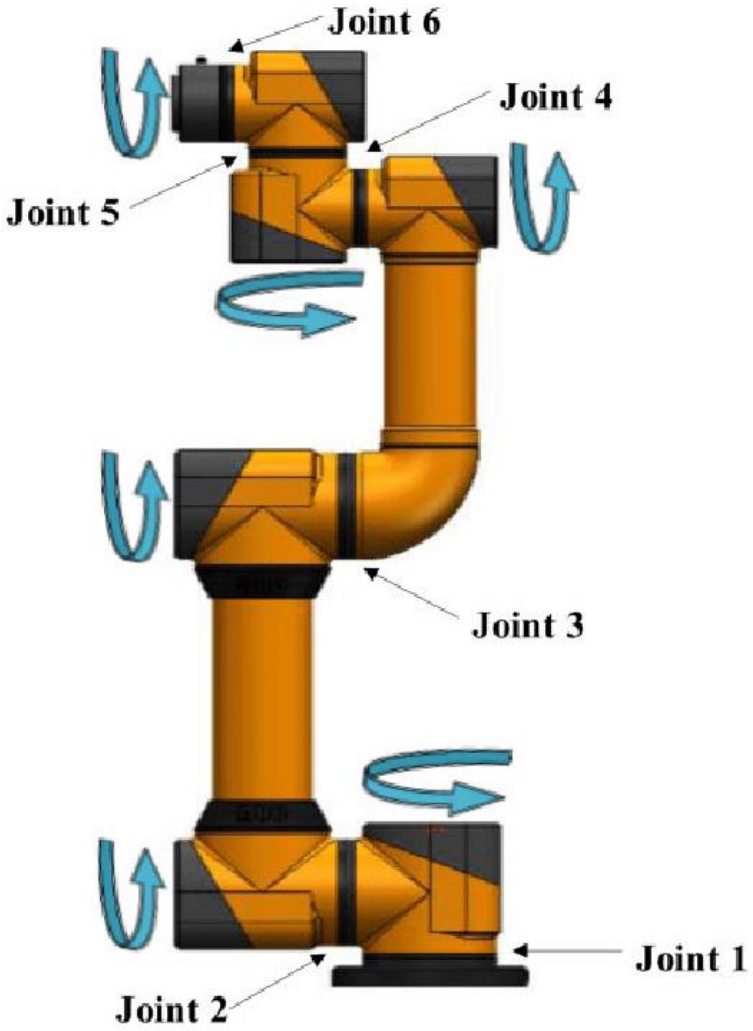
1.2. Robot Degrees of Freedom

The **degrees of freedom** (DOF) of a mechanical system is the number of independent parameters that define its configuration or state.



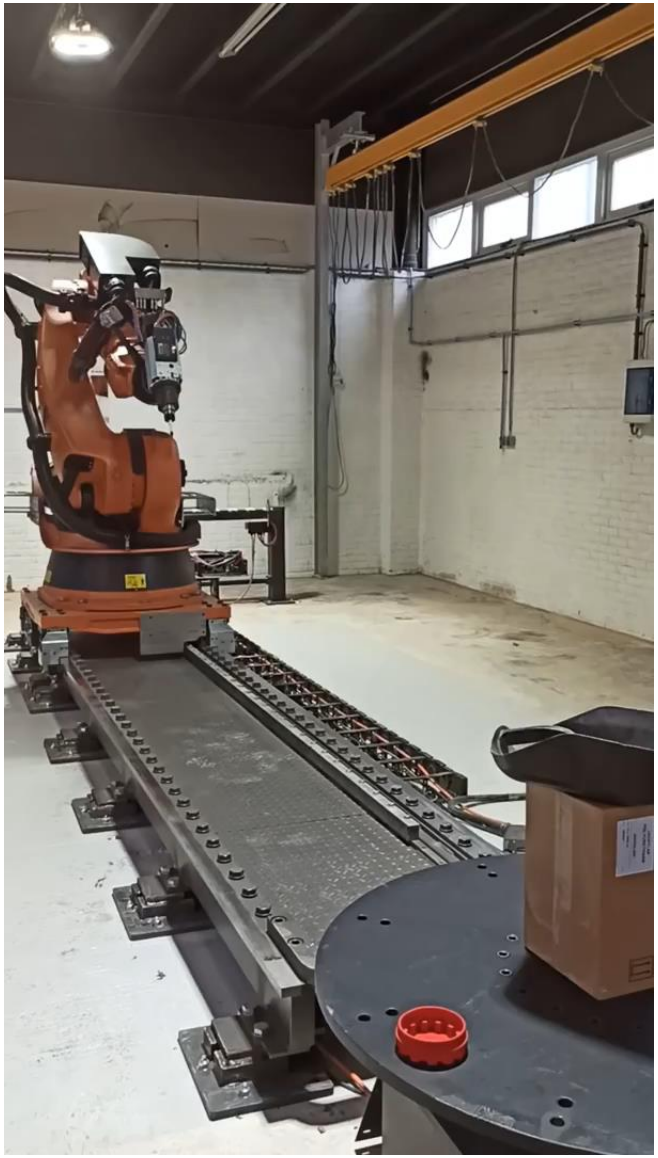
1.2. Robot Degrees of Freedom



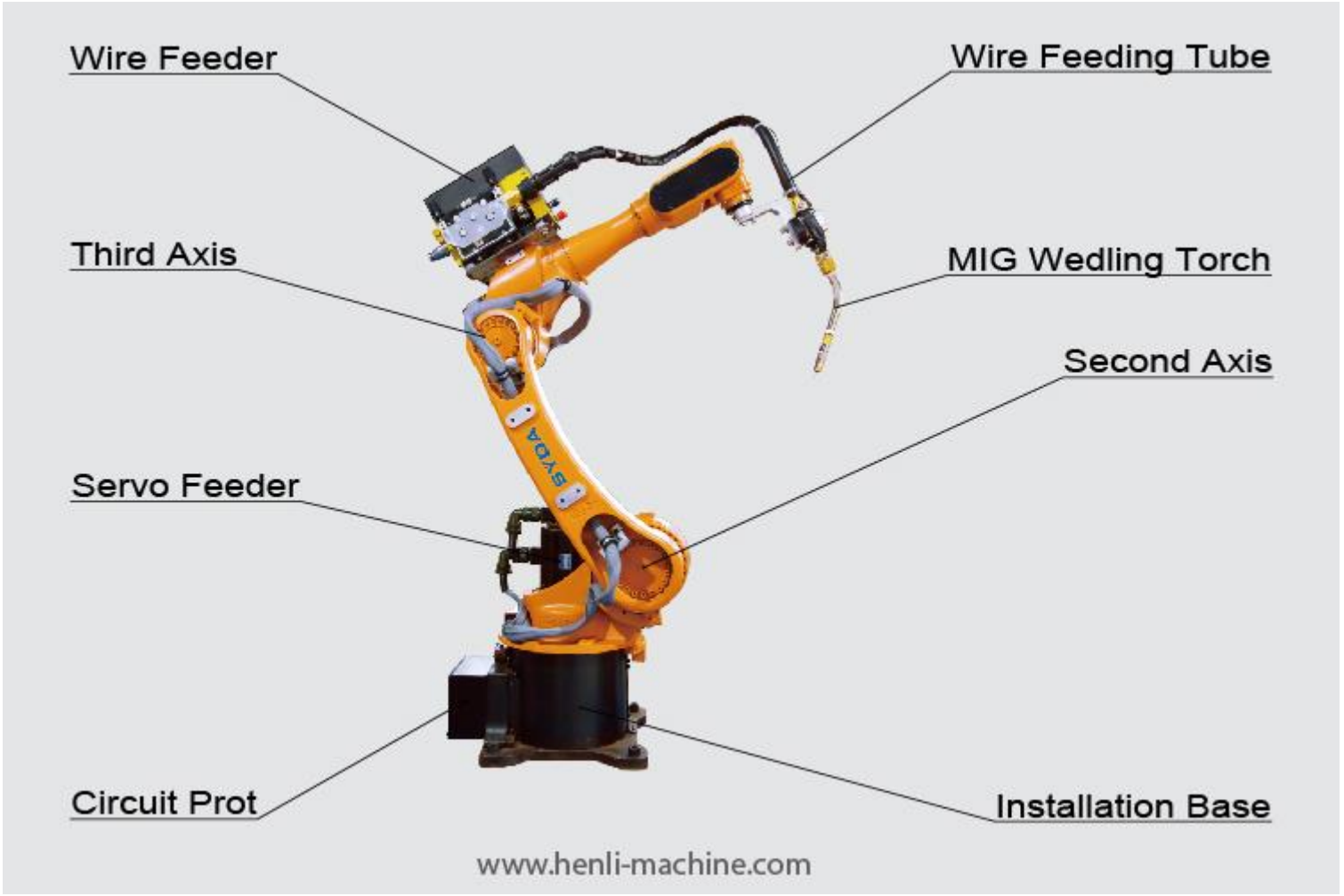


[Link video: KR240]

1.2. Robot Degrees of Freedom



1.3. Basic structure of Robot

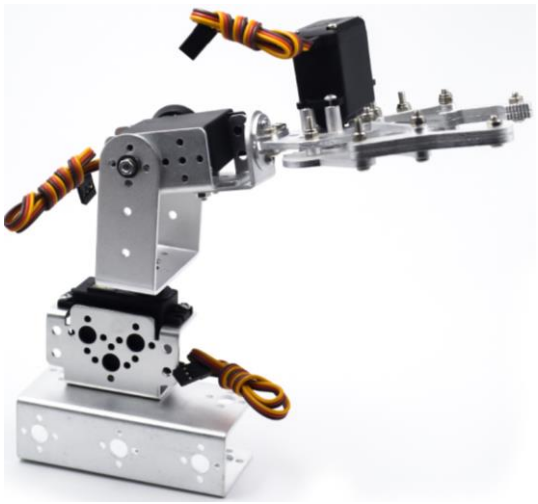


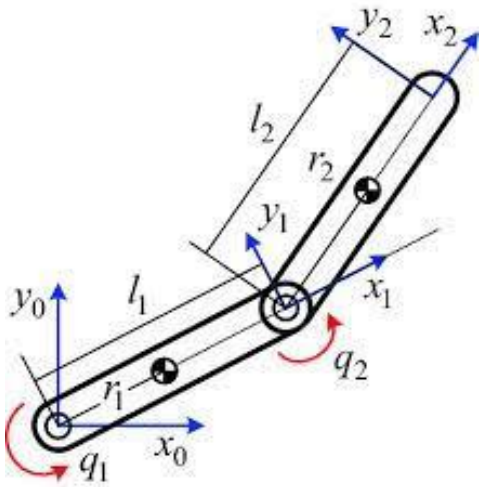
1.4. Robot Components

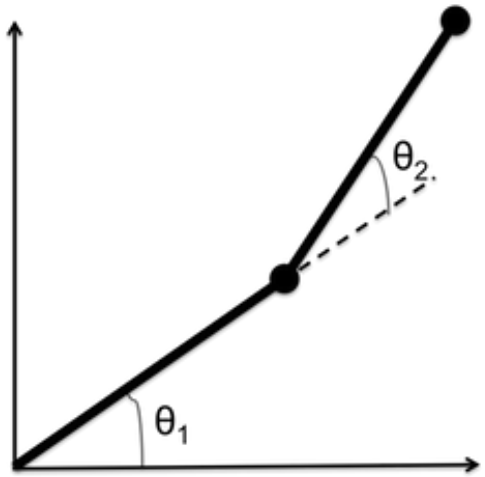
Link

Every individual rigid member of a robot that can move relative to all other members is called **a link**.

Any two or more connected links, such that no relative motion can occur among them, are considered **a single compound link**.







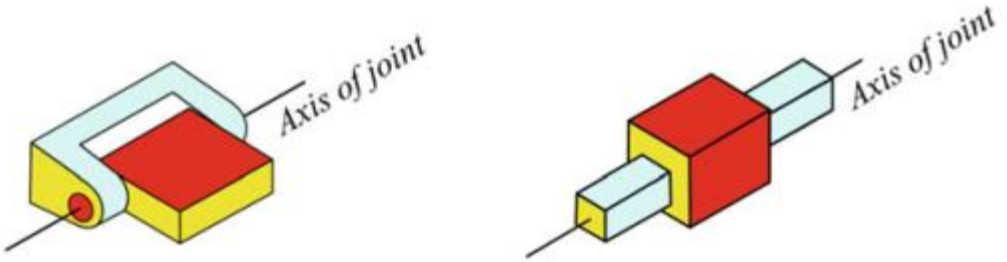
Study

Experiment

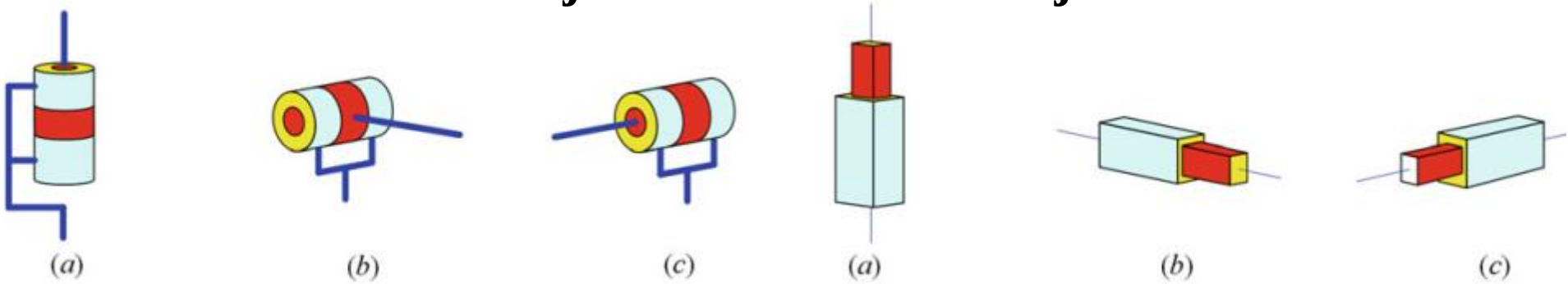
1.4. Robot Components

Joint

- Two links are connected by contact at **a joint** where their relative motion can be expressed by a single joint coordinate.
- Joints are typically **revolute (R)** (rotary) or **prismatic (P)** (translatory).



Revolute joint **Prismatic joint**

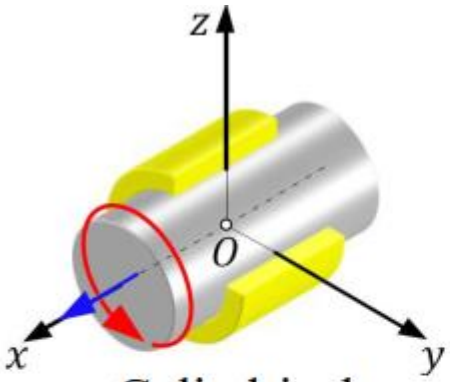


Symbol of **Revolute joint** and **Prismatic joint** in robot model

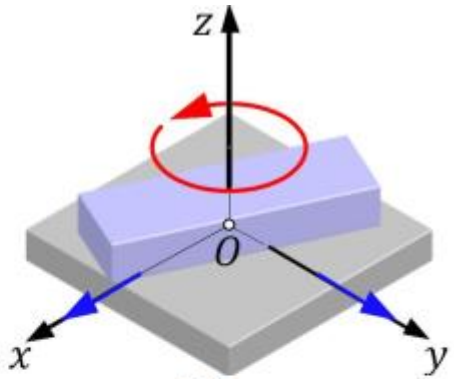
1.4. Robot Components

Joint

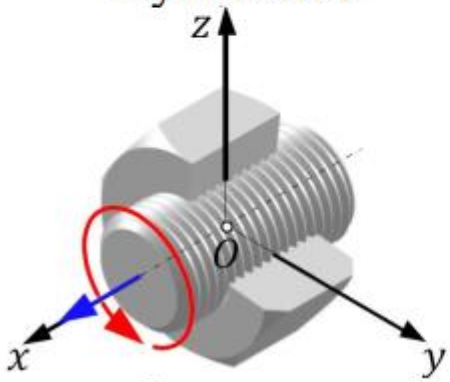
- The coordinate of an **active joint** is controlled by an actuator. **A passive** joint does not have any actuator.
- The value of the coordinate describing the relative position of two connected links at a joint is called joint coordinate or joint variable. It is **an angle** for a revolute joint, and **a distance** for a prismatic joint.



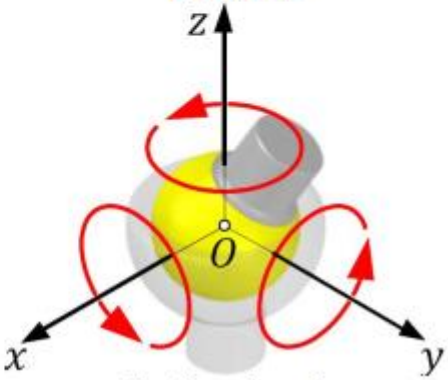
Cylindrical



Planar



Screw

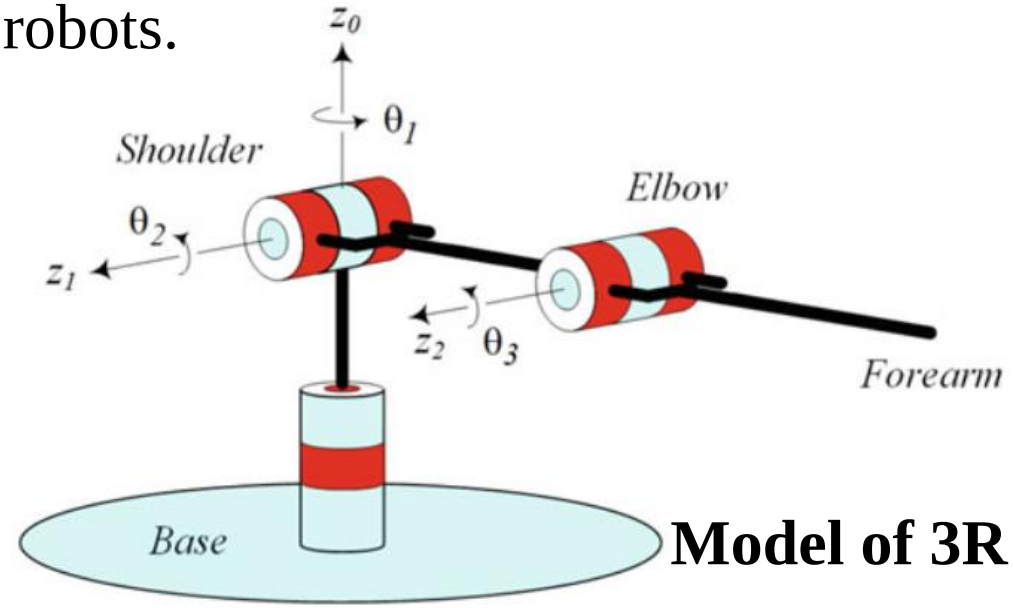


Spherical

1.4. Robot Components

Manipulator

- The main body of a robot consisting of the links, joints, and other structural elements is called **the manipulator**.
- **A manipulator** becomes **a robot** when we attach wrist and gripper, and install its control system.
- In literature robots and manipulators are utilized equivalently and both refer to robots.

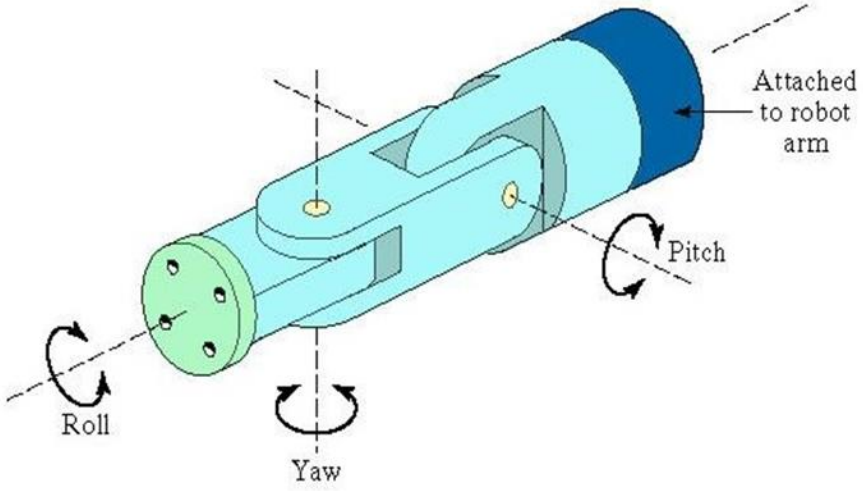


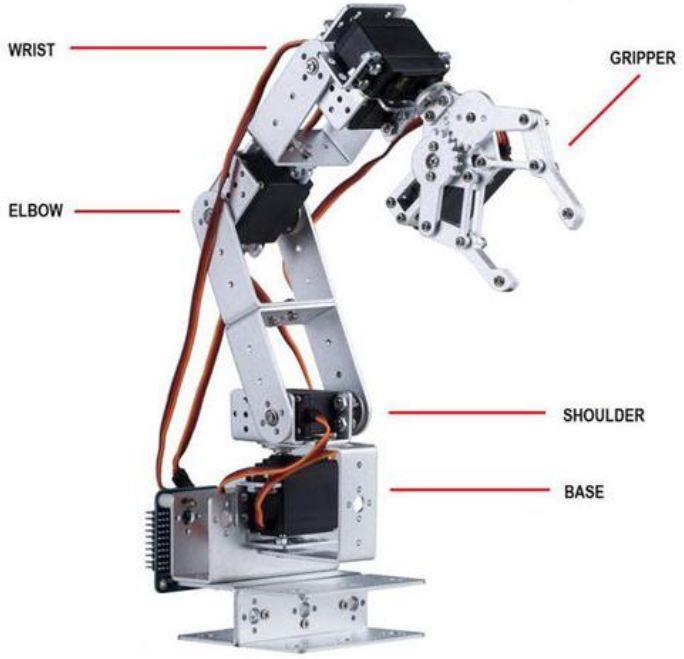
Model of 3R manipulator

1.4. Robot Components

Wrist

- The joints in the kinematic chain of a robot between the forearm and end-effector are referred to as **the wrist**.
- It is common to design manipulators with spherical wrists. It means three revolute joint axes intersecting at a common point called the wrist point.

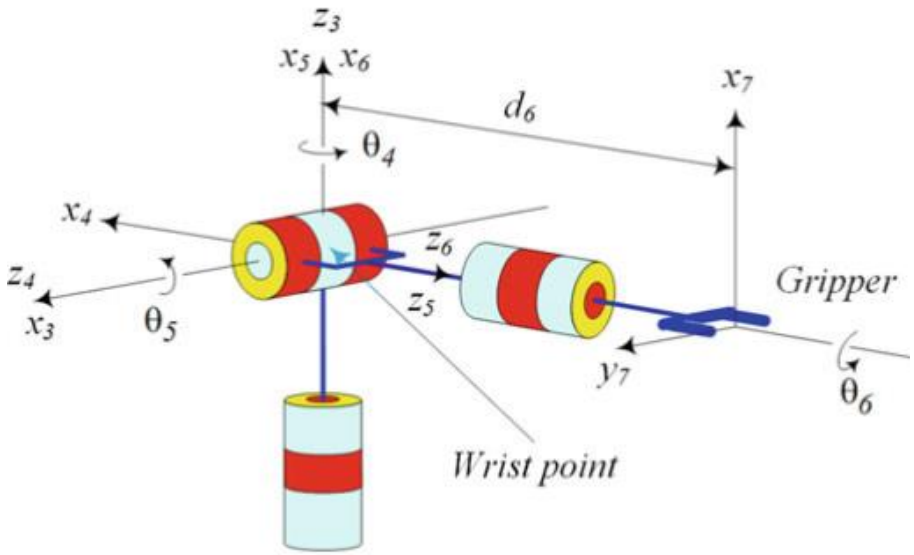


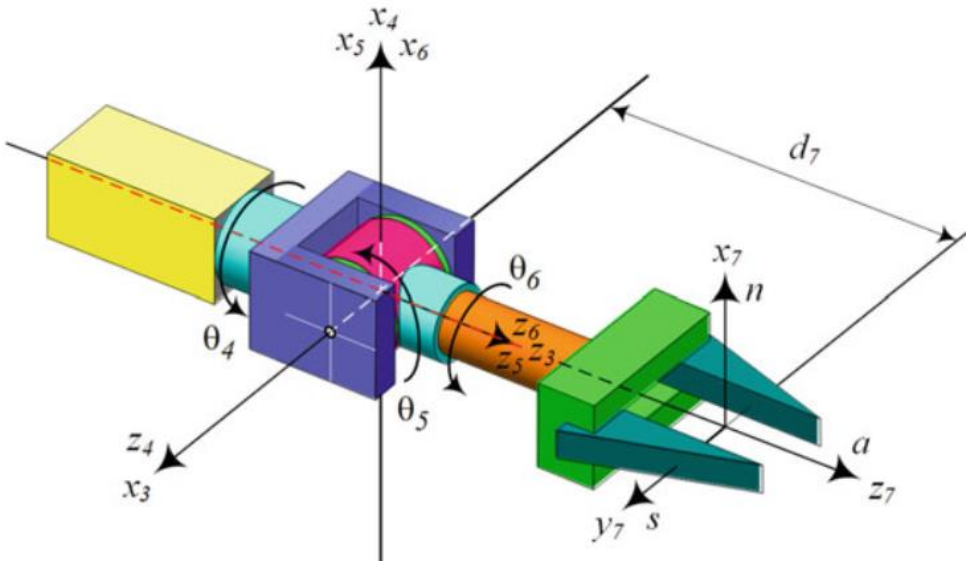


1.4. Robot Components

Wrist

- The manipulator will possess three degrees-of-freedom for position of the wrist point. Positioning is set by controlling three joints of three arms.
- The number of DOF for orientation will then depend on the wrist, having one, two, or three DOF depending on the application.

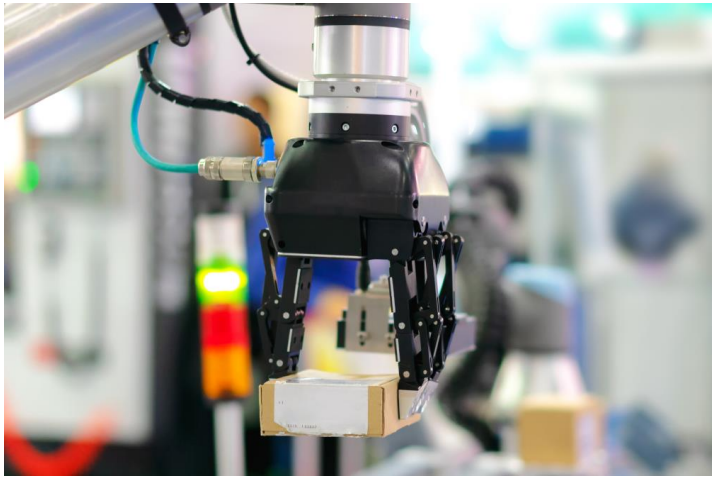




1.4. Robot Components

End-Effector

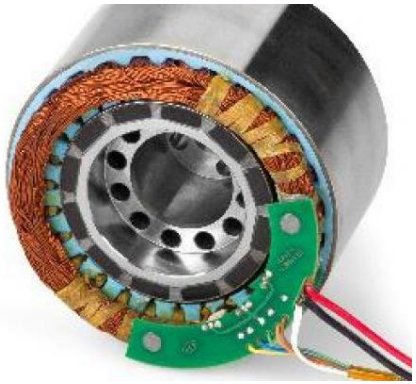
- **The end-effector** is the part mounted on the last link to do the required job of the robot, performing specific work.
- The wrist and end-effector assembly is also called **a hand**.



1.4. Robot Components

Actuators

- Actuators are drivers that act as muscles of robots to change their configuration.
- The actuators provide power to act on the mechanical structure against gravity, inertia, and other external forces to modify the geometric location and orientation of the robot's hand.
- The actuators can be of **electric**, **hydraulic**, or **pneumatic**, and have to be controllable.



1.4. Robot Components

Sensors

- The elements that are utilized to detect and collect information about internal and environmental states are **sensors**.
- The joints' positions, velocities, accelerations, and forces are the most important information to be sensed and measured.
- Sensors, integrated into the robot, send information about each link and joint to the control unit, and the control unit determines the configuration of the robot.

1.4. Robot Components

Controller

The controller or control unit of a robot has three roles:

- Information role, which consists of collecting and processing the information provided by the robot's sensors.
- Decision role, which consists of planning the geometric motion of the robot structure.
- Communication role, which consists of organizing the information between the robot and its environment.

The control unit includes **the processor** and **software**.

1.5. Robot Classifications

Classification of Robot Association

- The Robot Association divides robots in 6 different classes:
  - **Class 1: Manual handling devices:** A device with multi degrees of freedom that is actuated by an operator.
  - **Class 2: Fixed sequence robot:** A device that performs successive stages of a task according to a predetermined and fixed program.
  - **Class 3: Variable sequence robot:** A device that performs successive stages of a task according to a predetermined but programmable method.

1.5. Robot Classifications

Classification of Robot Association

- **Class 4: Playback robot:** A human operator performs the task manually by leading the robot, which records the motions for later playback. The robot repeats the same motions according to the recorded information.
- **Class 5: Numerical control robot:** The operator supplies the robot with a motion program rather than teaching it the task manually.
- **Class 6: Intelligent robot:** A robot with the ability to understand its environment and the ability to successfully complete a task despite changes in the surrounding conditions under which it is to be performed.

1.5. Robot Classifications

Classification of Robot Association

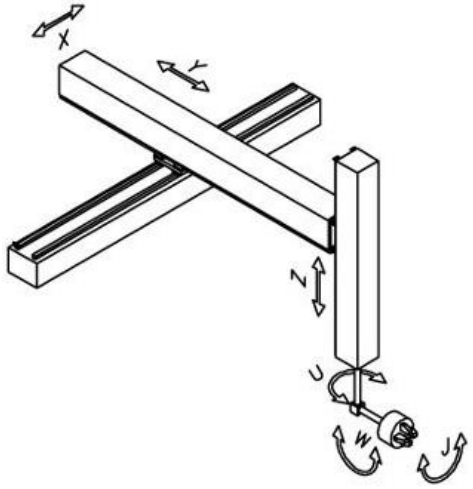
- **The Robotics Institute of America (RIA)** considers classes 3-6 of the following classification to be Robots.
- **The Association Francaise de Robotique (AFR)** combines classes 2-4, as the same type and divides robots in 4 classes.
- **The Japanese Industrial Robot Association** has 6 classes.

1.5. Robot Classifications

Robot Coordinates

Cartesian/Rectangular/Gantry Robots (3P): These robots use **three prismatic** joints to position the end effector, usually followed by additional revolute joints that orient the end effector.

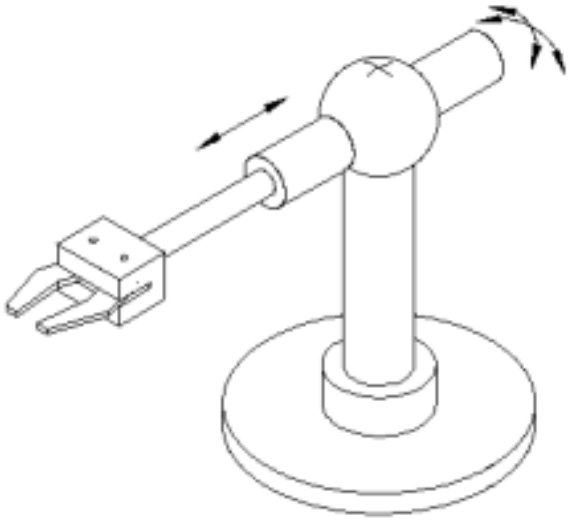
That is used for pick and place, assembly operations, application of sealant, and arc welding.



1.5. Robot Classifications

Robot Coordinates

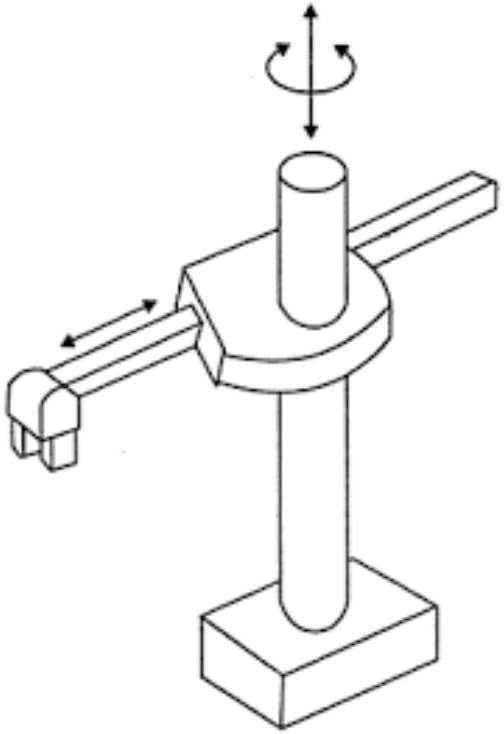
Spherical/Polar Robots (P2R): Robots follow a spherical coordinate system, which has **one prismatic and two revolute joints** for positioning the part, plus additional revolute joints for orientation.

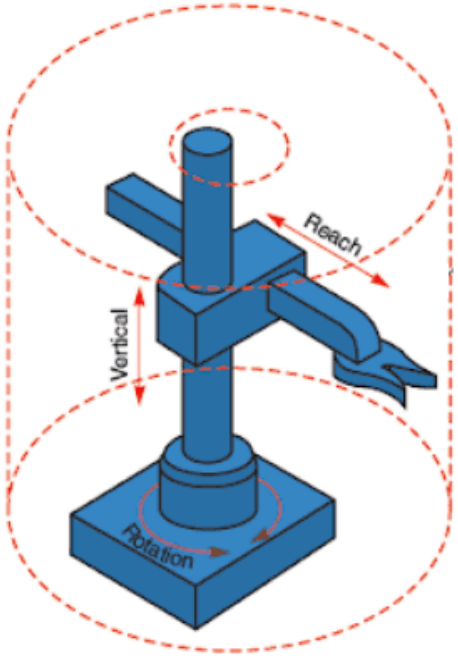


1.5. Robot Classifications

Robot Coordinates

Cylindrical Robots (PRP): Cylindrical coordinate robots have **two prismatic joints and one revolute joint** for positioning the part, plus revolute joints for orientation.



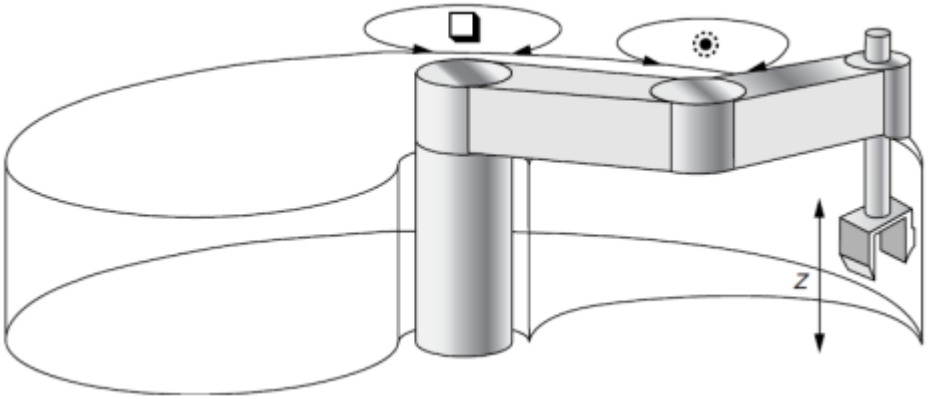


1.5. Robot Classifications

Robot Coordinates

Selective **C**ompliance **A**ssembly **R**obot **A**rm **(SCARA)**: SCARA robots have **two (or three) revolute joints** that are parallel and allow the robot to move in a horizontal plane, plus an additional prismatic joint that moves vertically.

SCARA robots are very common in assembly operations.



1.5. Robot Classifications

Robot Coordinates

Articulated/anthropomorphic Robots (3R): An articulated robot's joints are **all revolute**, similar to a human's arm. They are the most common configuration for industrial robots.

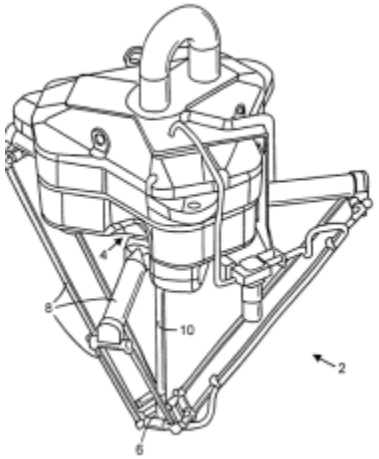
[Link video: welding robots]

1.5. Robot Classifications

Robot Coordinates

Parallel robots: Parallel robots is a mechanical system that uses **several serial chains** to support a single platform, or end-effector.

A delta robot is a type of parallel robot that consists of **three arms** connected to universal joints at the base.



[Link video]

1.5. Robot Classifications

Geometry

- A robot is called
  - **a serial or open-loop manipulator:** its kinematic structure does not make a loop chain.
  - **a parallel or closed-loop manipulator:** its structure makes a loop chain.
  - **a hybrid manipulator:** its structure consists of both open and closed-loop chains.
- Most industrial manipulators have **six DOFs**.

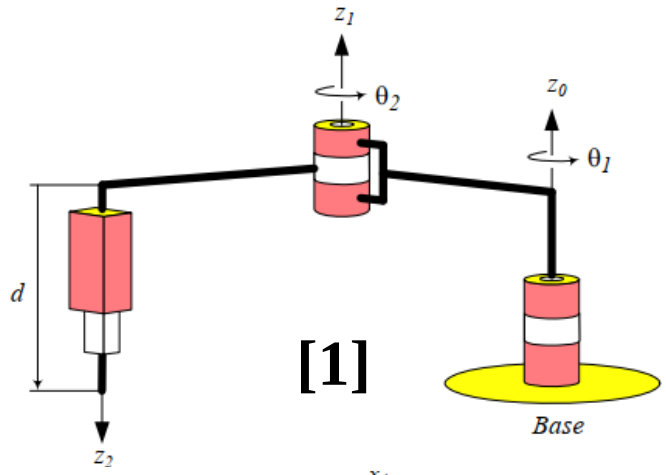
1.5. Robot Classifications

Geometry

- Using the two types of joints (**P or R**):
  - There are mathematically **72!?** different industrial manipulator configuration.
  - The axes of two adjacent joints can be parallel (∥), orthogonal (⊢), or perpendicular (⊥).
- Out of the 72 possible manipulators, the important ones are: **R∥R∥P** (SCARA), **R⊢R⊥R** (articulated), **R⊢R⊥P** (spherical), R∥P⊢P (cylindrical), and **P⊢P⊢P** (Cartesian).

1.5. Robot Classifications

Geometry



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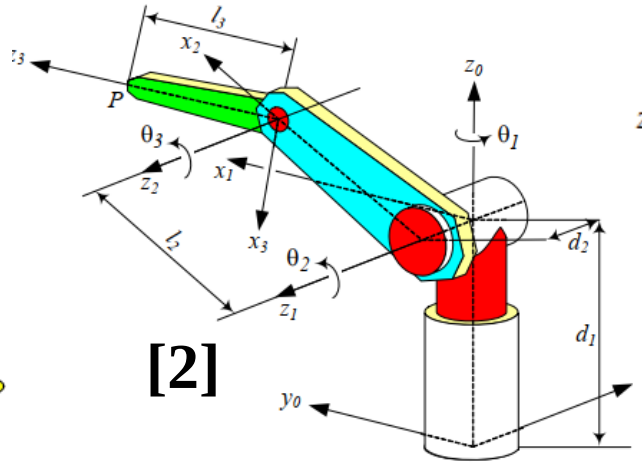

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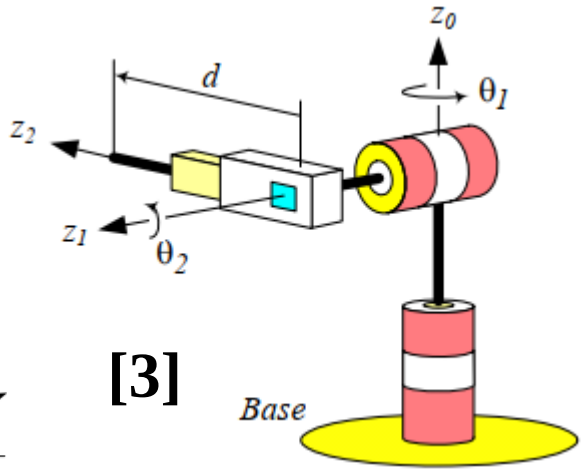

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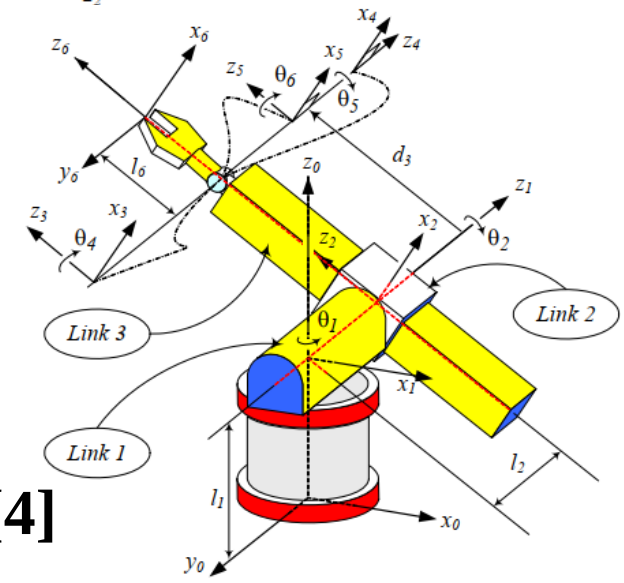

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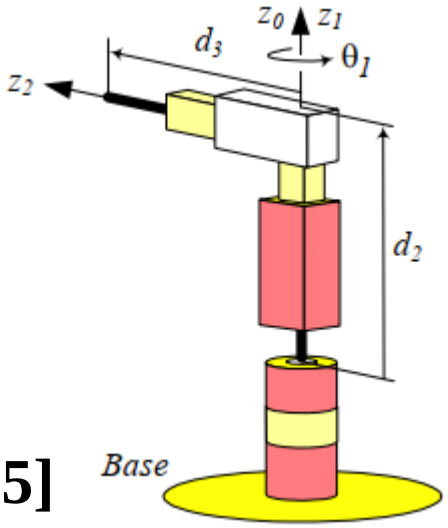

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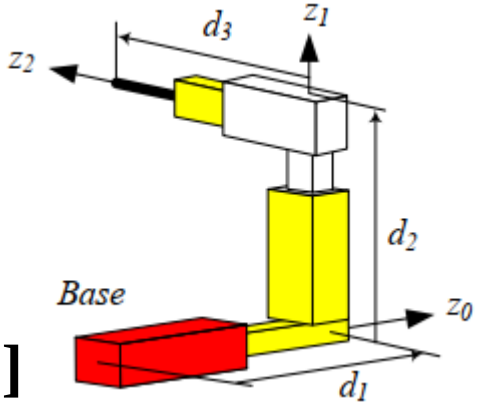


[6]

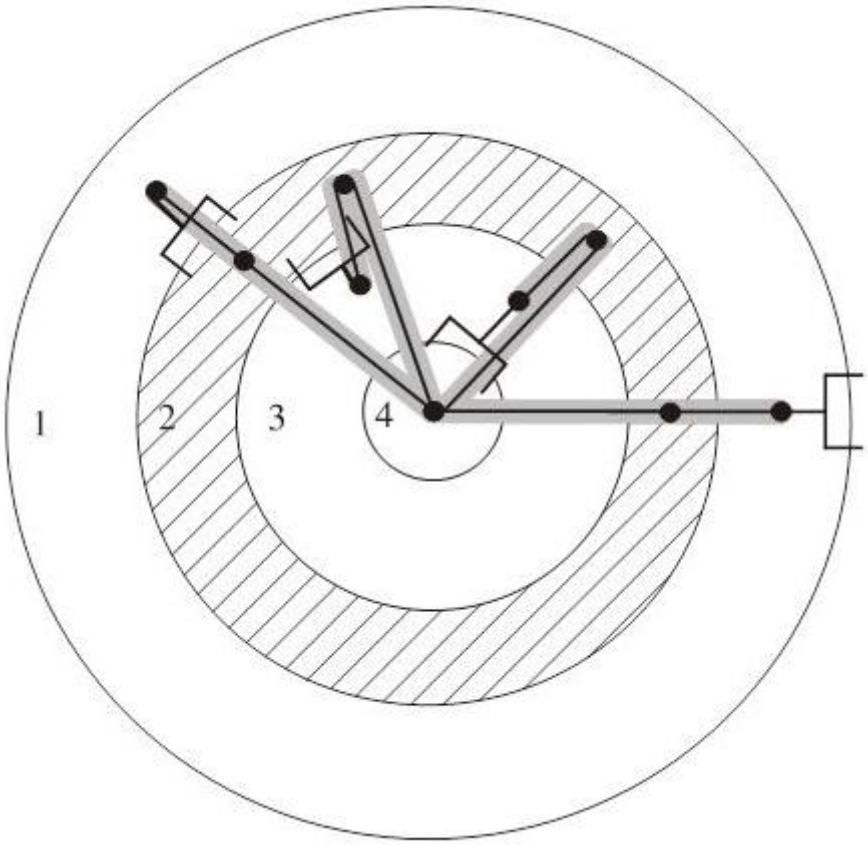
1.5. Robot Classifications

Workspace

- **The workspace of a manipulator**: the total volume of space the end-effector can reach. The workspace is constrained by the geometry of the manipulator as well as the mechanical constraints on the joints.
- The workspace is broken into
  - **a reachable workspace**: the volume of space within which every point is reachable by the end-effector in at least one orientation.
  - **a dexterous workspace:** The dexterous workspace is the volume of space within which every point can be reached by the end effector in all possible orientations. The dexterous workspace is a subset of the reachable workspace.

1.5. Robot Classifications

Workspace

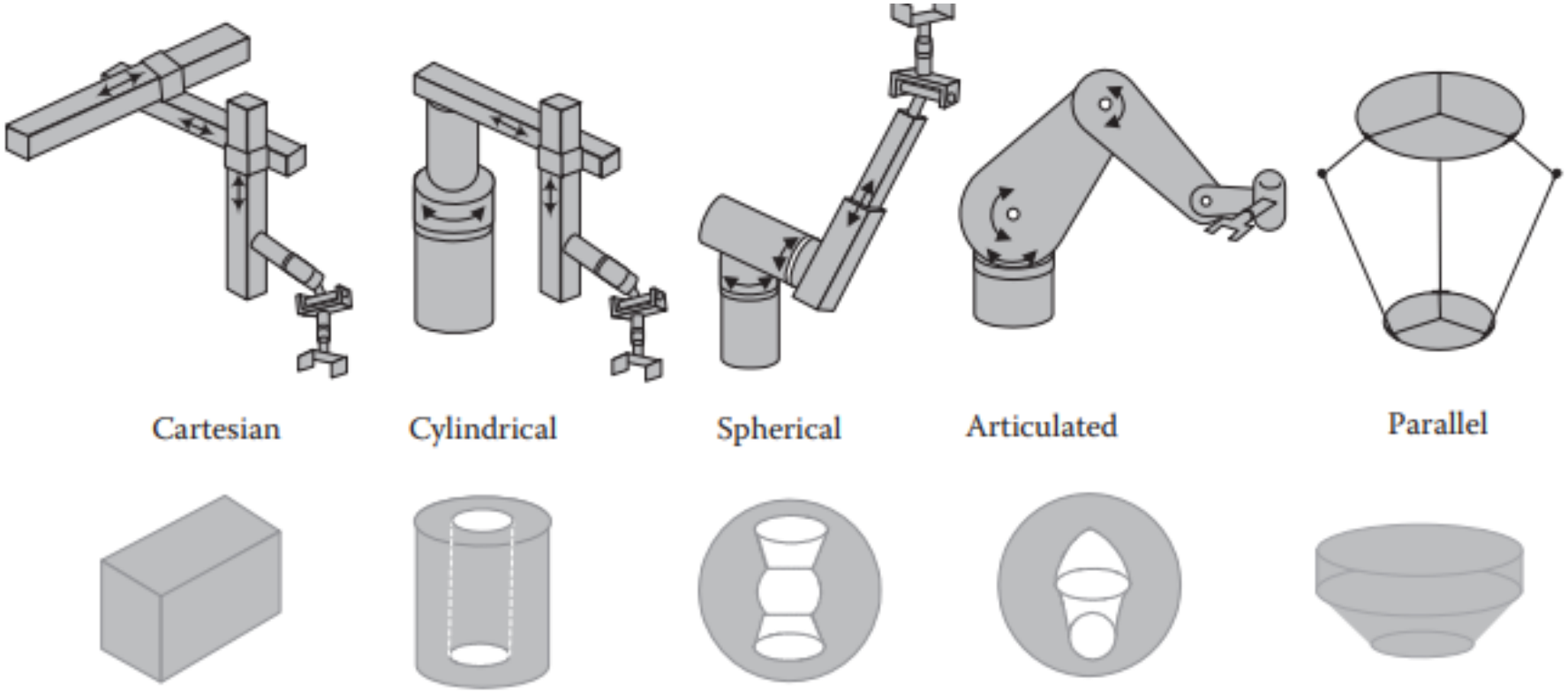


a reachable workspace & a dexterous workspace

[Link video]

1.5. Robot Classifications

Workspace



Typical approximate workspaces for common robot configurations

1.5. Robot Classifications

Actuation

- **Actuators** translate power into motion.
- Robots are typically actuated **electrically**, **hydraulically**, or **pneumatically**. Other types of actuation might be considered as piezoelectric, magnetostriction, shape memory alloy, and polymeric.
- **Electrically actuated robots**: AC or DC motors ; cleaner, quieter, and more precise compared to the hydraulic and pneumatic actuated.
- **Hydraulic actuators:** high speed and high torque/mass or power/mass ratios; lifting heavy loads.
- **Pneumatic actuated robots:** inexpensive and simple but cannot be controlled precisely.

1.5. Robot Classifications

Control

- Robots can be classified by control method into **servo (closed loop control) and non-servo (open loop control)** robots.
- **Servo (closed loop control)**
  - Point-to-point.
  - Continuous path.
- **Non-servo (open loop control)**
  - Movement is limited to predetermined mechanical stops, and they are primarily used for materials transfer.

1.5. Robot Classifications

Application

- Robots can mainly be classified according to their application into **assembly** and **non-assembly** robots.
- In the industry they are classified by the category of application
  - Machine loading
  - Pick and place
  - Welding
  - Painting
  - Assembling
  - Inspecting
  - Sampling
  - Manufacturing
  - Biomedical
  - Assisting
  - Remote controlled mobile
  - Telerobot

C1. End!