Introduction to Robotics

Unit 1: Introduction, History, and Future Trends

Todays class

- What is robotics
- History of Robotics
- Why do we study robotics
- What are possible applications of robots
- Classification of robots
- Specifications of Robots
- Present status and future trends

What is Robotics?

- Robotics is an interdisciplinary field involving fundamentals of Physics, Mathematics, Mechanical, Electronics and Electrical, and Computer Sciences
- It deals with the design, construction, operation, and use of robots.
- **1942** — Isaac Asimov introduced the term “robotics” in his short story *Runaround*, along with formulating the influential Three Laws of Robotics.

Asimov’s 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 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 theFirst or SecondLaws.

Interdisciplinary Areas in Robotics

Mechanical Engineering

- **Kinematics**: Study of motion without considering forces or moments
- **Dynamics**: Study of forces and moments that cause motion

Sensing: Acquiring data from the environment

Computer Science

- **Motion Planning**: Planning the robot's actions or trajectory
- **Artificial Intelligence**: Developing the robot's "brain" or decision-making system

Electrical & Electronics Engineering

- **Control Systems**: Designing feedback and control loops
- **Hardware Implementation**: Designing circuits, boards, and power systems

General Sciences

- **Physics**: Mechanics, electromagnetism, thermodynamics, etc.
- **Mathematics**: Linear algebra, calculus, probability, and optimization

What is a Robot?

- Robots are programmable machines capable of carrying out a series of actions autonomously or semi-autonomously.

The word “robot” comes from the Czech word “robota”, meaning *forced labor*. Initially viewed as machines to carry out monotonous and repetitive tasks.

In 1921, **Karel Capek**, a Czech playwright, used the term: robot first in his drama named **Rossum’s Universal Robots** (R.U.R). According to **Karel Capek**, a robot is a machine look-wise similar to a human being

Definition: The Robot Institute of America (1969) defines robot as a re-programmable, multifunctional manipulator designed to move materials, parts, tools or specialized devices through various programmed motions for the performance of a variety of tasks.

What is Automation?

- Use of technology to perform tasks with minimal human input
- Employs control systems like computers and robots
- Goals: Increase efficiency, accuracy, safety, and speed
- Reduces human error and operational costs

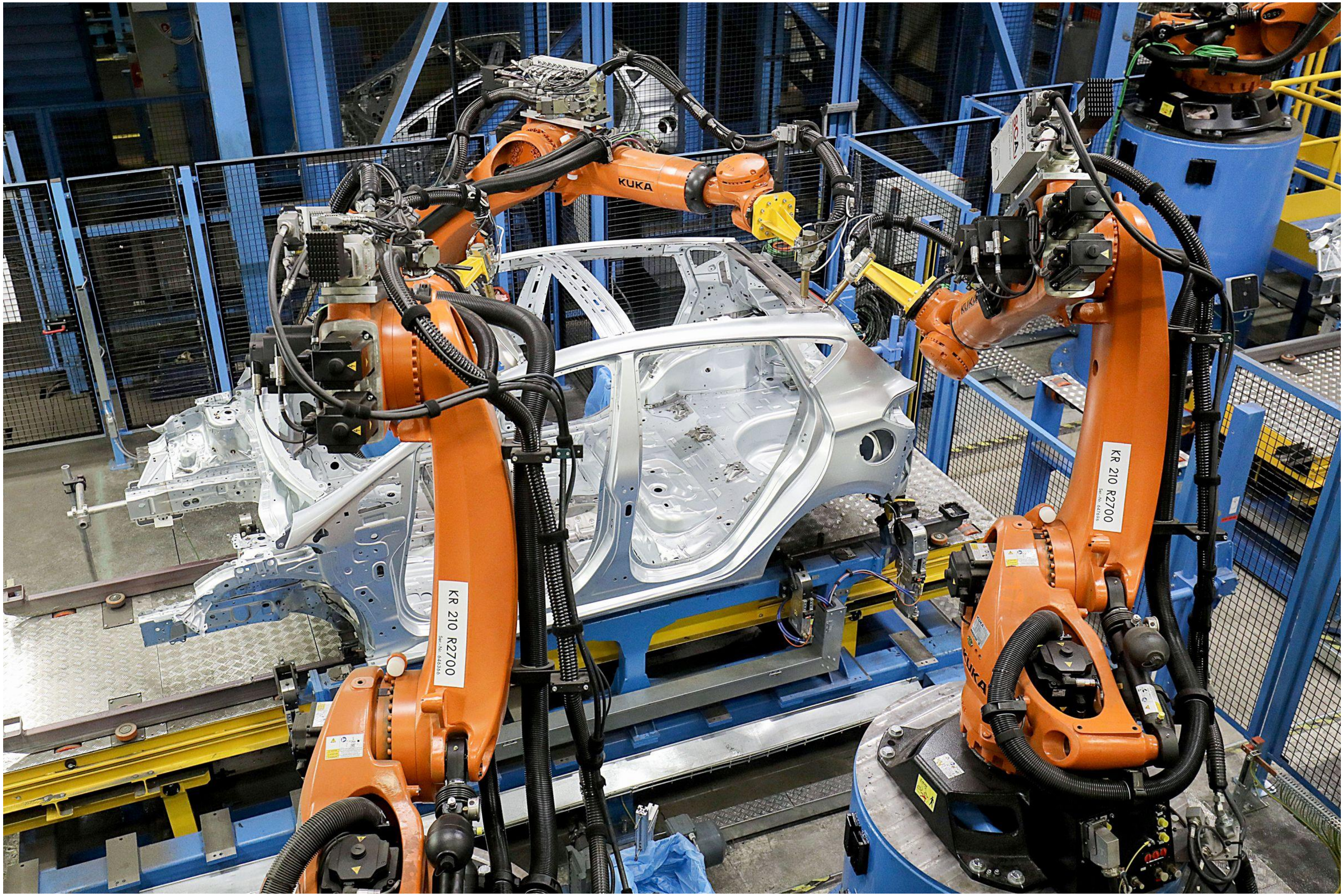
How Robots Help in Automation

- Central to automating tasks across industries
- Work 24/7 with precision and consistency
- Take on repetitive, dangerous, or complex tasks
- Improve productivity and reduce human workload

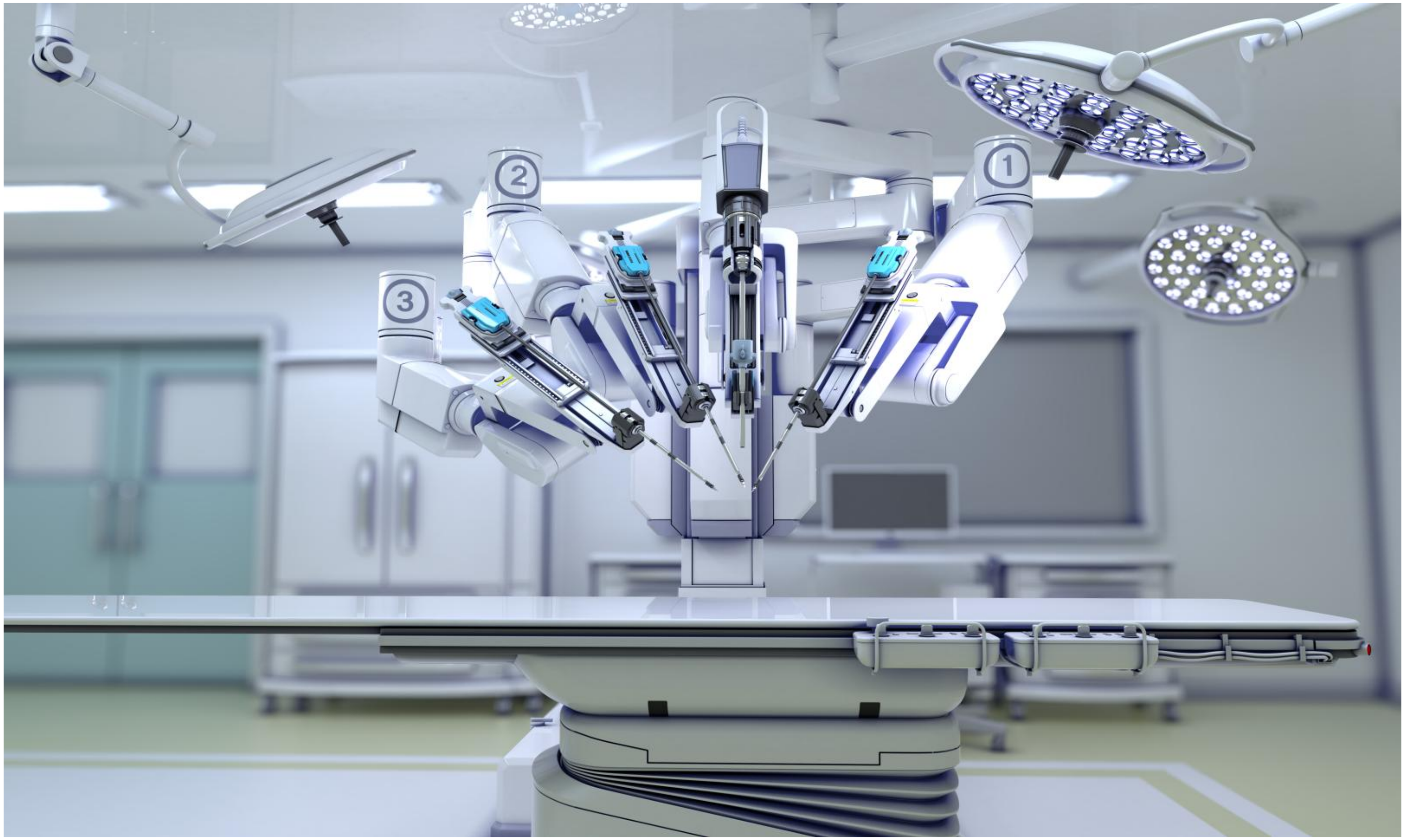
Applications of Robots in Automation

1. Manufacturing – assembly lines, welding, packaging
2. Healthcare – surgery, patient care, sanitization
3. Agriculture – planting, harvesting, monitoring
4. Warehousing – inventory, sorting, order picking
5. Exploration – space (Mars rovers), underwater
6. Home – cleaning bots, smart assistants, security

- **Field Robot**: Agricultural drones, underwater exploration robots, Mars rovers
- **Service Robot**: Robotic vacuum cleaner (e.g., Roomba), robotic nurse assistant



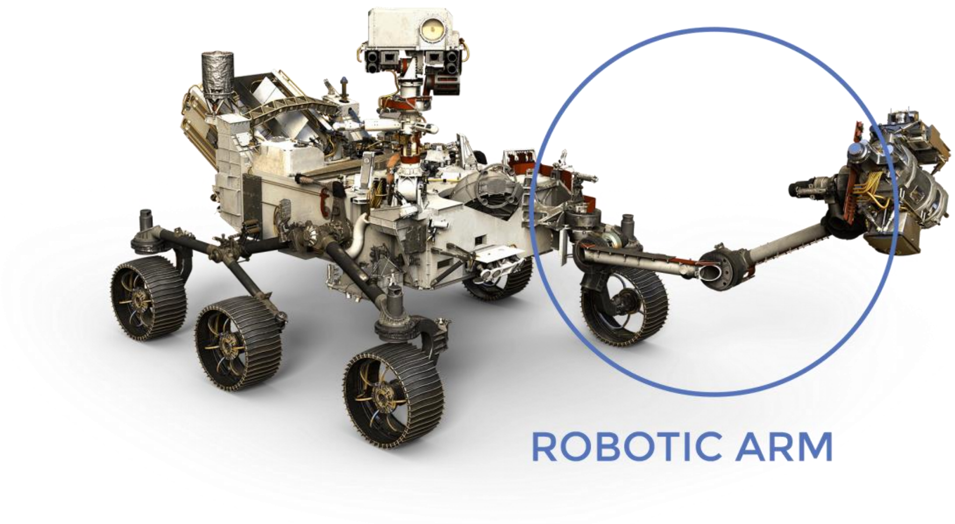
Manufacturing: *Robot arms assembling vehicles efficiently on a modern production line.*
— Source: Wired (Ford's smarter robotic assembly line)



Healthcare (Surgery): *A da Vinci surgical robot aiding with precise, minimally invasive procedures.*
— Source: Image from urologyaustin.com showcasing robotic surgery

Agriculture: *Robotic systems used for harvesting or handling crops in an agricultural setting.*
— Source: Oxyzo blog on robotics in the auto industry (photo depicts similar mechanized processes)

Warehousing: *Robotic arms sorting and handling goods in a high-tech warehouse environment.*
— Source: StockCake image of automated car assembly often used in logistical contexts



Exploration (Space): *A robotic arm on the Mars rover navigating and gathering samples on Martian terrain.*
— Source: The Robot Report image of robotic application in planetary exploration

Home Automation: Smart Homes: The Role of Robotics in Home Automation Systems
https://community.robotshop.com/blog/show/smart-homes-the-role-of-robotics-in-home-automation-systems

Why Do We Need Robotics?

1. Reduce human effort

2. Improve safety

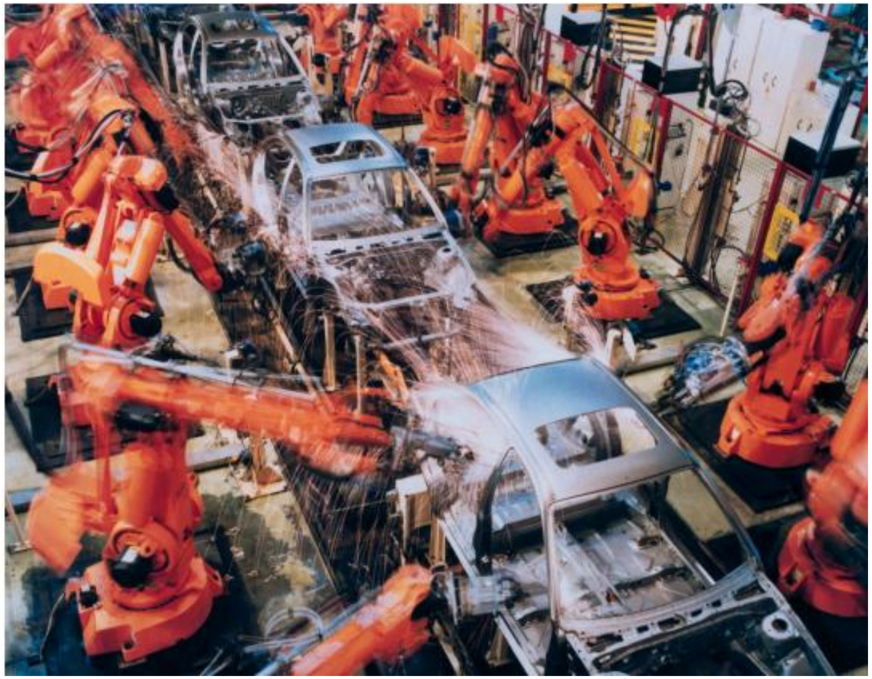
3. Work in inaccessible areas

4. Operate 24/7

5. Assist elderly or disabled

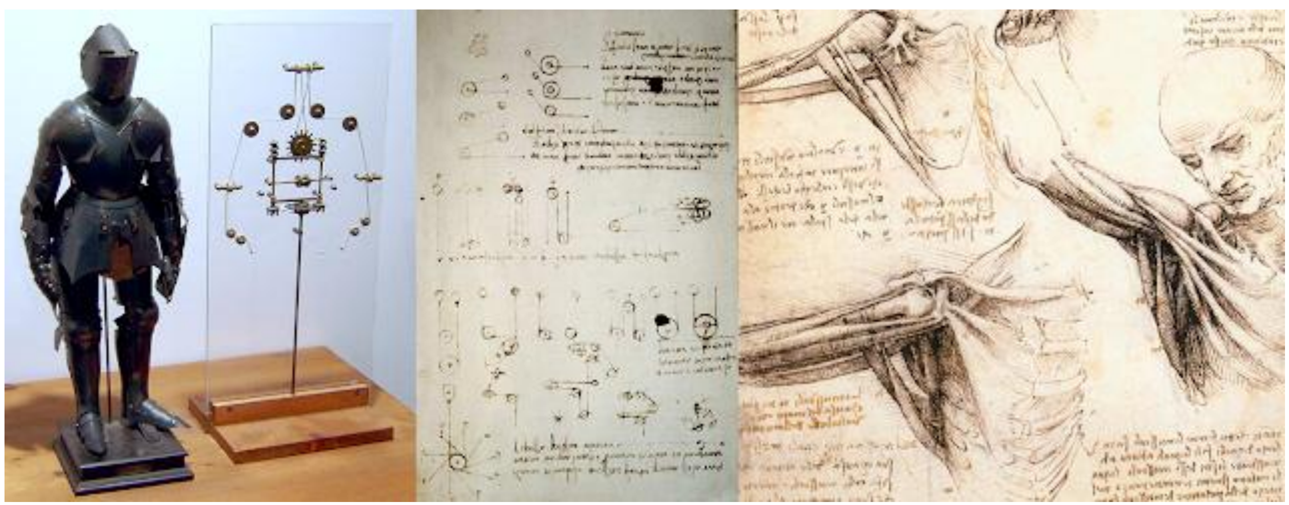
6. Boost efficiency and accuracy

7. Support disaster response



History of Robotics

- Ancient Era: Mythical mechanical beings and automata in Greek and Chinese literature.
- 1495: Leonardo da Vinci sketches a mechanical knight.



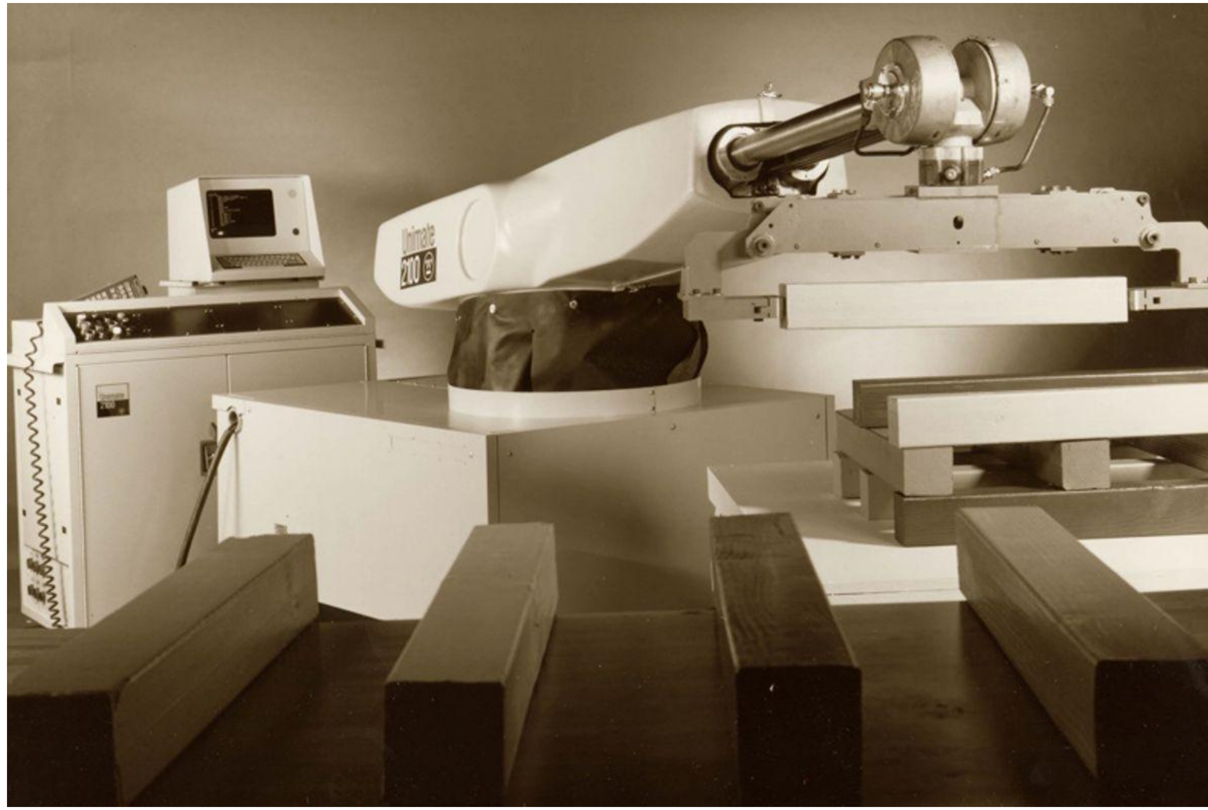
https://blog.salvius.org/2014/01/a-history-of-robotics-da-vincis.html

A Brief History of Robotics

Year	Events and Development
1954	George Devol filed his patent for the *Unimate*, the first programmable robotic arm.
1956	Devol and Joseph Engelberger founded Unimation Inc., the first company dedicated to producing industrial robots
1961	General Motors used the manipulator: Unimate in die-casting application
1963	Development of the first computer-controlled robotic arm (the Rancho Arm) designed to assist people with disabilities
1967	General Electrical Corporation made a 4-legged vehicle
1969	Shakey, an intelligent mobile robot, with sensors was built by Stanford Research Institute (SRI)
1970	1. Victor Scheinman demonstrated a manipulator known as Stanford Arm 2. SRI introduced the *Stanford Cart*, an early autonomous mobile system that could navigate a room using onboard sensors.

- 1956: First industrial robot invented by George Devol (Unimate).

- 1961: Unimate installed in General Motors factory. In 1961 the first Unimate was installed at a GM plant in Trenton, New Jersey, to assist a hot die-casting machine. Unimation would soon develop robots for welding and other applications.



https://spectrum.ieee.org/george-devol-a-life-devoted-to-invention-and-robots

Year	Events and Development
1973	WABOT-1 World's first full-scale humanoid robot; could walk, grip objects, and converse.
1978	SAM (Spacecraft Assembly Manipulator) NASA (USA)
1981	SCARA Robot Hiroshi Makino (Japan) Selective Compliance Assembly Robot Arm – fast and precise for industrial use.
1986	Honda’s E0 robot First in series of bipedal humanoid robots that led to ASIMO.
1996	Honda’s P2 Advanced humanoid robot capable of autonomous movement.
1999	Sony Robotic pet dog with AI – first consumer entertainment robot.

Year	Robot / Development
2000	Honda ASIMO humanoid robot launched with improved mobility and human interaction capabilities.
2002	Roomba by iRobot – a robotic vacuum cleaner for home use.
2004	DARPA Grand Challenge launched, promoting autonomous vehicle development.
2011	IBM Watson defeats humans on Jeopardy!, showcasing AI capabilities.
2012	Baxter, a robot by Rethink Robotics, designed for industrial automation with safe human interaction.
2015	Pepper, a humanoid robot by SoftBank Robotics, designed to recognize emotions.
2016	Boston Dynamics' Atlas robot shows advanced bipedal locomotion and balance.
2018	Sophia (by Hanson Robotics) becomes a global AI ambassador; granted citizenship by Saudi Arabia.
2020	Spot by Boston Dynamics is commercially released for industrial inspections and remote tasks.
2022	Tesla unveils Optimus (Tesla Bot), a humanoid robot for general-purpose tasks.
2023	NVIDIA’s AI-powered robotics platform Isaac Sim gains popularity for simulating robots in virtual environments.
2024	SAM (Sample Analysis at Mars) robotic suite by NASA continues Mars exploration on Perseverance rover.

Boston Dynamics

- Video

Components of a Robot:

1. Mechanical Platform (Hardware Base)

Structure: Wheeled base, arm, fixed frame, etc.

2. Joints

Function: Connect links and allow motion (flex, rotate, translate).

Importance: Enable mobility and **Degrees of Freedom (DOF)**.

3. Actuators

Role: Robot's **muscles** – enable movement.

Types:

- **Electrical**: Stepper, DC/AC servo motors
- **Pneumatic**: Air pressure-based
- **Hydraulic**: Fluid-powered

4. Sensors

Role: Provide **environmental feedback** to controller.
Types: Proximity, vision, touch, IR, force, etc.

5. Controller

The **"Brain"** of the robot – runs coded instructions.
Contains: Memory, logic, processing unit.

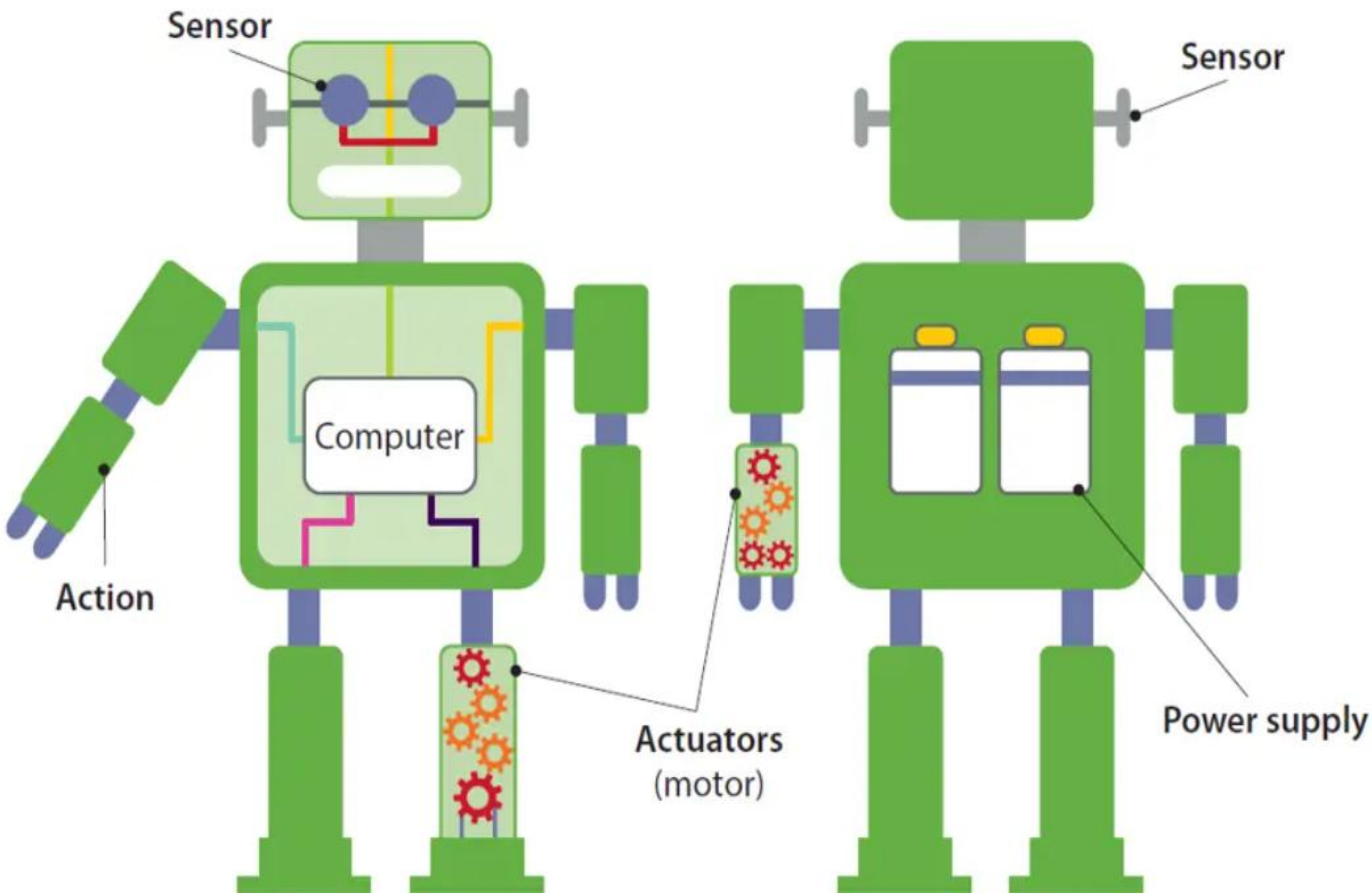
6. Power Source

Supplies energy: Battery (DC), AC supply, solar, pneumatic or hydraulic sources.

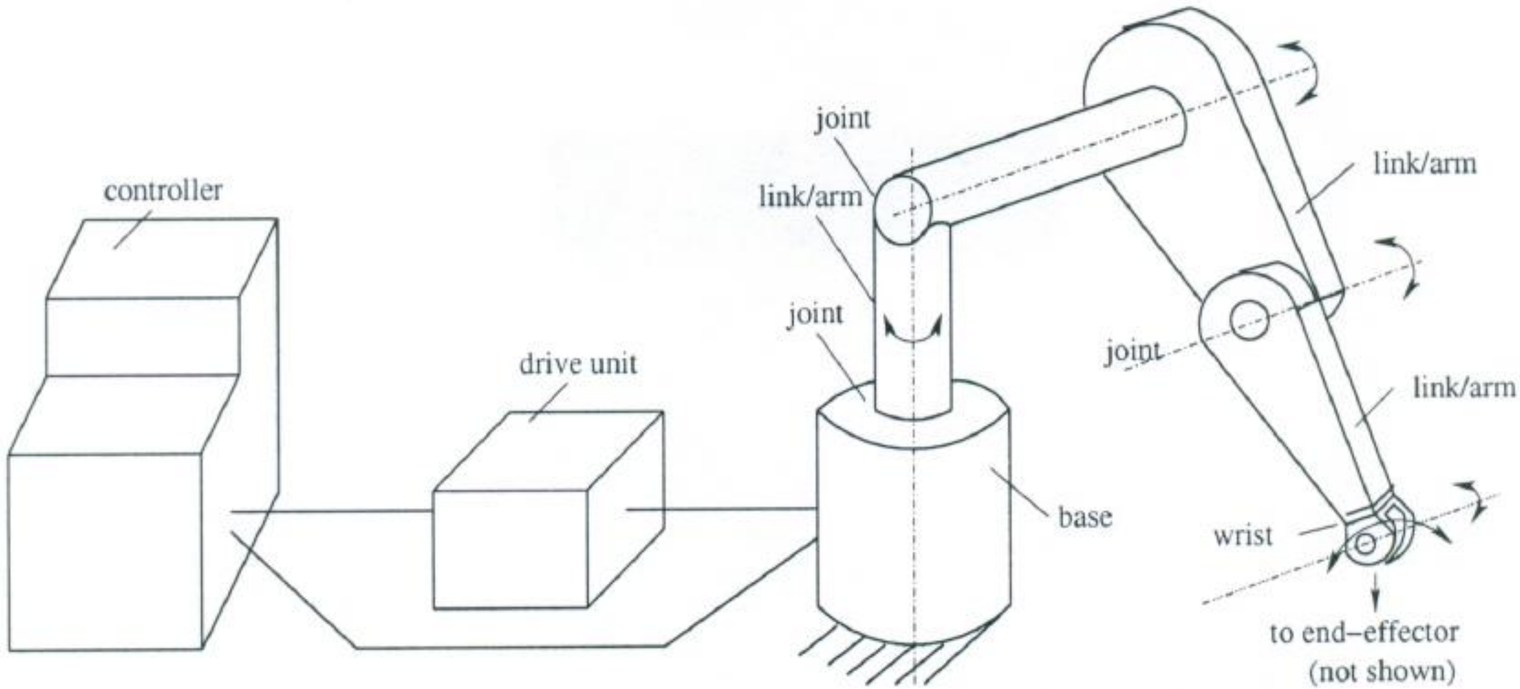
7. Artificial Intelligence (AI)

Optional: Enables **learning, decision-making**, human-like reasoning.
Requires: Advanced programming + sensor integration.

Components of a Robot:



A Robotic System



Various Components

1. Base,
2. Links and Joints,
3. End-effector / gripper,
4. Wrist,
5. Drive / Actuator
6. Controller
7. Sensors

Classification of Robots

- By Mobility
- By Application
- By Control Method
- Based on the Type of Tasks
- Based on Configuration (coordinate system) of the Robot
- Type of Controllers

Classification Based on Structural Capability

- **Mobile Robot:**
  - An automatic machine capable of locomotion and movement within its environment.
  - Not fixed to one location.
  - Can be:
    - **Autonomous Mobile Robot (AMR):** Navigates uncontrolled environments without physical or mechanical guidance.
    - **Automated Guided Vehicle (AGV):** Follows pre-defined routes using guidance devices in controlled spaces.
  - Example: Spying robot, warehouse robots.
- **Fixed Robot:**
  - Stationary base with movable robotic arms.
  - Common in industrial environments.
  - Typically consists of a multi-jointed manipulator and an end effector (gripper).
  - Used for tasks like welding, assembly, and painting.

By Control Method:

Teleoperated Robots

Controlled directly by a human operator in real-time

Often used in hazardous or remote environments (e.g., bomb disposal, space exploration)

No autonomous decision-making

Autonomous Robots

Operate without human intervention

Make decisions using sensors, AI, and programming

Used in self-driving cars, warehouse automation, etc.

Semi-autonomous Robots

Perform tasks partly on their own and partly with human input

Often used in medical surgery (robot assists but doctor controls)

Balance between automation and human control

Classifications of Robots

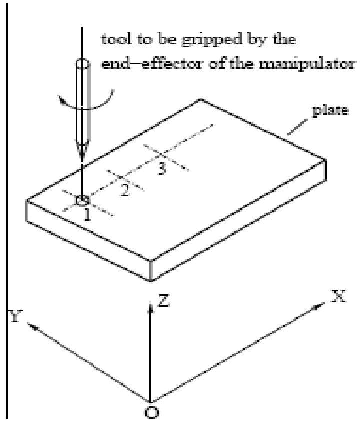
- Based on the Type of Tasks Performed

1. Point-to-Point Robots

Examples:

Unimate 2000

T^3

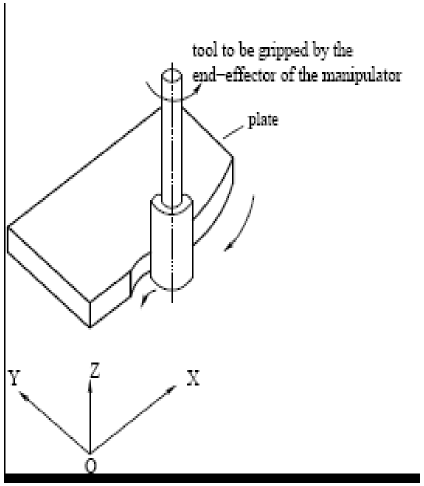


2. Continuous Path Robots

Examples

PUMA

CRS



Based on the Type of Controllers

1. **Non-Servo-Controlled Robots**
   - Open-loop control system

   Examples: Seiko PN-100
   - Less accurate and less expensive

2. **Servo-Controlled Robots**
   - Closed-loop control system

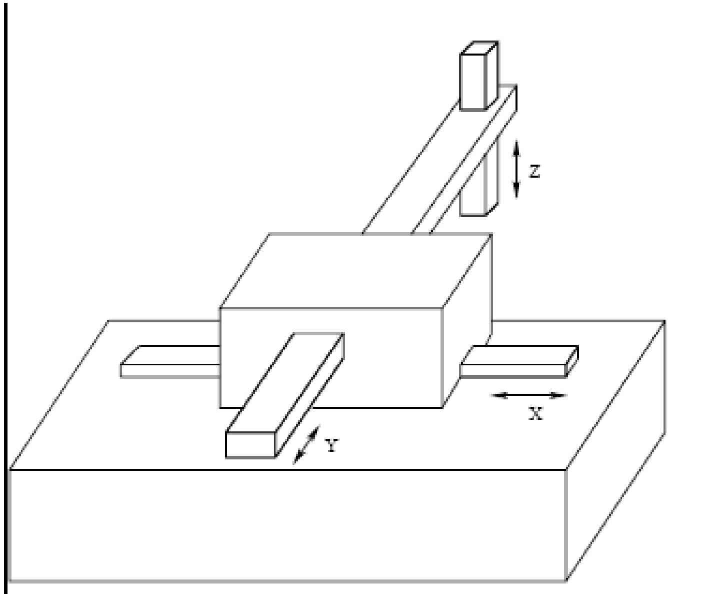
   Examples: Unimate 2000 PUMA

•More accurate and more expensive

Based on Configuration (coordinate system) of the Robot

1. Cartesian Coordinate Robots

- Linear movement along three different axes
- Rigid and accurate
- Suitable for pick and place type of operations
- Examples: IBM's RS-1, Sigma robot



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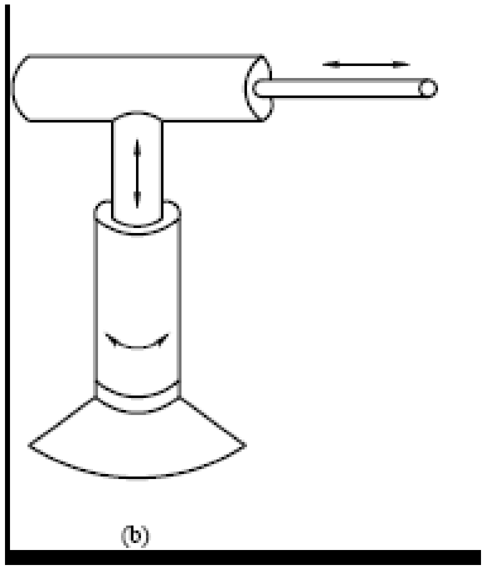
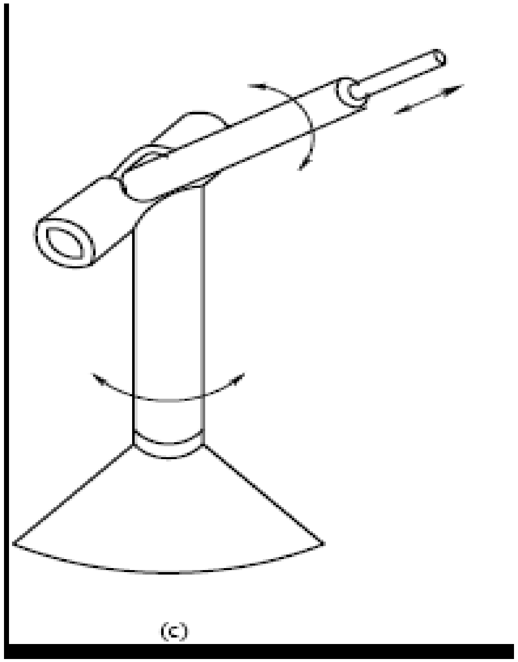
2. Cylindrical Coordinate Robots

- Two linear and one rotary movements
- Used to handle parts/ objects in manufacturing
- Cannot reach the objects lying on the floor
- Poor dynamic performance
- Examples: Versatran 600



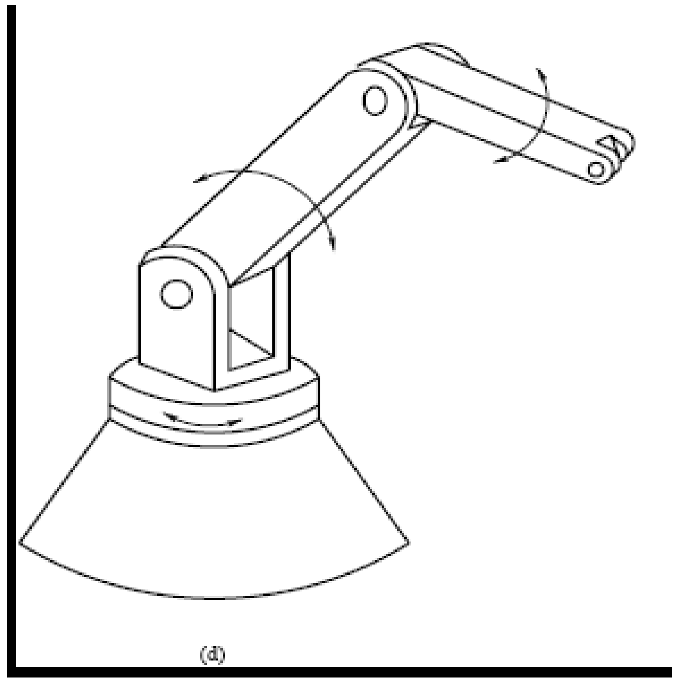
3. Spherical Coordinate or Polar Coordinate Robots

- One linear and two rotary movement
- Suitable for handling parts/objects in manufacturing
- Can pick up objects lying on the floor
- Poor dynamic performance
- Examples: Unimate 2000B



4. Revolute Coordinate or Articulated Coordinate Robots

- Rotary movement about three independent axes
- Suitable for handling parts/components in manufacturing system
- Rigidity and accuracy may not be good enough
- Examples: T^3, PUMA



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Workspace of Manipulators

It is the volume of space that the end-effector of a manipulator can reach

Dextrous Workspace
It is the volume of space, which the robot's end-effector can reach with various orientations
Reachable Workspace
It is the volume of space that the end-effector can reach with a minimum of one orientation
Note
Dextrous workspace is a subset of the reachable workspace

Resolution, Accuracy and Repeatability

Resolution

It is defined as the smallest allowable position increment of a robot

Programming resolution

Smallest allowable position increment in robot programme

Basic Resolution Unit

Control resolution

Smallest change in position that the feedback device can measure

Accuracy (mm)

It is the precision with which a computed point can be reached

Repeatability (mm)

It is defined as the precision with which a robot re-position itself to a previous taught point

Specification of a Robot

- Control type
- Drive system
- Coordinate system
- Teaching/Programming methods
- Accuracy, Repeatability, Resolution
- Pay-load capacity
- Weight of the manipulator
- Applications
- Range and speed of arms and wrist
- Sensors used
- End-effector/ gripper used

Future of Robotics (2024 and Beyond)

- **AI-Powered Robots:** Learn from data, predict maintenance needs, make decisions independently, Integration with AI, IoT, and cloud computing
- **Cobots (Collaborative Robots):** Work safely *side-by-side with humans* in factories
- **Mobile Handlers (MoMas):** Robots that *move and handle objects* in real-time
- **Digital Twins:** *Virtual copies* of machines for testing and predicting failures
- **Humanoid Robots:** Human-like design for *domestic work, warehouse tasks*, etc.
- **Green Robotics:** Energy-efficient, used in making solar panels and EV batteries
- **Robot-as-a-Service (RaaS):** Rent robots instead of buying – great for small businesses
- **Solving Labour Shortage:** Robots do *dangerous or repetitive jobs*, humans do creative work