Introduction to Robotics

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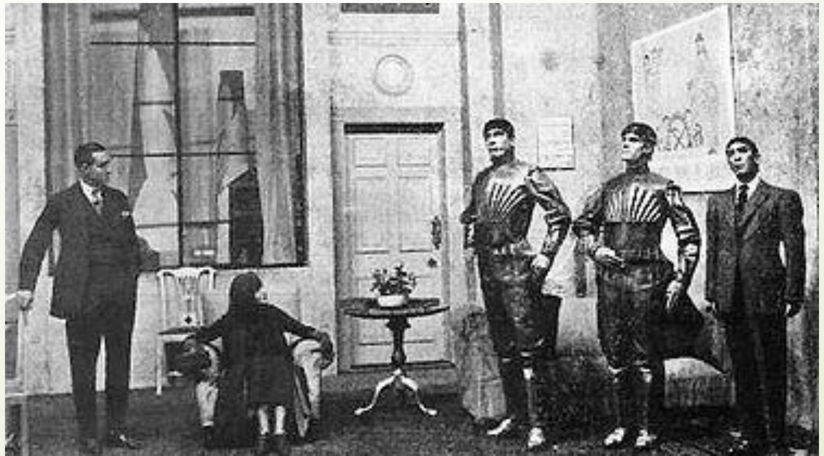
Karel Capek (January 9, 1890 – December 25, 1938)

He wrote the play R.U.R. (Rossum's Universal Robots) staged on 2nd January 1921 and introduced the word Robot meaning forced labor.



Isaac Asimov (January 2, 1920 – April 6, 1992)
"Three laws of robotics" (introduced in his 1942 short story "Runaround")

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 Laws.**
4. **Near the end of his book *Foundation and Earth*, a zeroth law was introduced:**
   0. A robot may not injure humanity, or, by inaction, allow humanity to come to harm.

ROBOTS in HISTORY

Automata

Jaquet-Droz automata 2005

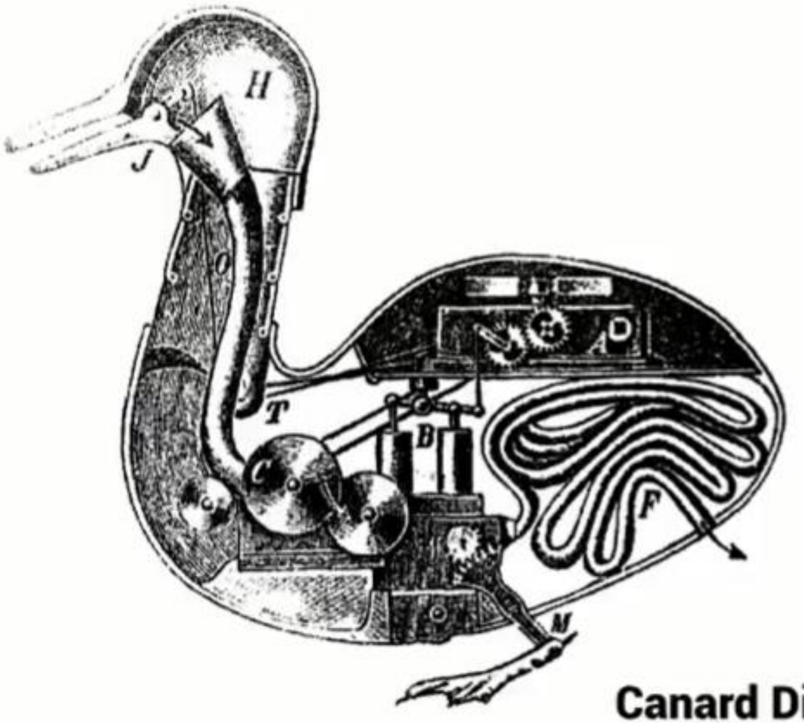
Automaton, CIMA museum 2007

Photo: Daderot

Maillardet's Automaton's Drawing of a ship

1808–1840

Vaucanson's automata



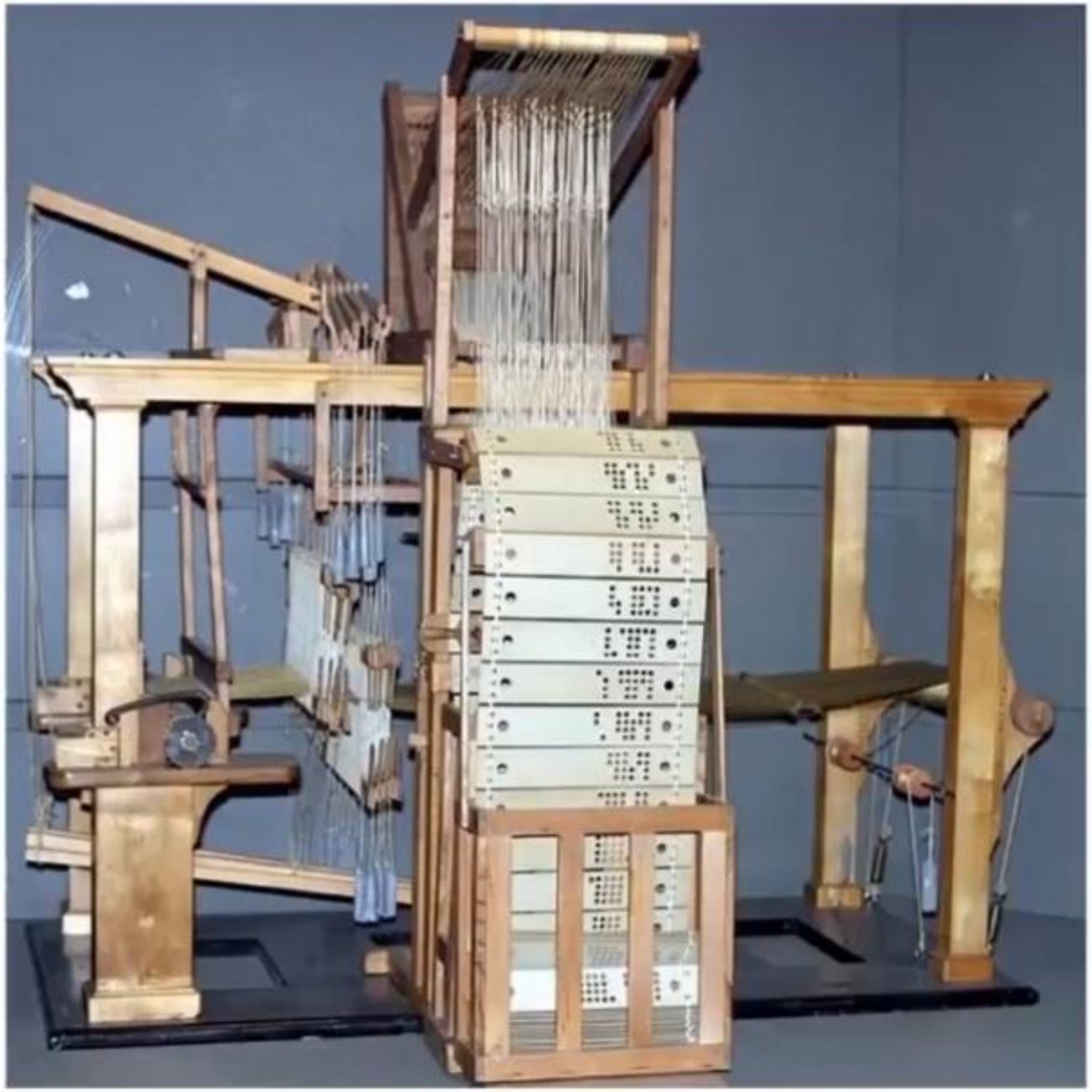
Canard Digérateur

1739

Jacques de Vaucanson
1709–1782

- French

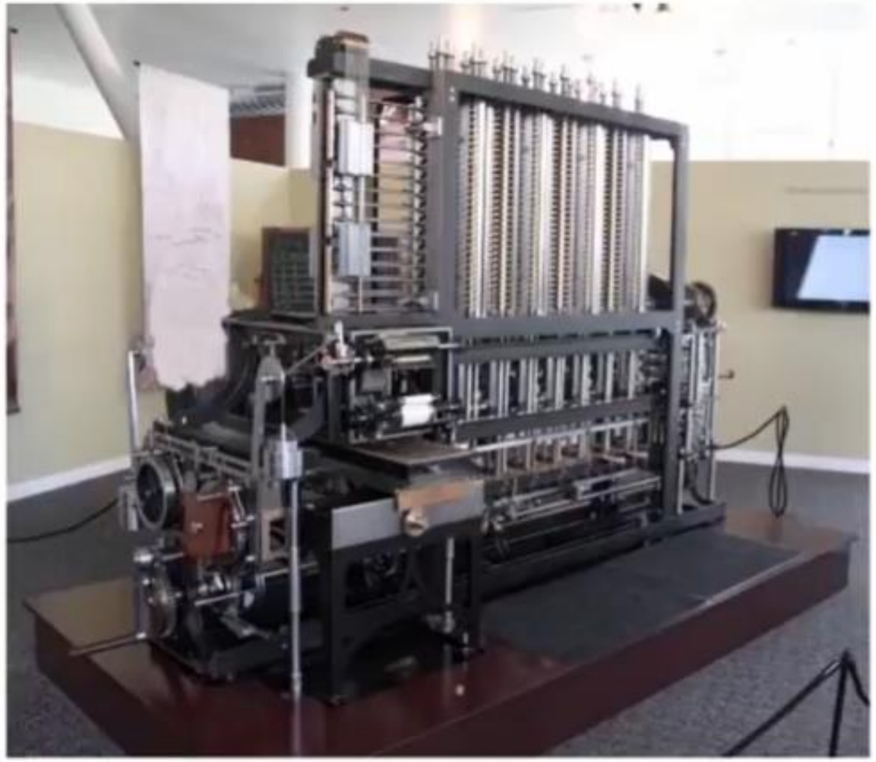
Jacquard's loom



Untitled 2006

1801

Card controlled computing engine

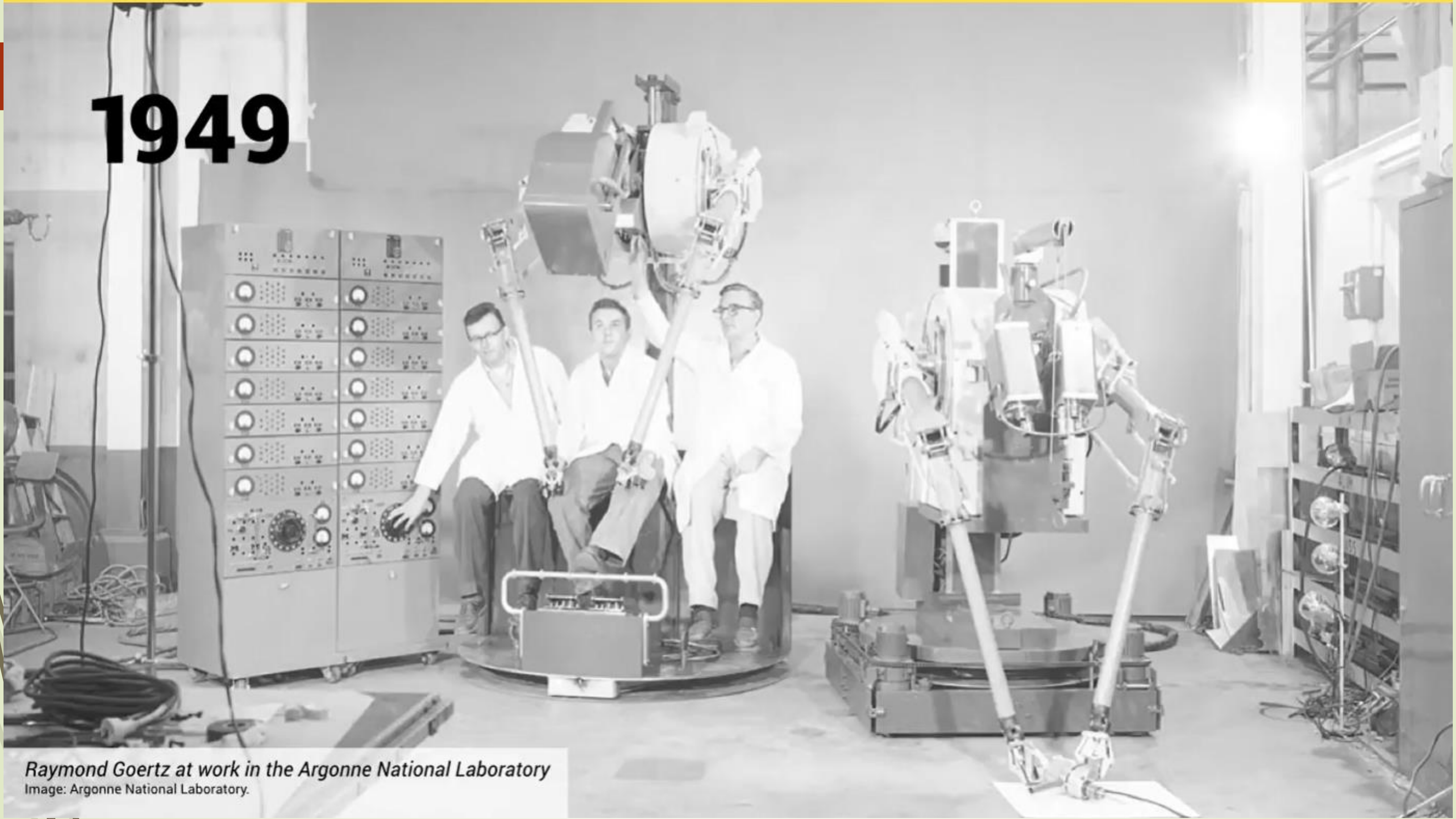


Babbage Difference Engine No. 2 2009
Allan J. Cronin | CC BY-SA 3.0

1870

Charles Babbage
1791 - 1871

- English



Raymond Goertz at work in the Argonne National Laboratory
Image: Argonne National Laboratory.

Unimation Inc.

George C. Devol
Image: The Estate of George C. Devol

Image: The Estate of George C. Devol

Joe Engelberger presenting at ARS Symposium 1996
Image courtesy of ARS Electronica

1956

Robots in Fiction

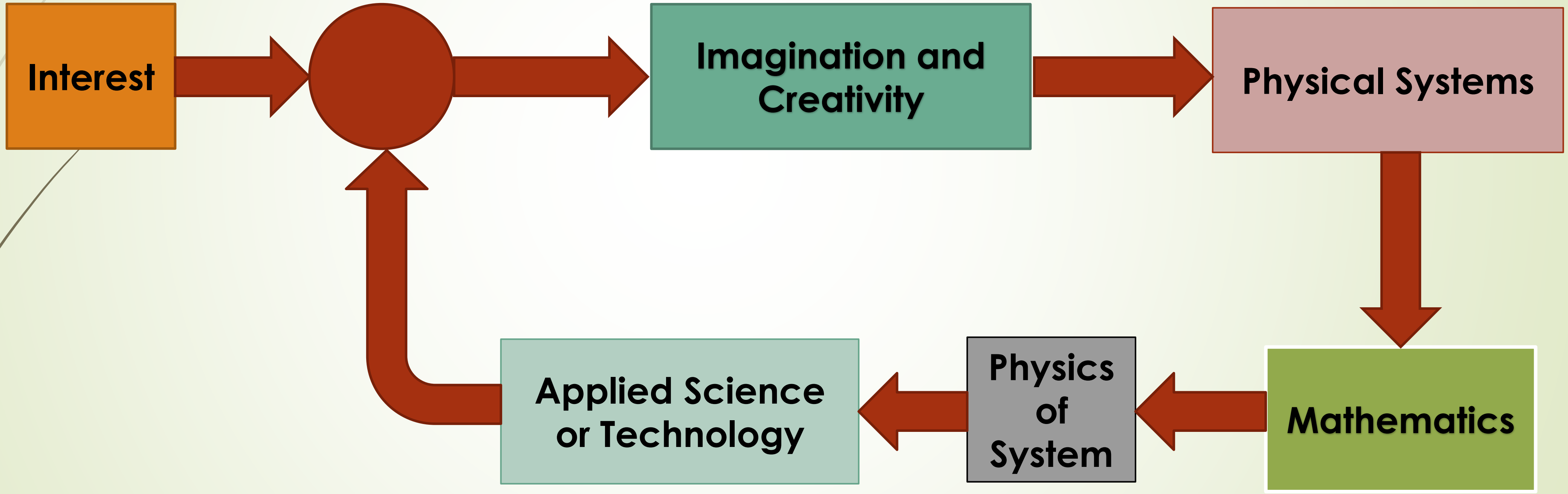
- https://www.youtube.com/watch?v=g3gb7PlhkoA&t=12s

Robots today

- https://www.youtube.com/watch?v=eiKAQVmwBzM&t=84s

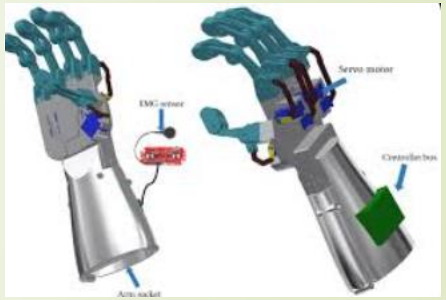
Deliverables:
To become a Robotics engineer to build robots, which are economical, to solve problems in society.

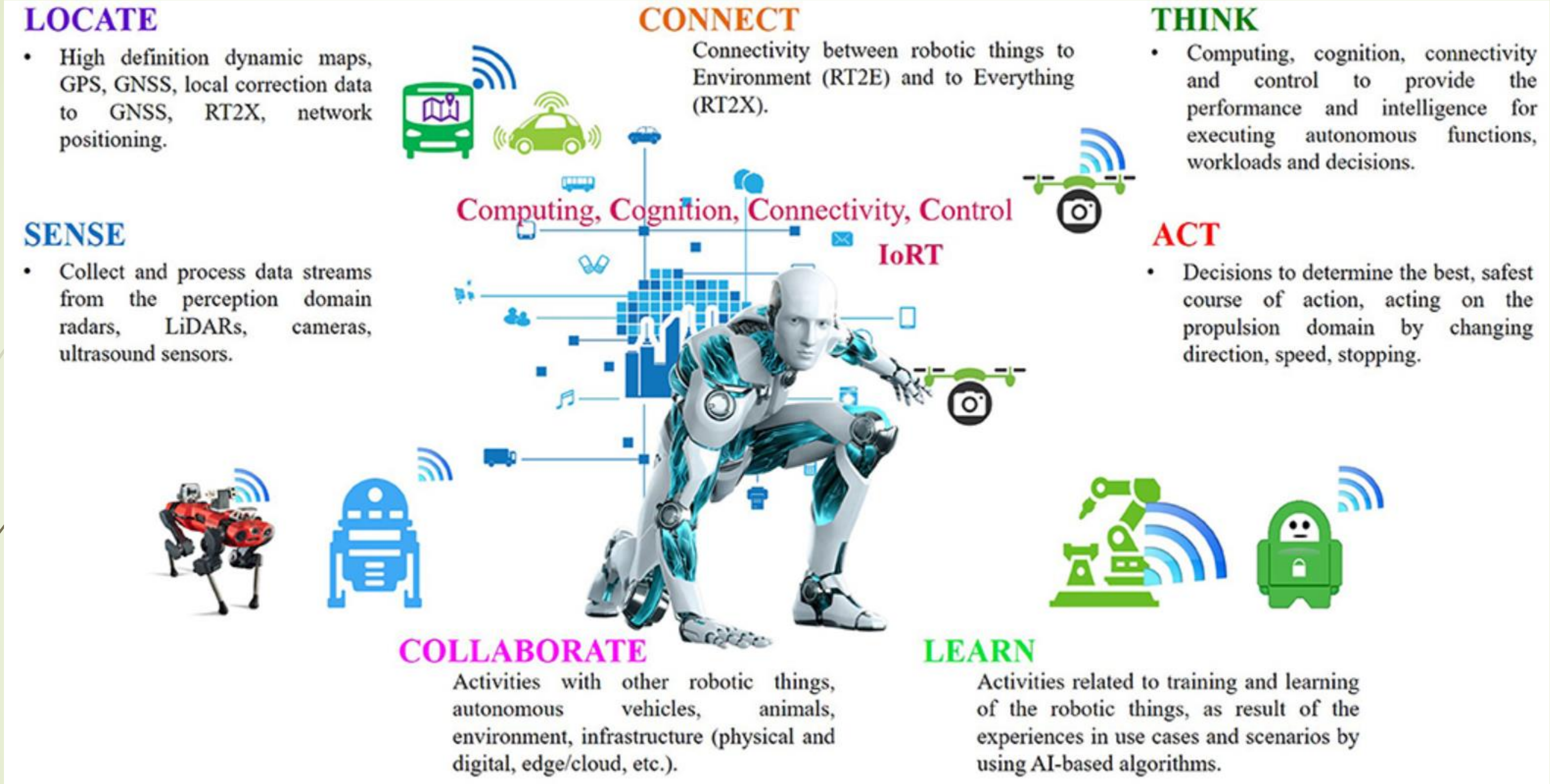
Requirements:



Robot Types:

1. Manipulators, eg. Painting, Welding, Material Handling, Pick and Place, etc.,
2. Mobile Robots, Wheeled and Legged types,
3. Hybrid Robots, eg. Humanoid Robots,
4. Prosthesis,
5. Intelligent Environments refer pic in next slide
6. Multi-body System or Swarm Robots.





Internet of Robotic Things Intelligent connectivity and platforms

Swarm robotics and computation

Intelligence Requirements:

1. Perception using Sensors such as Computer Vision and Digital Image Processing,
2. Communication using Natural Language Processing,
3. Knowledge Representation developed from First Order Logic, Boolean Algebra and Learning such as Supervised, Unsupervised, Reinforced Learning,
4. Automated Reasoning.

Software Requirements:

1. C++, C#, Java,
2. Python (interpreter language) using various libraries and packages including:
   Jupyter and Spyder for interactive programming,
   Pandas, NumPy, SciPy, Matplotlib, etc., which are data analysis packages,
3. Robot Operating System (ROS), along with Gazebo and RViz, etc.,
4. Solidworks, Ansys, Adams, Matlab, Simulink, Simechanics, etc.

Hardware Requirements:

Robot is a computer controlled intelligent electro-mechanical machine using suitable electronic circuitry between computer and electrical actuators, sensors, SLAM systems. (Simultaneous Localization and Mapping)

1. Computer,
2. Electronic circuitry,
3. Electrical, Pneumatic or Hydraulic Actuators,
4. Mechanical System,
5. Sensors,
6. Instrumentation, Control System, GPS, etc.

Mathematical Requirements:

1. Calculus and Differential Equations,
2. Vector and Linear Algebra,
3. Vector and Matrix Calculus,
4. Boolean Algebra and First-Order Logic,
5. Optimization theory,
6. Statistics and Probability.

Earlier Definitions of Robots

1) A machine that moves things from A to B (location)

2) A machine that moves from A to B (location)

3) A goal-oriented machine that can sense, plan and act (these three actions are repeated continuously)

4) Human like look and capabilities – ASIMO(Advanced step in Innovative mobility)

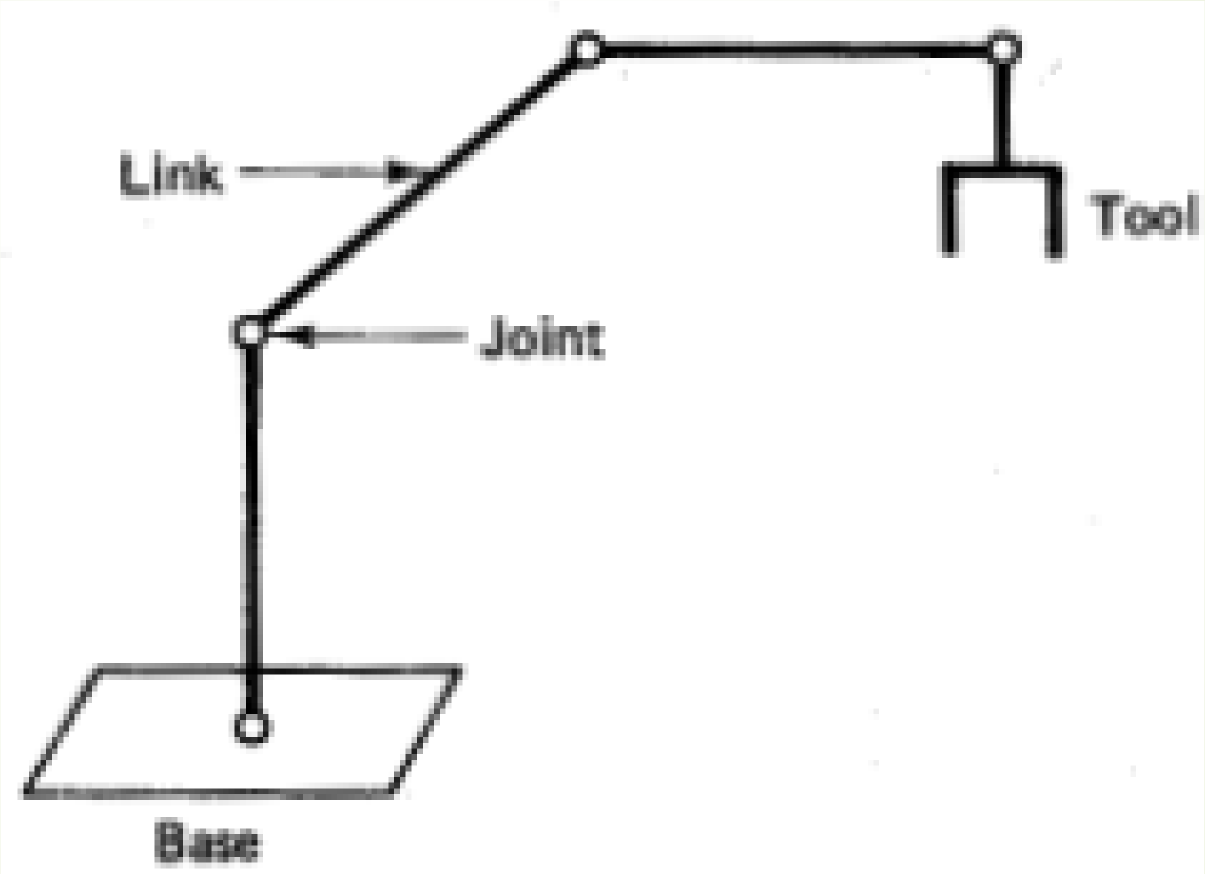
5) Robots that can drive

Definition of Robot

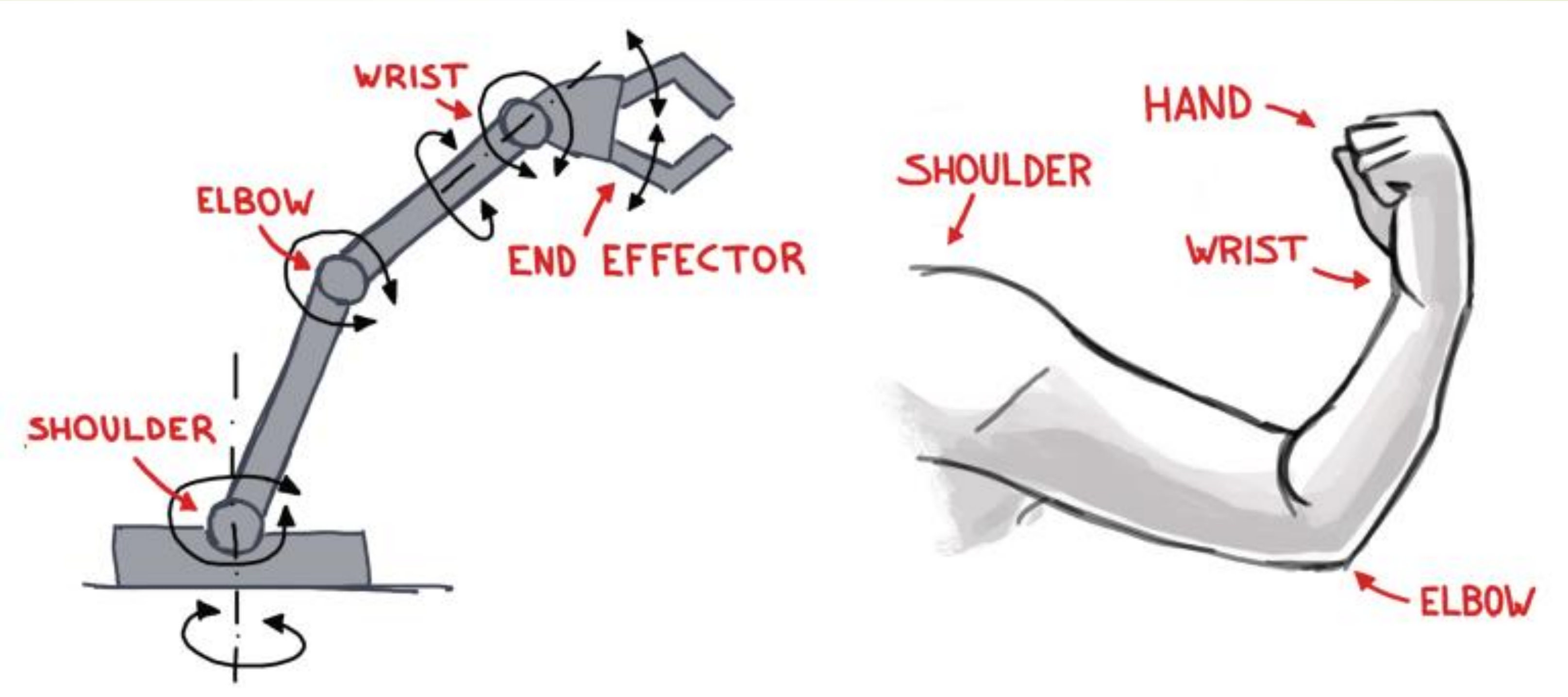
A robot is a software-controllable mechanical device that uses sensors to guide one or more end-effectors through programmed motions in a workspace in order to manipulate physical objects.

Industrial Robots are also called as Robotic Arms or Robotic Manipulators.

Robotic Manipulator modelled as a chain of links



Serial Robotic Manipulator and it's ideological parent - the human arm



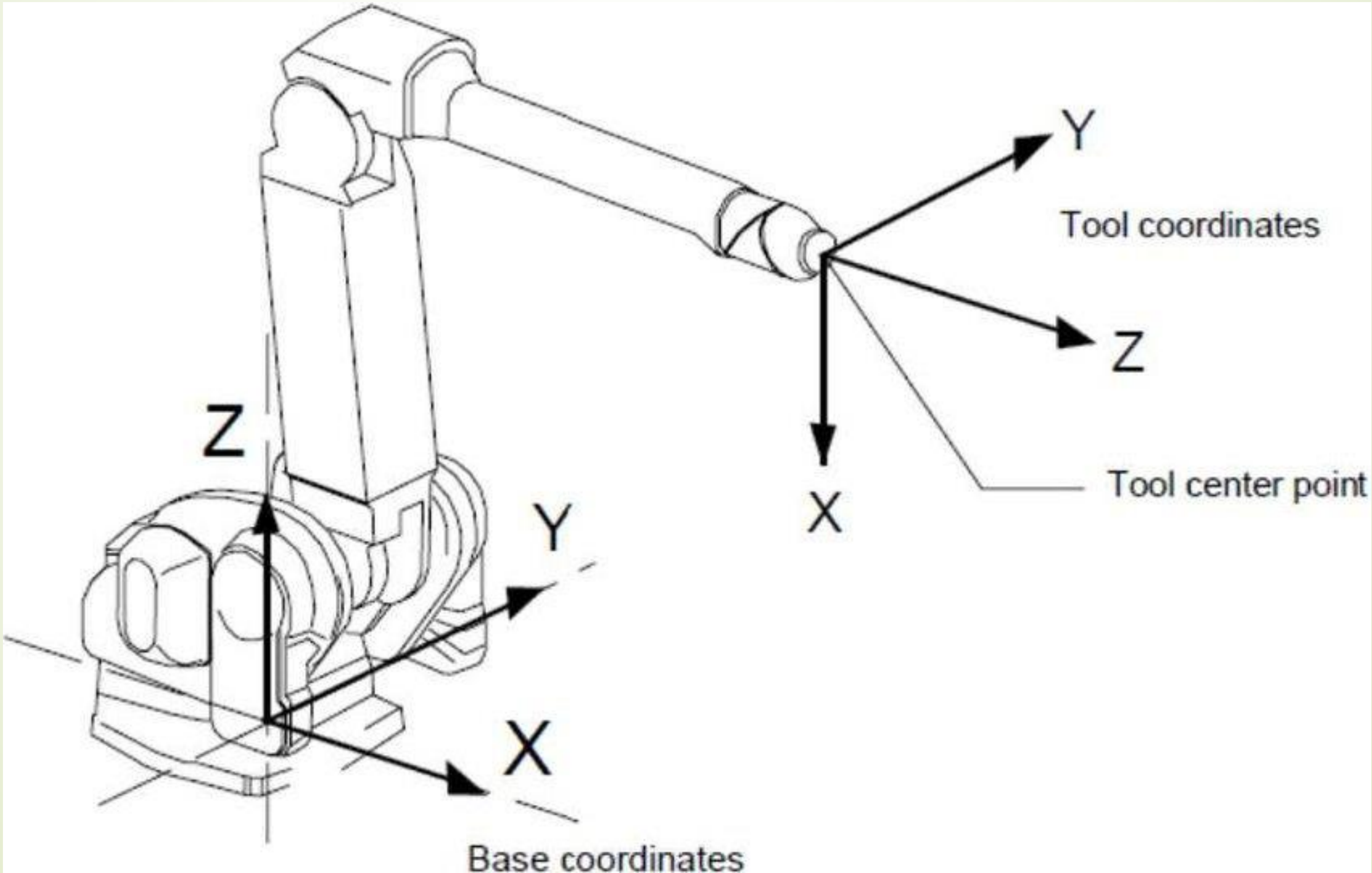
Serial Robotic Manipulator

Serial Robotic Manipulators

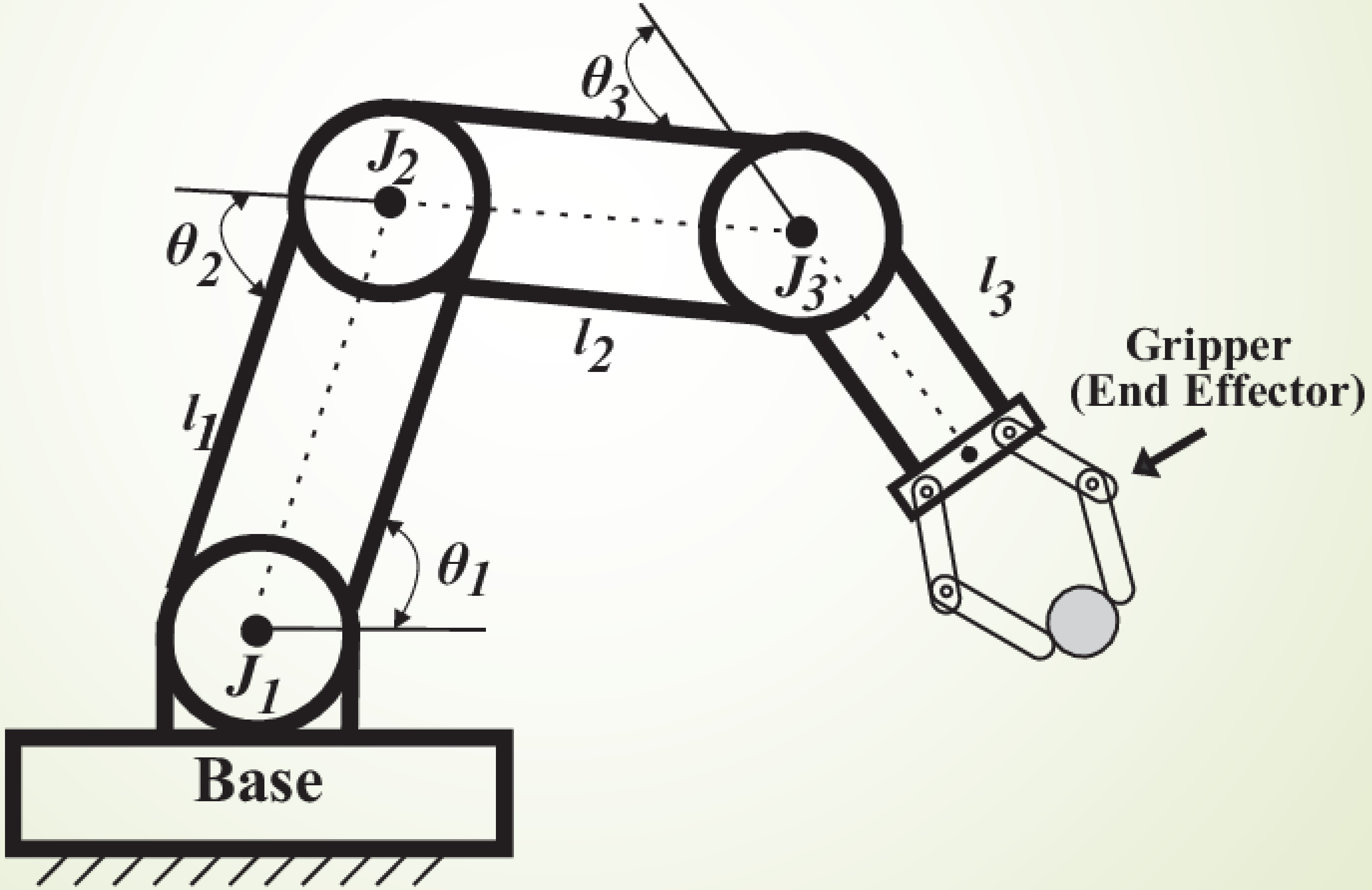
- They are the most common type of Industrial Manipulators.
- They are a $ 2 Billion industry.
- They are an open kinematic chain of mechanical links.
- They are physically anchored at the base.

Components of a Robotic Manipulator

Base and Tool Coordinate Frames for a Manipulator

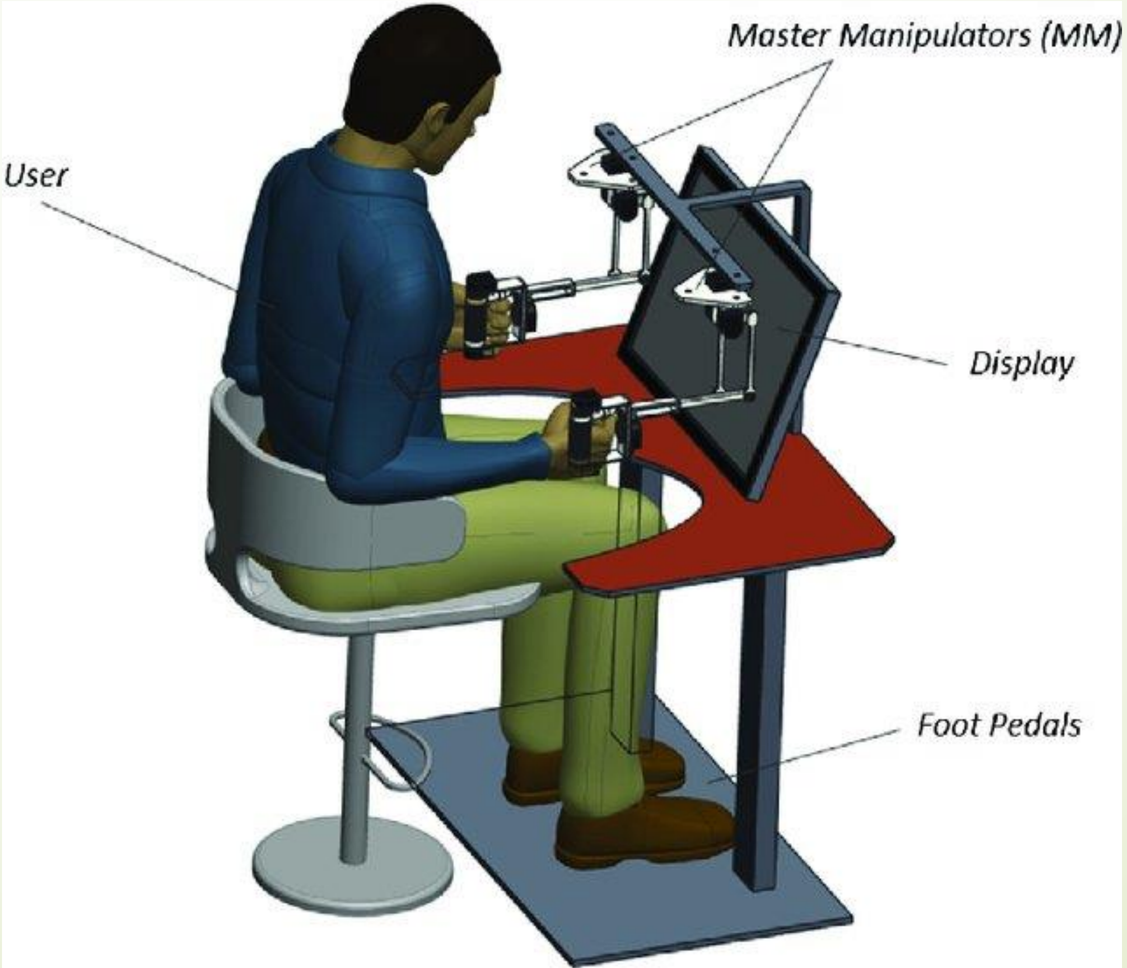


Schematic Diagram of a Robotic Manipulator

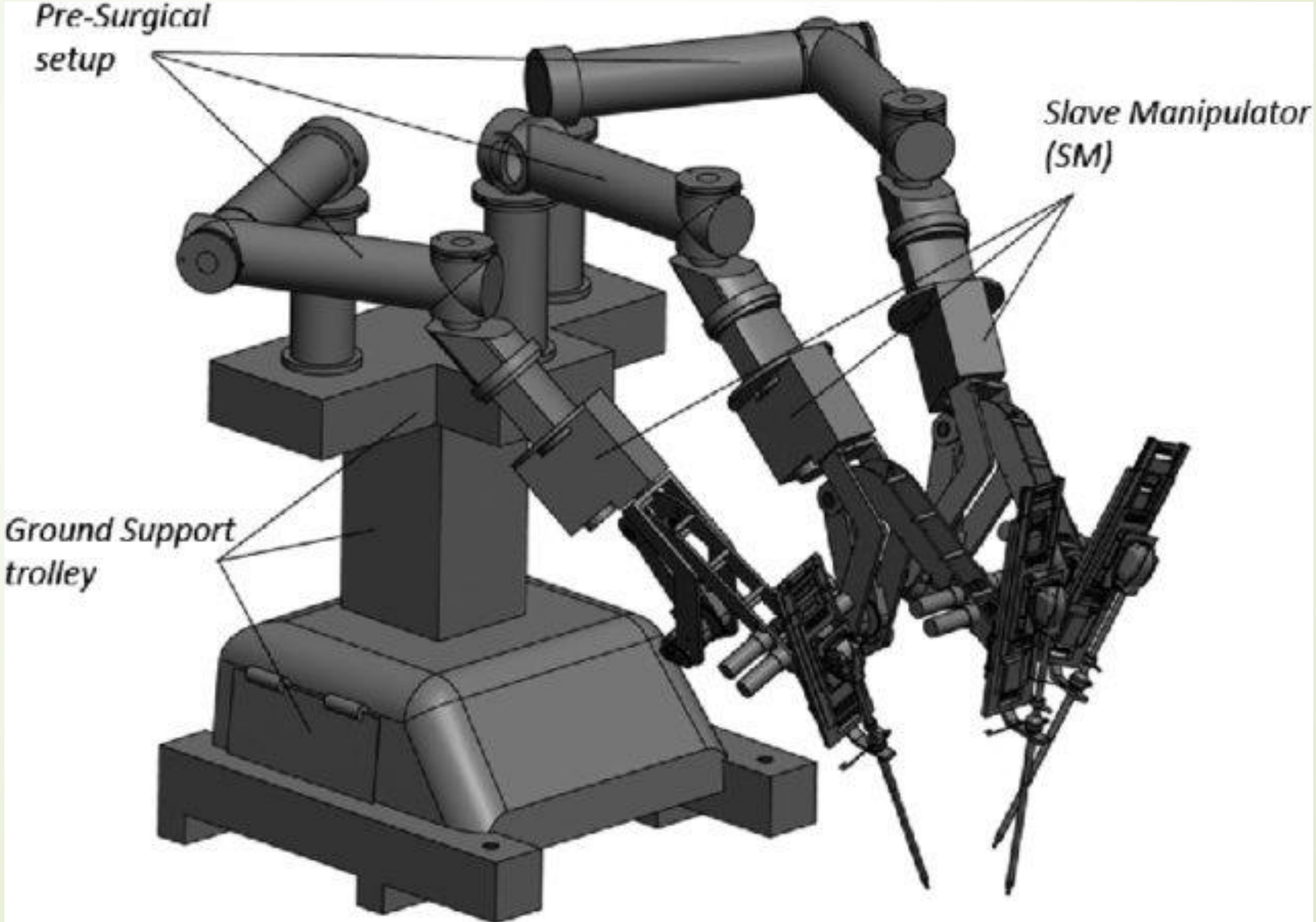


Few types of Manipulators

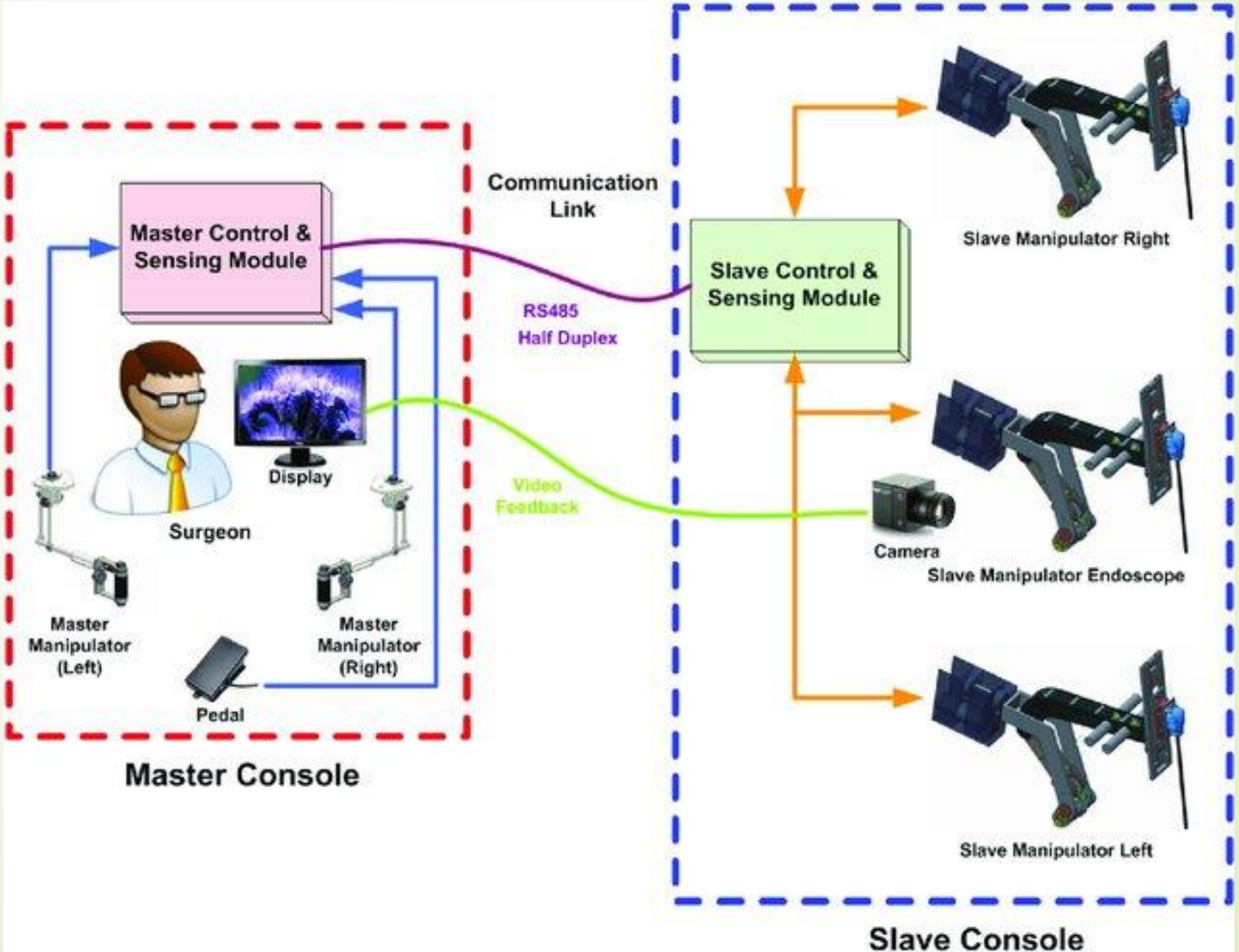
Master Manipulator



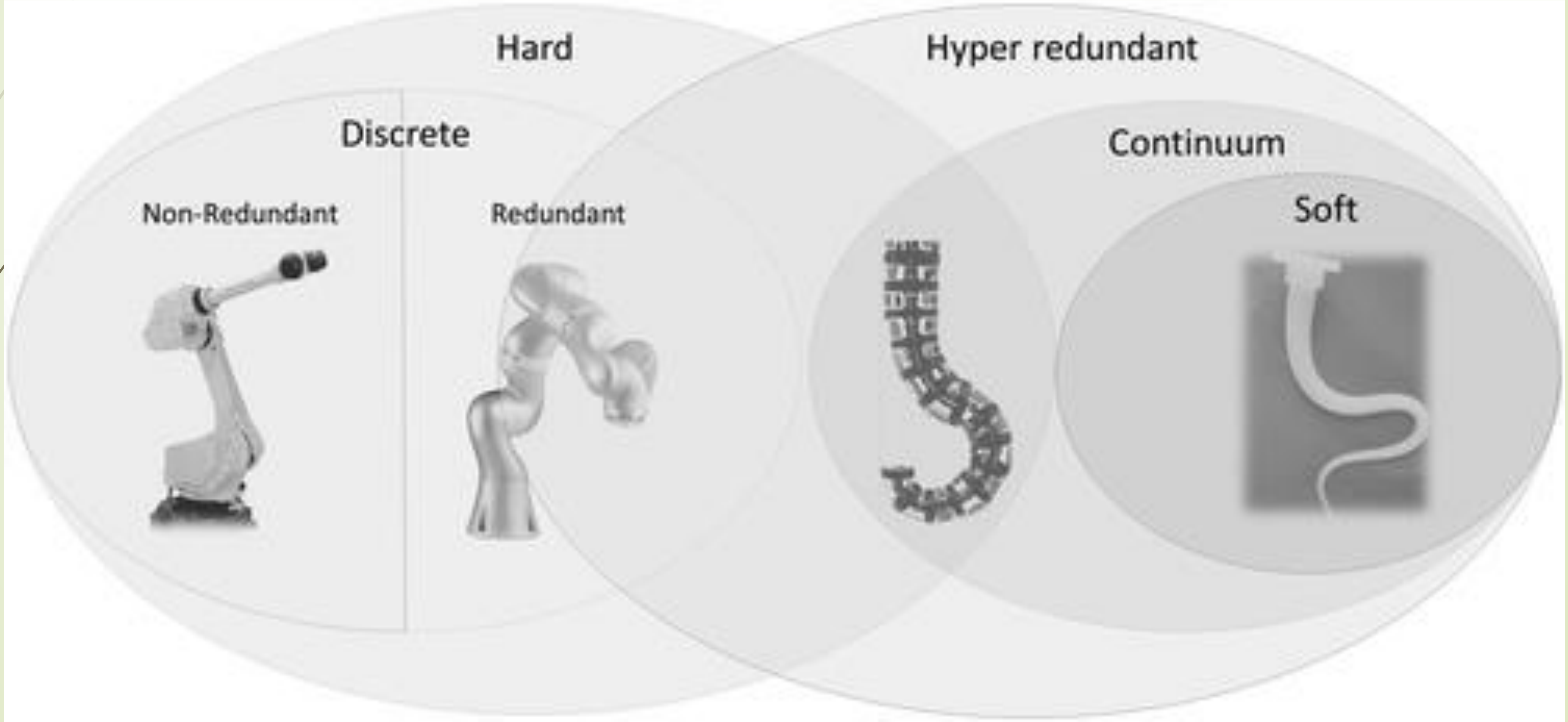
Surgery Robot (Slave Manipulator)



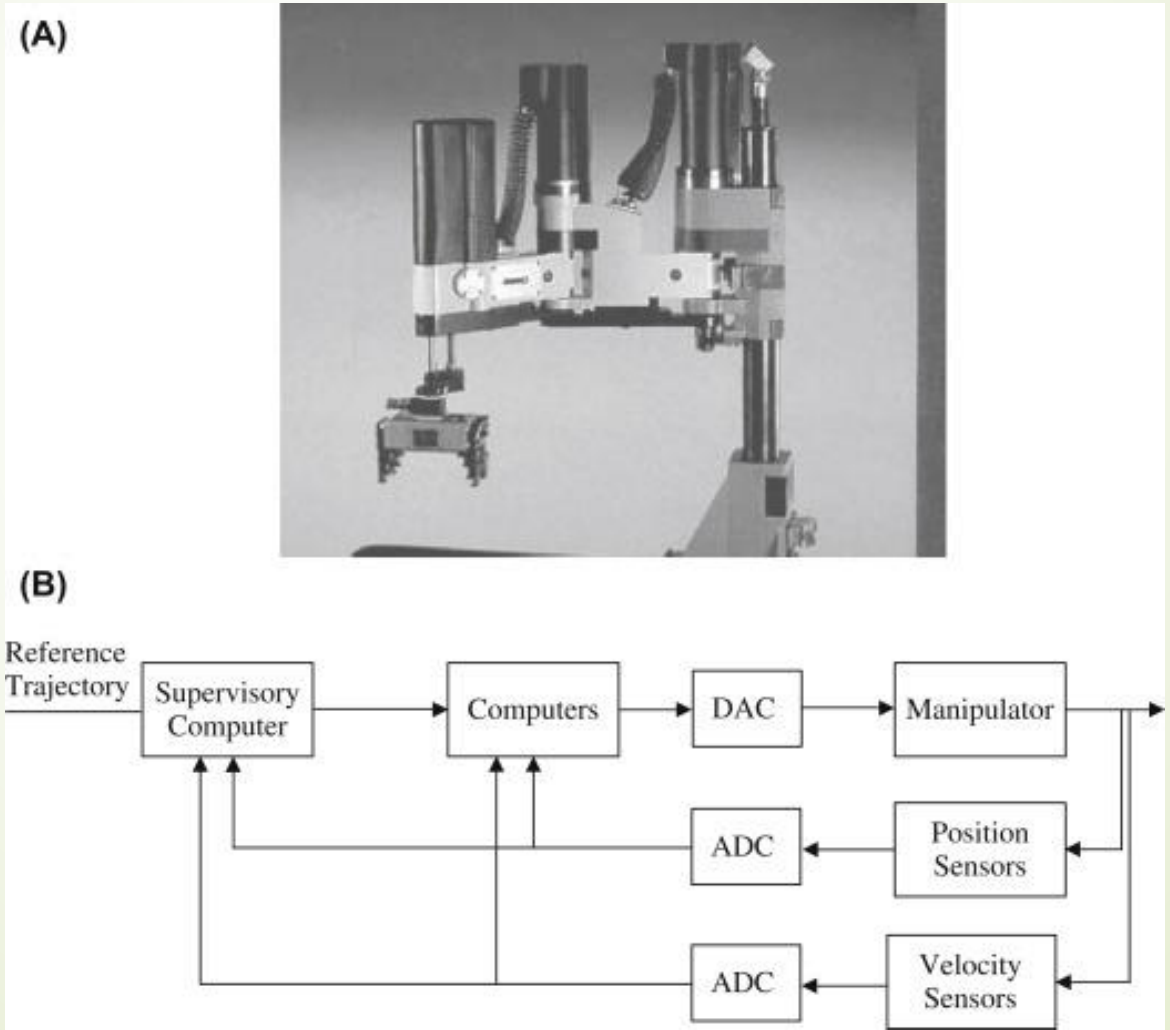
Master-Slave Control Scheme



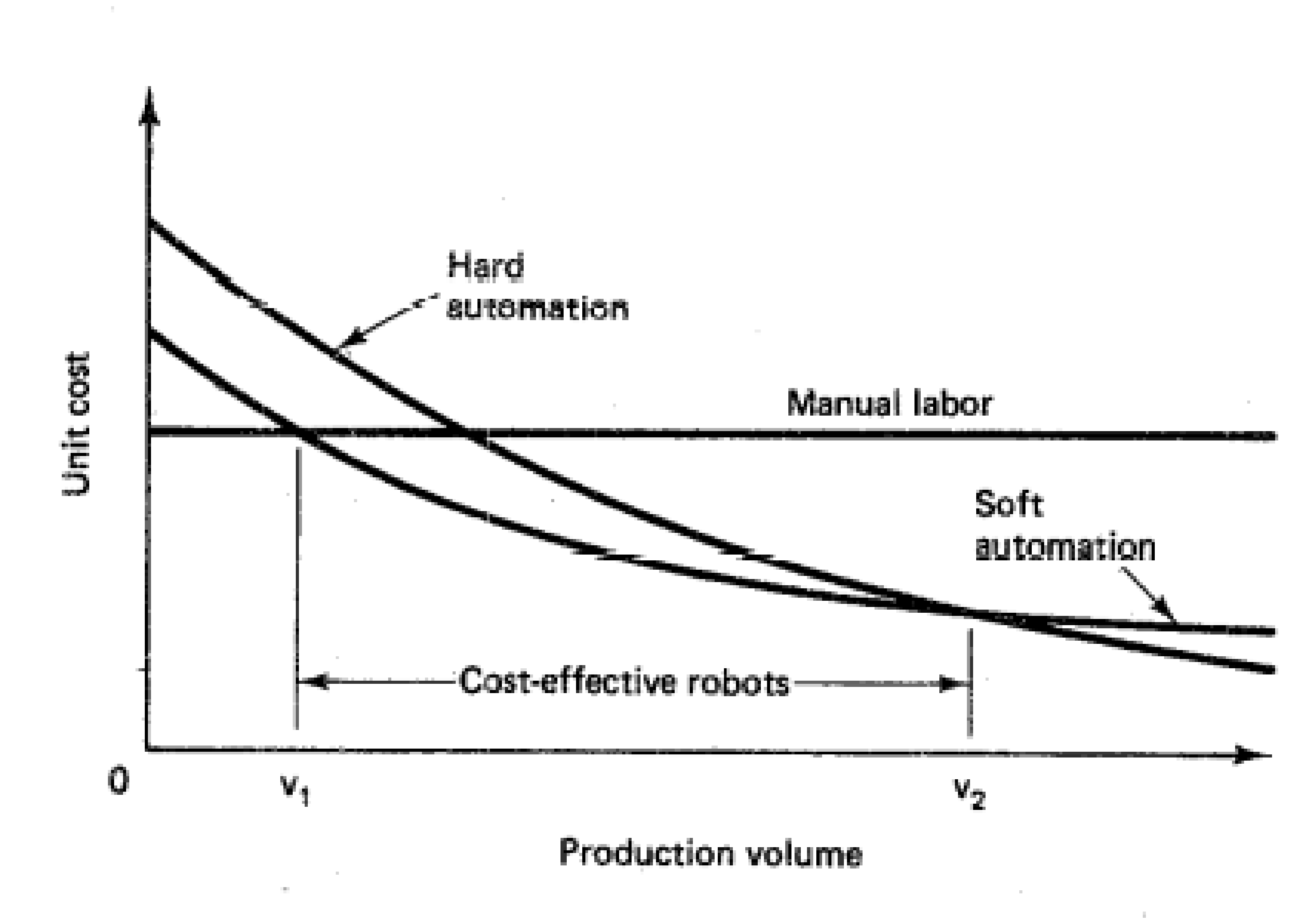
Hard and Soft Robots



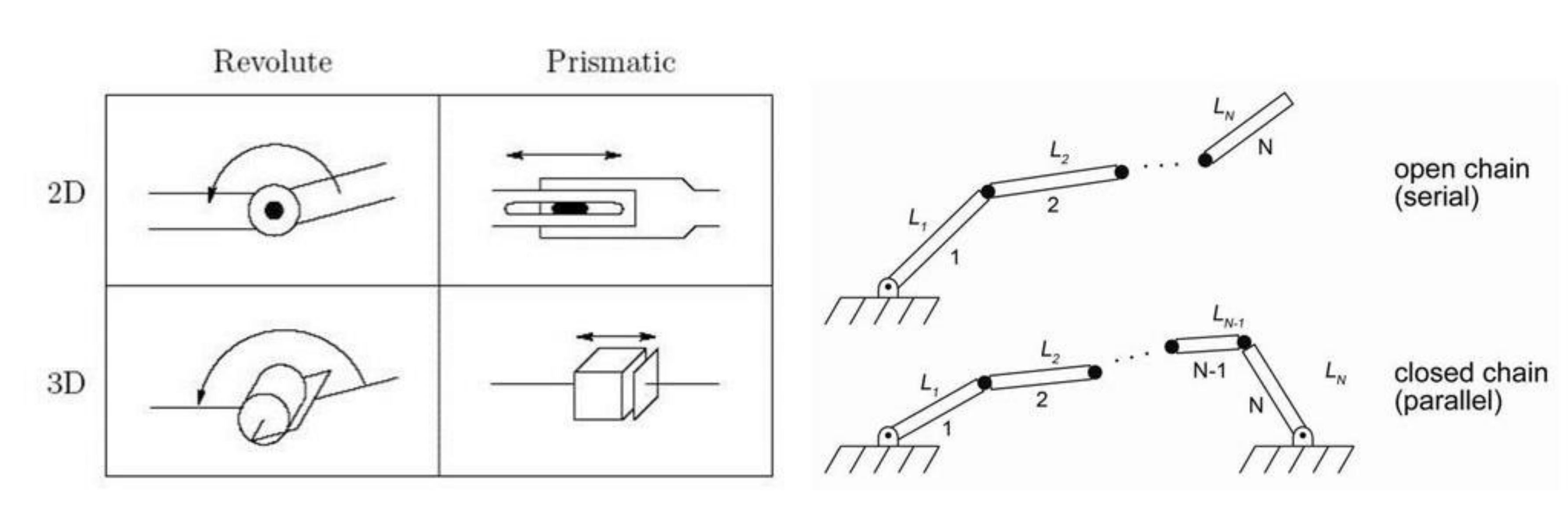
Control Scheme of a Robotic Manipulator



Relative Cost-effectiveness of Soft Automation



Types of Robot Joints



Type	Notation	Symbol	Description
Revolute	R		Rotary motion *about* an axis
Prismatic	P		Linear motion *along* an axis

Classification of Robots

1. Drive Technologies such as Electric, Pneumatic and Hydraulic. Electric drives are generally DC Servomotors or DC Stepper motors.

2. Work-Envelope Geometries.

3. Motion Control Methods:
   i. Point-to-point control and,
   ii. Continuous path control.

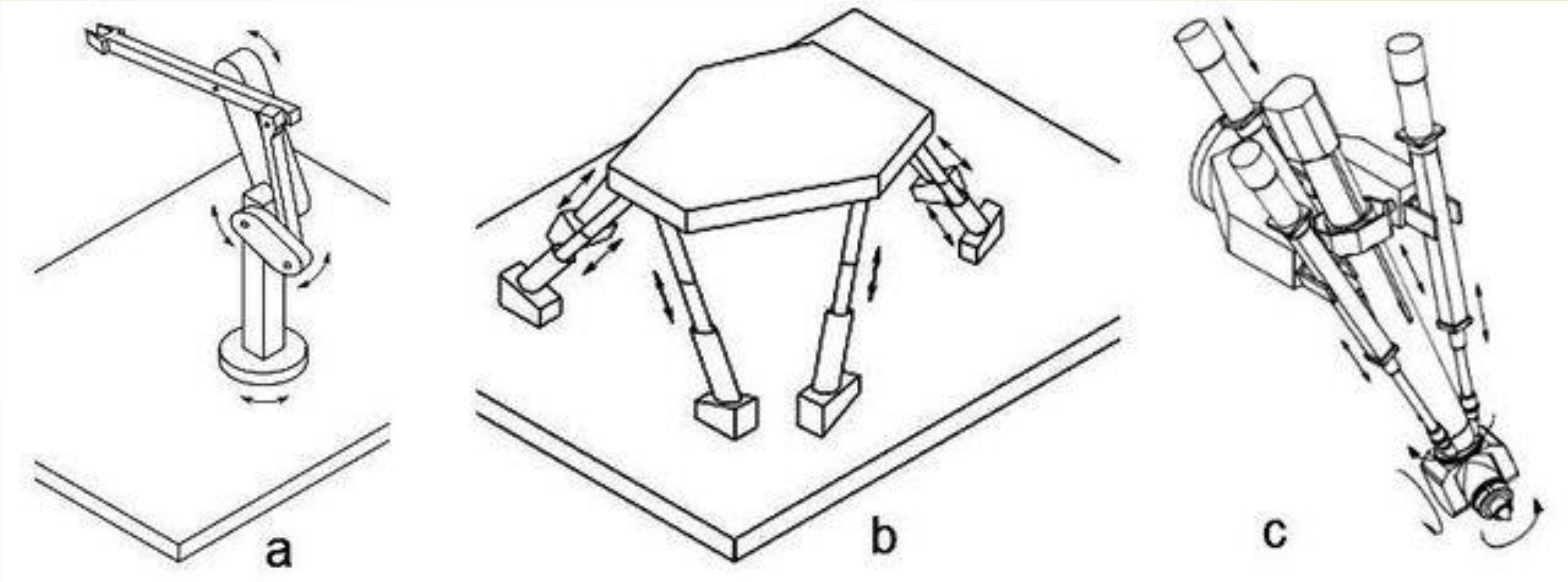
Work Envelope Geometries based on Major Axes

Robot	Axis 1	Axis 2	Axis 3	Total revolute
Cartesian	P	P	P	0
Cylindrical	R	P	P	1
Spherical	R	R	P	2
SCARA	R	R	P	2
Articulated	R	R	R	3

P = prismatic, R = revolute.

Refer Robot Configurations.pdf

Parallel Robotic Manipulators



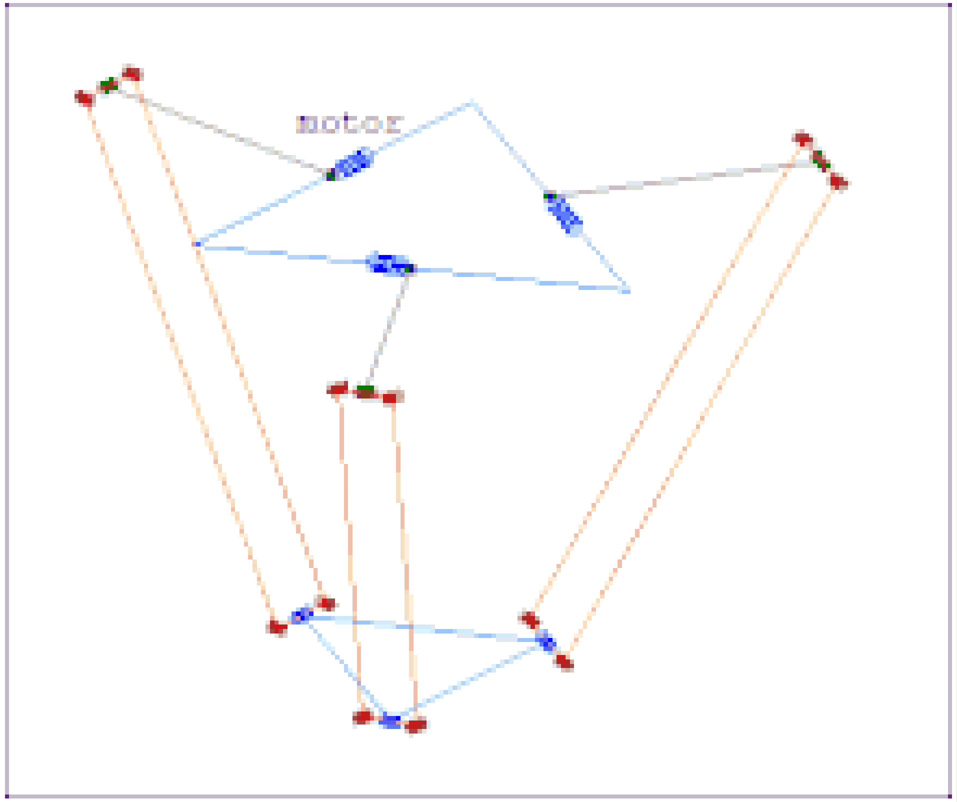
a. Closed Chain with Parallelogram.

b. Parallel. e.g., Stewart's Platform.

c. Hybrid Parallel-Serial.

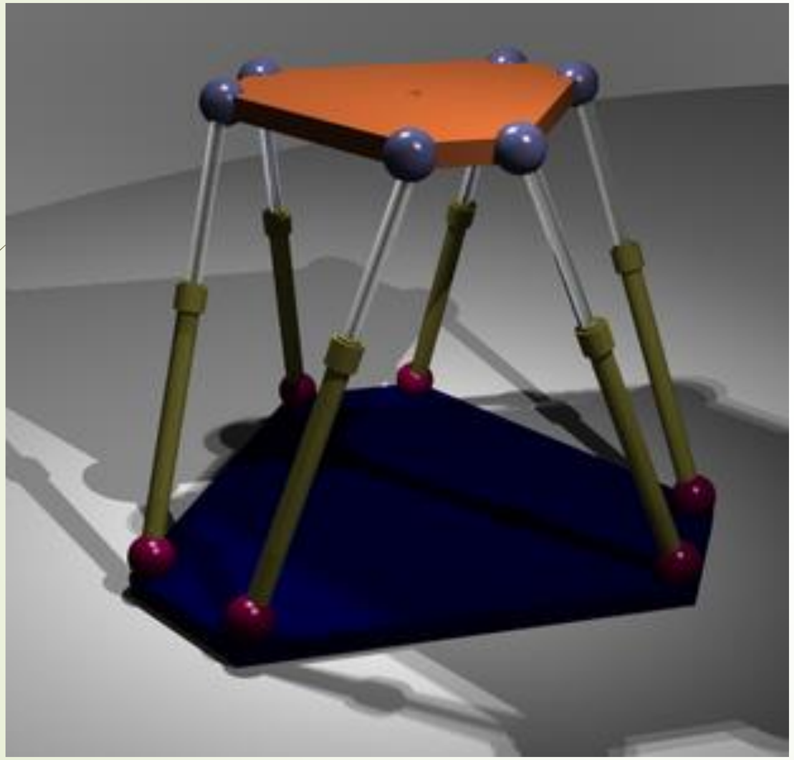
Delta Robot (Parallel Robot)

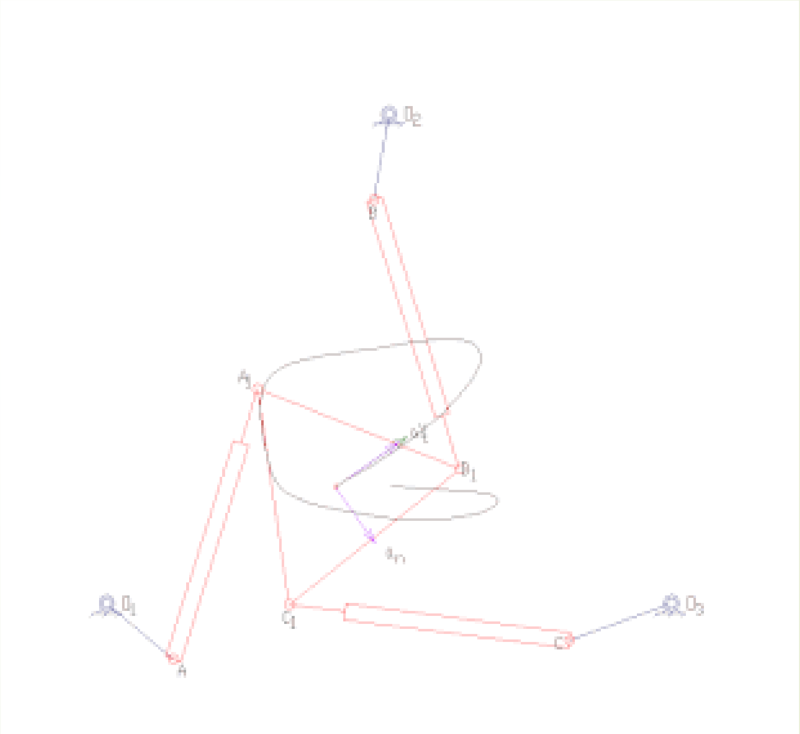
A delta robot is a type of parallel robot that consists of three arms connected to universal joints at the base. The key design feature is the use of parallelograms in the arms, which maintains the orientation of the end effector.



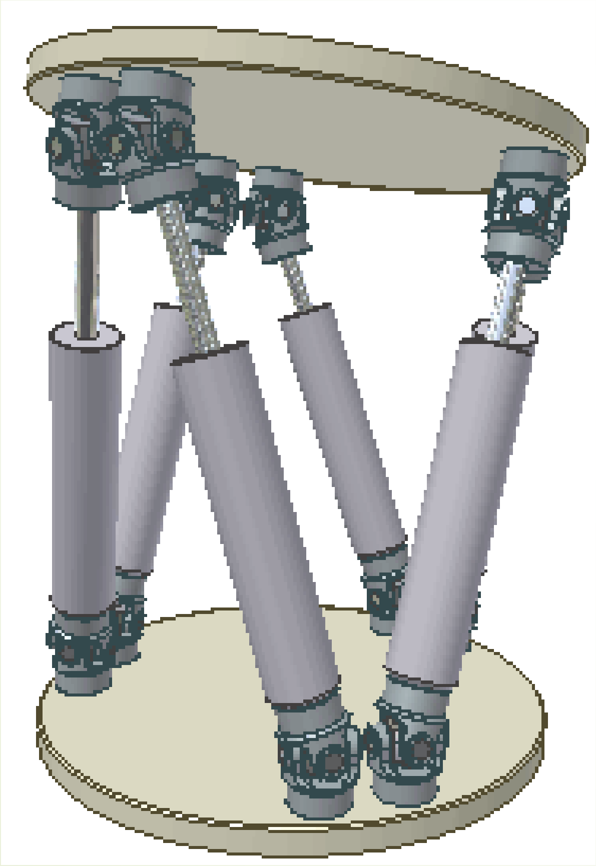
Stewart platform can change the orientation of its end effector.

Gough-Stewart Platform (Hexapod Platform) Parallel Robot





Gough-Stewart Platform (6 DoF Platform) Parallel Robot



Application: Flight Simulator

AMiBA Radio Telescope

Comparison between Parallel and Serial Manipulators

	Type of manipulator	
	Parallel manipulator	Serial manipulator
Type of manipulators	Closed loop	Open loop
End effectors	Platform	Gripper
Natural description	In Cartesian space	In joint space
Location of actuators	Near the immobile base	On the links
Inertia forces & stiffness	Less and high respectively	High and less respectively
Design considerations	Structure, workspace considerations, singularities, link interference	Strength and stiffness considerations, vibration characteristics.
Preferred property	Stiffness	Dexterity
Use of direct kinematics	Difficult and complex	Straightforward and unique
Use of inverse kinematics	Straightforward and unique	Complicated
Singularity	Static	Kinematic
Direct force transformation	Well defined and unique	Not well defined; may be non-existent, unique or infinite
Preferred application	Precise positioning	Gross motion

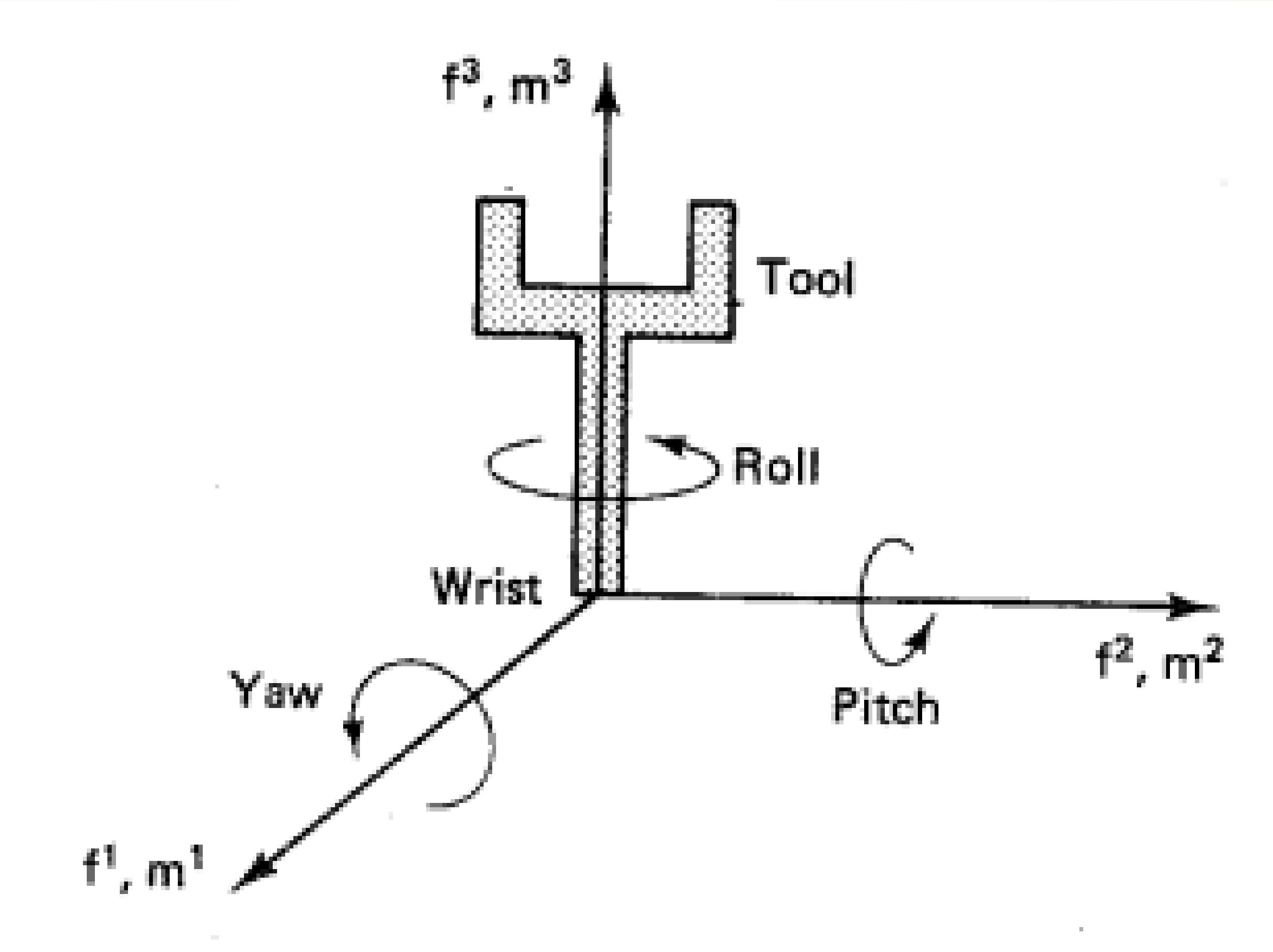
Robot Specifications or Characteristics

1. Number of axes,
2. Load carrying capacity, kg,
3. Maximum speed, mm/s,
4. Reach and Stroke, mm,
5. Tool orientation, deg,
6. Repeatability, mm,
7. Precision and Accuracy, mm,
8. Operating environment.

Rhino XR-3 Robot Specifications (contd.)

Characteristic	Value	Units
Number of axes	5	—
Load-carrying capacity	0.5	kg
Maximum tool-tip speed	25.0	cm/sec
Horizontal reach and stroke	62.23	cm
Vertical reach and stroke	88.27	cm
Tool pitch range	270.0	deg
Tool roll range	infinite	deg
Repeatability	±0.1	cm

Tool Orientation (Yaw-Pitch-Roll or X-Y-Z system)



Repeatability, Precision and Accuracy

Repeatability is a measure of the ability of a robot to position the tool tip in the same position repeatedly.

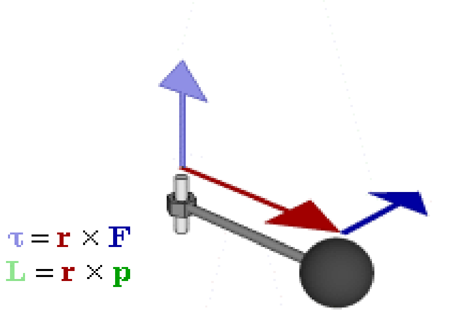
Precision of a robot is the spatial resolution with which the tool can be positioned within the work envelope.

Accuracy of a robot is a measure of the ability of the robot to place the tool tip at an arbitrarily prescribed position in The work envelope.

Repeatability, Precision and Accuracy (contd.)[just read]

Type of Robot	Vertical Precision	Horizontal Precision	Repeatability	Accuracy
Rectangular	Uniform	Uniform	Very Good	Very Good + Highly Accurate
Cylindrical	Uniform	Decreasing radially	Good	Good + Accurate
Spherical	Decreasing radially	Decreasing radially	Satisfactory	Less Accurate
SCARA	Uniform	Decreasing radially	Very Good	Very Good
Articulate	Decreasing radially	Decreasing radially	Good	Very, Very Less Accurate

Some robotic terms



Let’s get introduce with some important robotic terminologies:

a) **Link** → A rigid component of a robot, often attached to other links via joints.
b) **Joint** → An articulation point between two robot links.
c) **Sensor** → Sensors are devices that measure some physical quantities of the world and encode the signals into electrical (typically digital) form.
d) **Actuator & Transmission** → An actuator is a mechanism that generates a force/torque given electrical signals; a transmission is a mechanism that applies an actuator's forces/torques to the robot's links.
e) **Payload** → The ability to carry a given maximum weight at a given speed.
f) **Velocity** → The maximum speed at which the tip of a robot is capable of moving at full extension.
g) **Cycle** → Time it takes for the robot to complete one cycle of picking up a given object at a given height, moving it to a given distance, lowering it, releasing it, and returning to the starting point.
h) **Repeatability** → The ability of a robot to return consistently to a previously defined and achieved location.
i) **Resolution** → The smallest incremental change in position that it make or its control system can measure.
j) **Size** → The physical size of a robot, which influences its capacity and its capabilities.

Operating Environment

1. Harsh, dangerous and unhealthy environments such as transport of radioactive materials, spray painting, welding, loading and unloading of furnaces, etc.

2. Clean rooms are required for semiconductor industry, where temperature, humidity and airflow are controlled.

Thank You