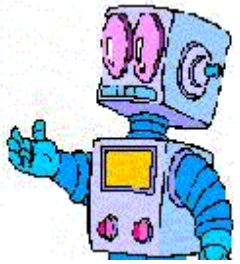
INTRODUCTION TO ROBOTICS

(Kinematics, Dynamics, and Design)

SESSION # 5:

CONCEPTS & DEFENITIONS



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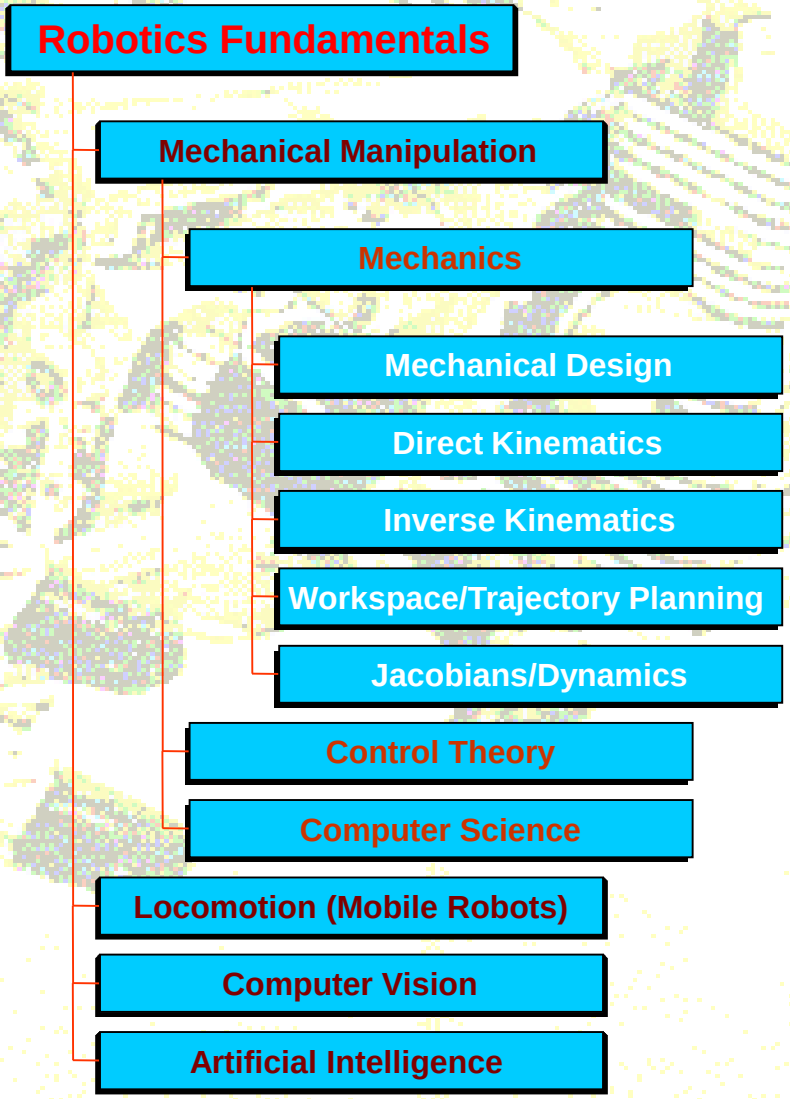
Foundations of Robotics



Important Definitions & Terminologies

- Android: A robot which resembles a human in physical appearance.
- Artificial Intelligence: The ability of a machine to respond to a new situation and to solve problems without human interference. (To learn from experience).
- Manipulation: Grasping, releasing, moving, transporting, or otherwise handling an object.
- Manipulator: A mechanism usually with several degrees-of-freedom which is designed for manipulation.
- Master/Slave Manipulator: A type of teleoperator consisting of a master arm held, moved, and positioned by a person, and a slave arm which simultaneously duplicates the operators motions (with a scale factor).

Important Definitions & Terminologies

- **Prosthetic Robot:** A controlled mechanical device connected to the human body which provides a substitute for human arms or legs when their function is lost.
- **Intelligent/Adaptive Robot:** A category of robots that have sensory perception, making them capable of performing complex tasks which vary from cycle to cycle. (Automatically adjusts its task to the changing conditions in the environment).
- **End-Effector/Gripper:** A device connected to the end of a manipulator by which objects can be clamped, grabbed, or otherwise secured for movement.
- **Mobile Robot:** A robot mounted on a movable platform (base).
- **Payload:** The maximum weight that can be handled by a robot without failure.
- **Actuator:** An electrical, hydraulic, or pneumatic driver, such as a cylinder or electric motor, which delivers power for robot motion.

Assembly and Manipulation at Different Scales

Assembly scale	Mesoscale	Microscale	Nanoscale
Attribute			
Positioning	Easy	Difficult	Very difficult
Velocity	Cm/s or m/s are not unusual	Slow (μm/s), or (mm/s), vibration suppression	Very slow Nm/s, or μm/s
Force Sensing and Control	Easy / Necessary to avoid part damage and improve manipulability.	Difficult, The range of forces to be sensed could be as low as μN.	Difficult, AFM (atomic force microscope) is used to measure force.
Dominant forces	Gravity, Friction	Friction, Surface forces (stiction, electrostatic, Van der Waals)	Molecular/Atomic forces
Throughput	Serial assembly provides adequate throughput.	Serial assembly is usually not sufficient. Parallel manipulation methods are preferred.	Parallel manipulation methods, or self-assembly are necessary.
Gripper	Mechanical, many examples, RCC, Utah/MIT hand, etc.	Micromechanical, gripper-free manipulation preferred.	Other, optical, proximity force, etc.
Fixturing	Mechanical	Micromechanical fixturing must be used	Chemical
Compliance	Gripper compliance is not necessary if force is measured.	Gripper compliance is usually necessary.	Mechanical compliance does not apply.
Vision	Easy	Difficult (expensive optics)	Impossible in visible wavelengths.

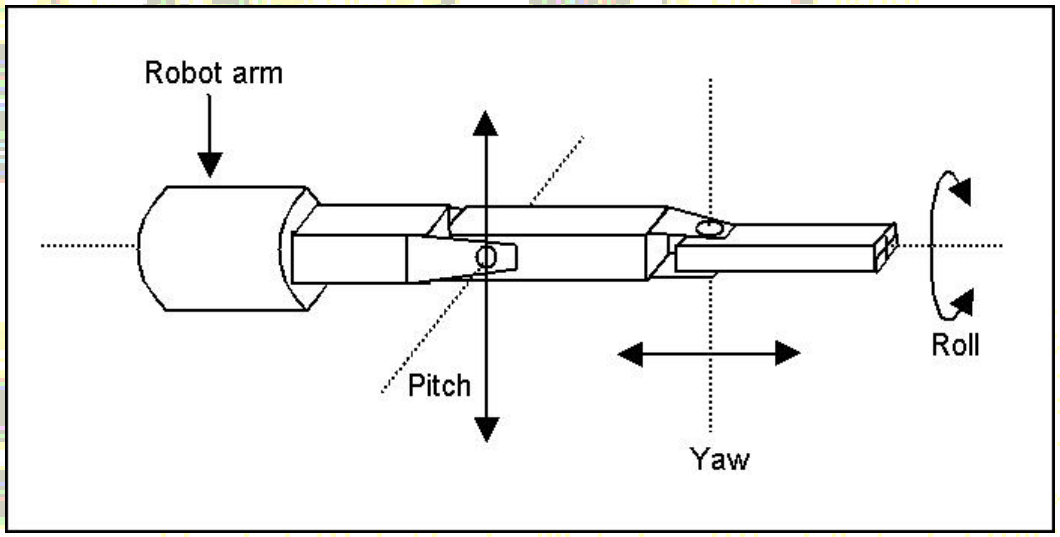
Wrist and End Effector

- **Wrist:** the joints between the arm and the end effector.

- Typically, the **arm** controls the **position** of the end-effector, and the **wrist** controls the **orientation**.

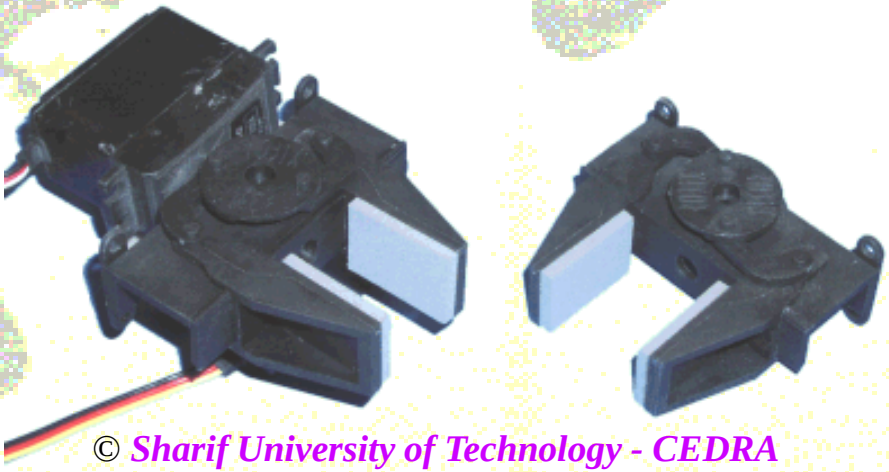
3 DOF Wrist

- A typical wrist would have 3 DOF described as **roll**, **pitch** and **yaw**.
  Roll - rotation around the arm axis
  Pitch - up and down movement (assuming the roll is in its centre position)
  Yaw - right to left rotation (assuming the roll is in its centre position)

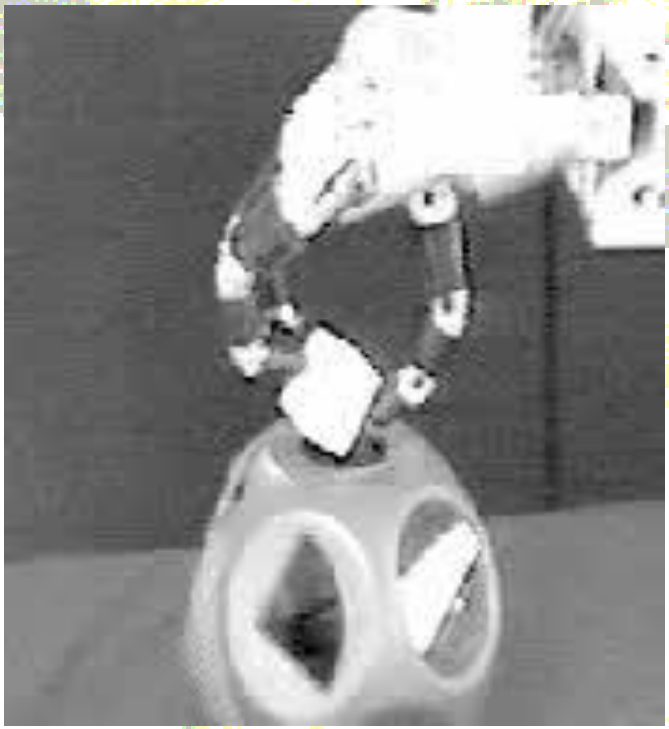


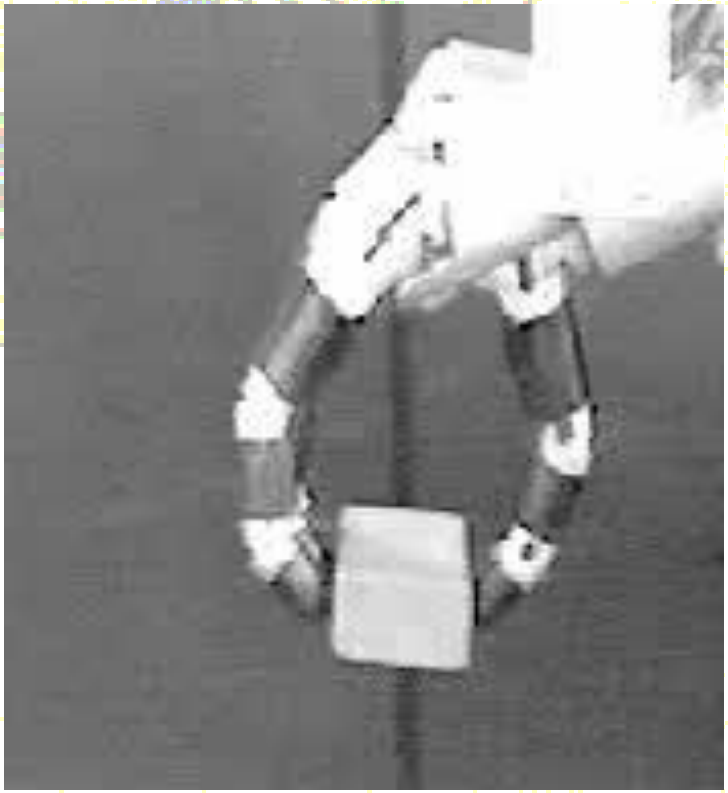
End Effector

- The device on the end of the arm, attached via the wrist, that performs the task, such as:
- **Grippers -** Use to hold and move objects
- **Tools -** Used to perform work on a part, not just to pick it up. A tool could be held by a gripper, making the system more flexible (i.e. welding gun, painting gun)

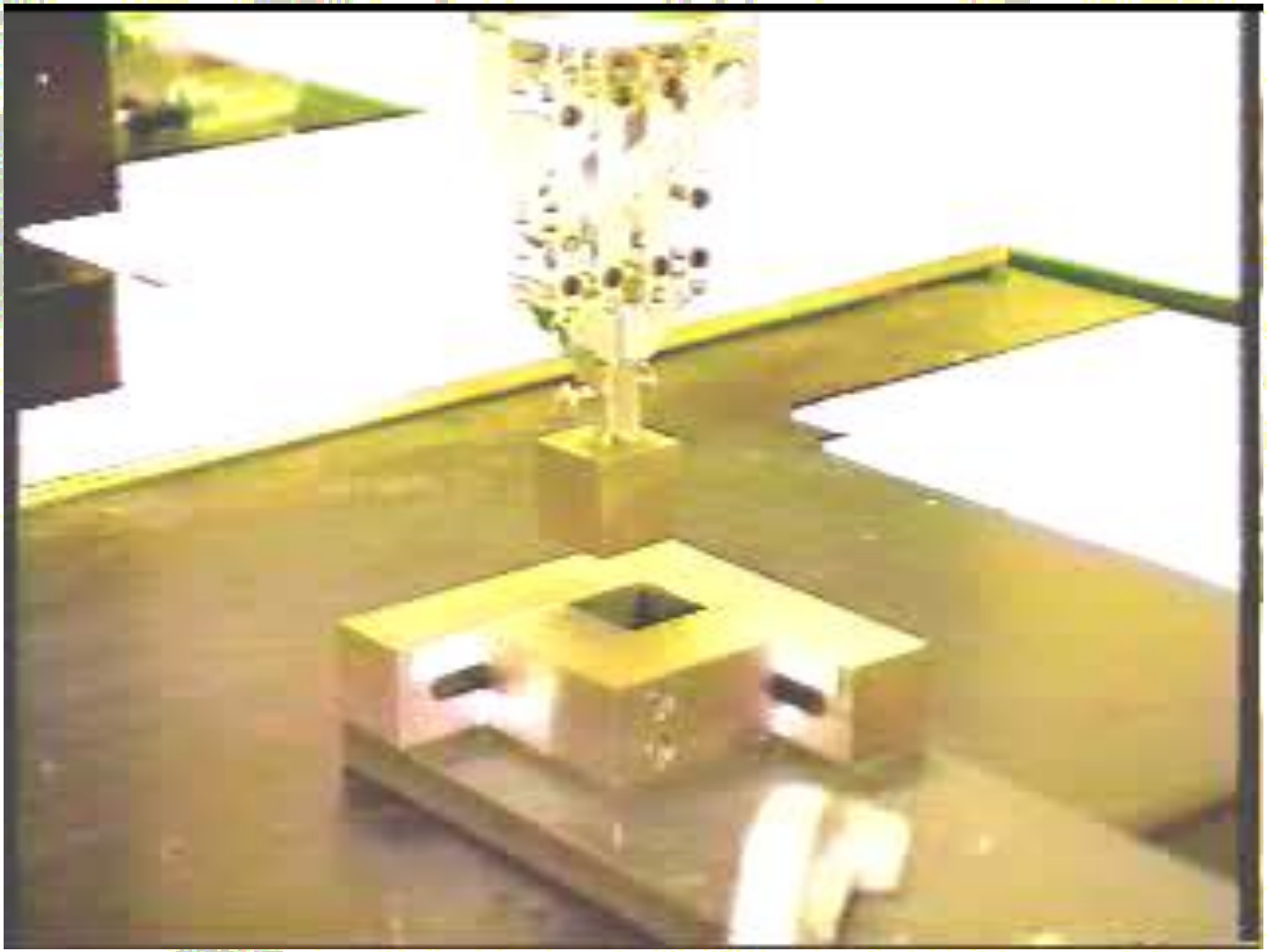


Robot Gripper/End Effector

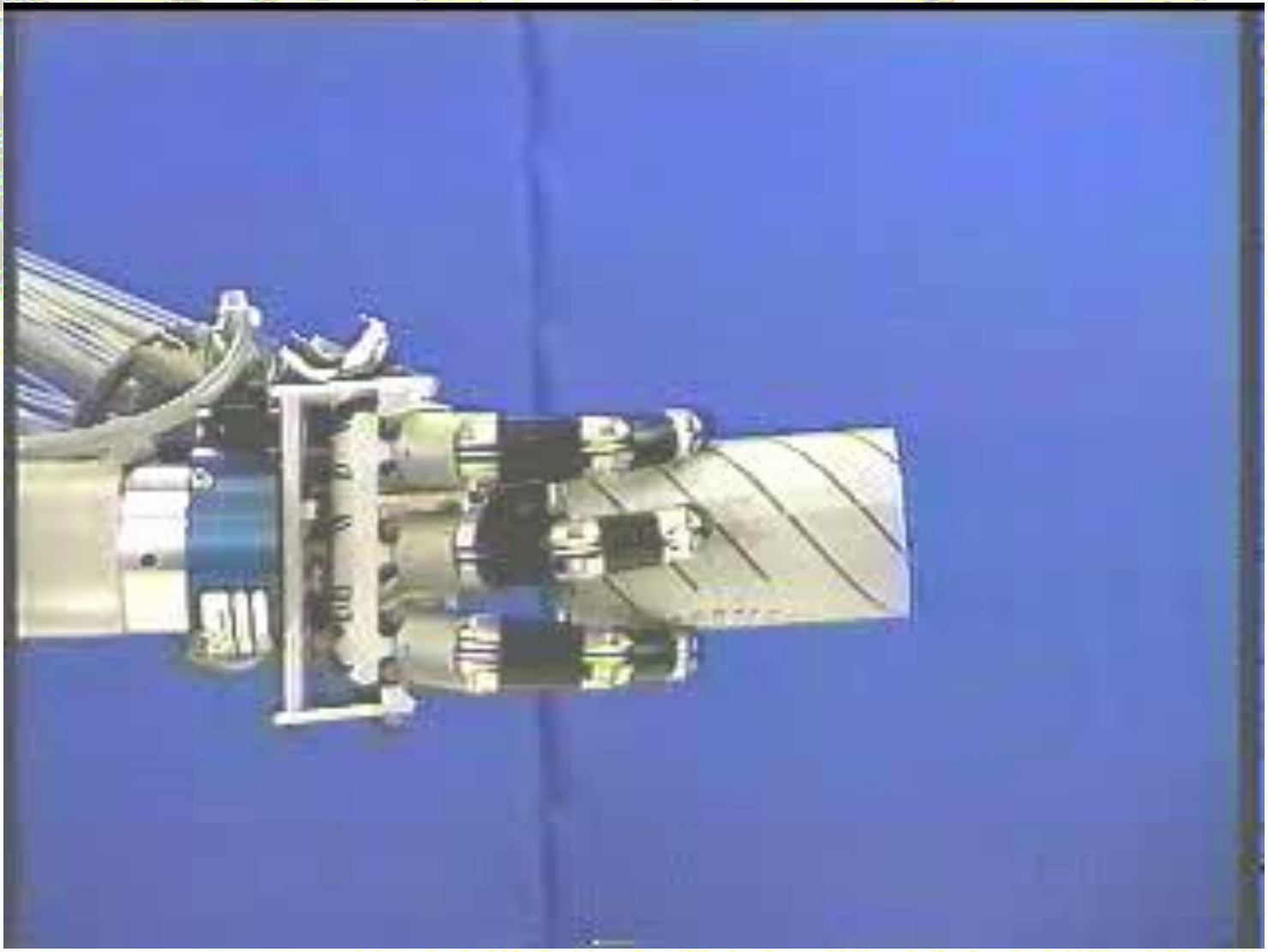




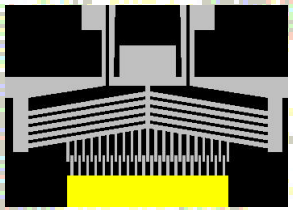
Robot Gripper/End-Effector



Robot Grippers/End Effectors

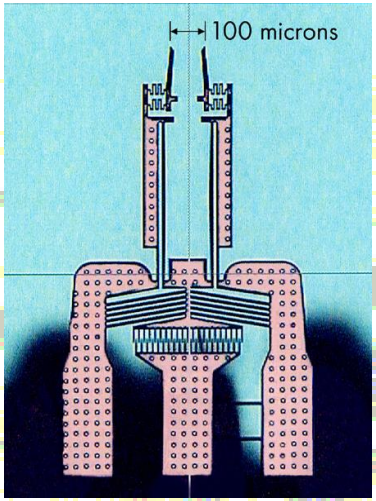


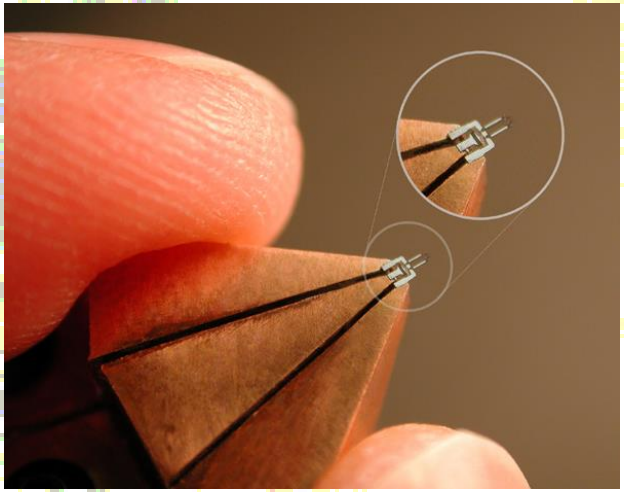
Micro-Grippers for Micro-Assembly

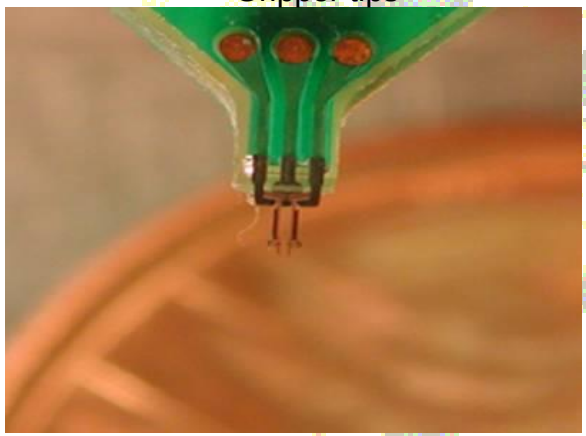


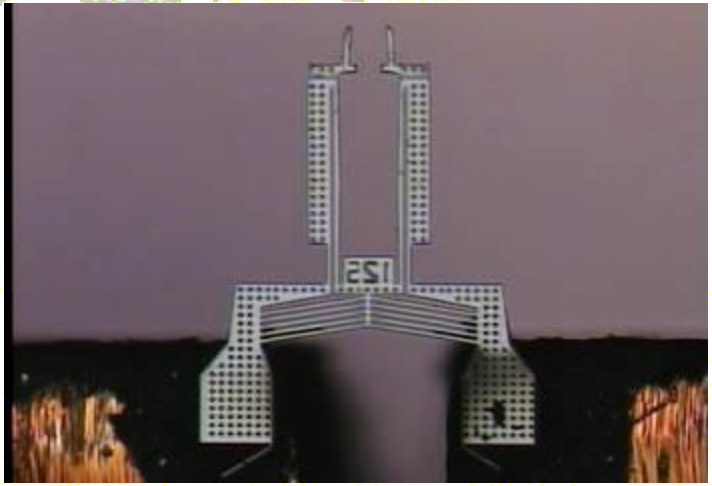
Capacitive force sensor

Gripper tips



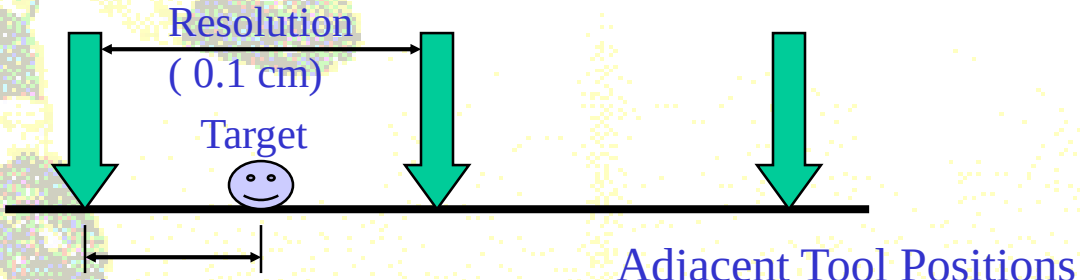




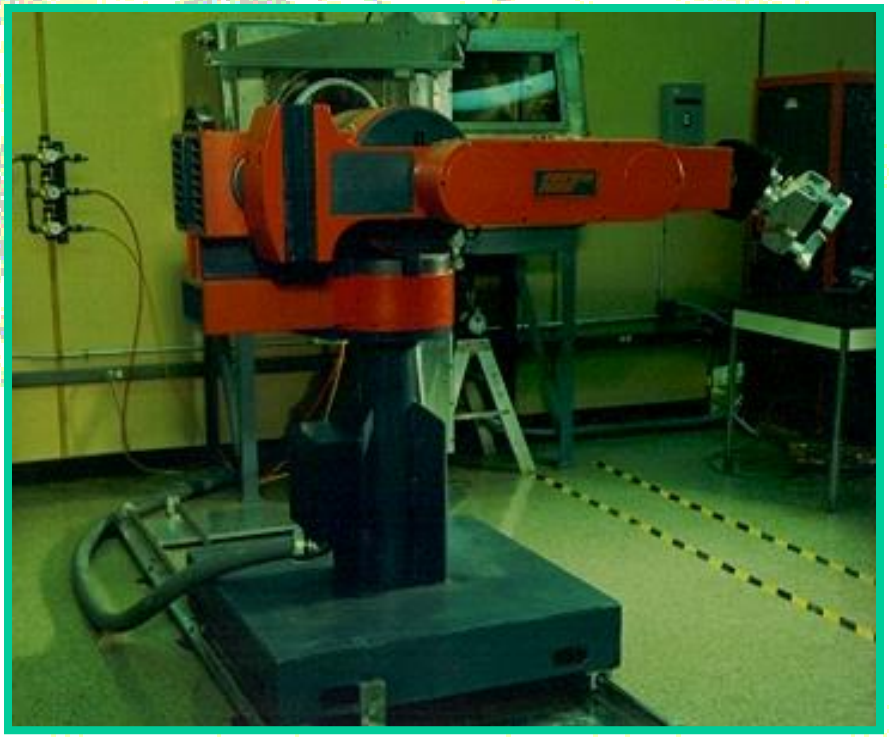


Accuracy, Resolution, and Repeatability

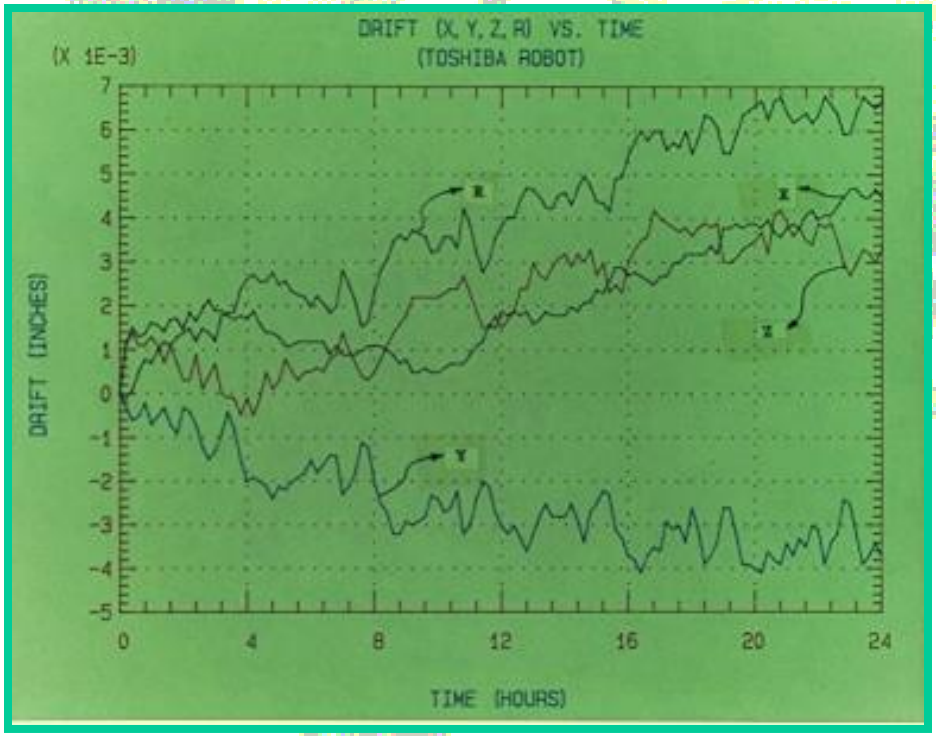
- **Accuracy:** The difference between the point that a robot is trying to achieve and the actual resultant position ≅ ½ Res., depends on backlash in gears and elastic deformations in links.
- **Resolution:** The smallest increment of motion or distance that can be detected or controlled by the control system of a mechanism/robot.
- **Repeatability:** The ability of a system or mechanism to repeat the same motion when presented with the same control signals. The cycle-to-cycle error of a system when trying to perform a specific task. (The precision of a robotic arm in returning to a previously taught position).

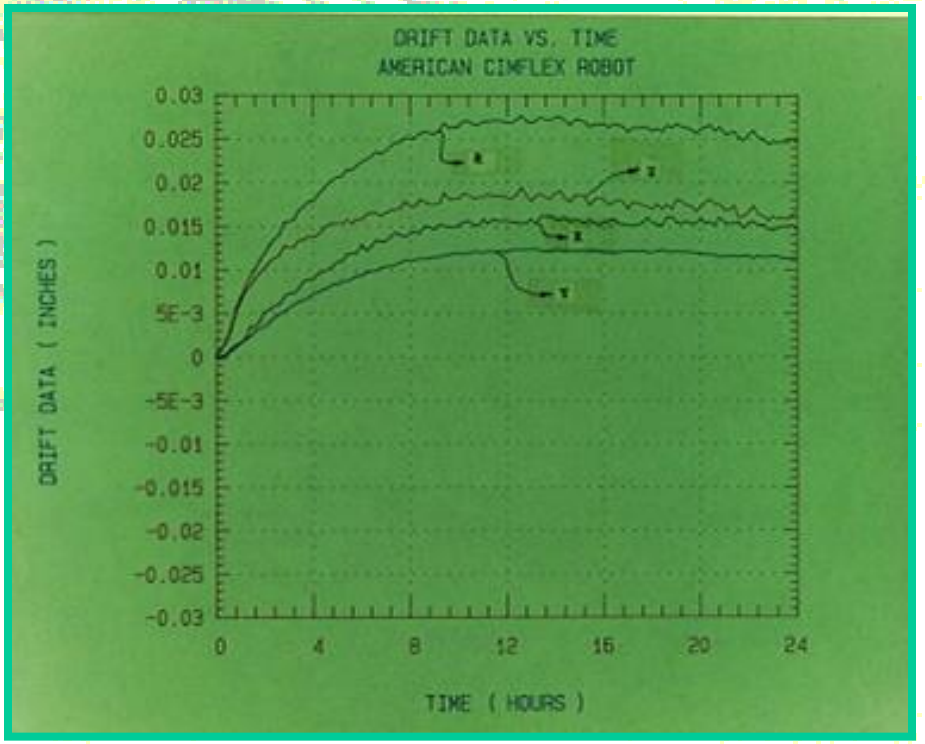


Robotics Group:
Los Alamos National Laboratory



Robotics Accuracy and Repeatability (Drift) Measurement and Analysis



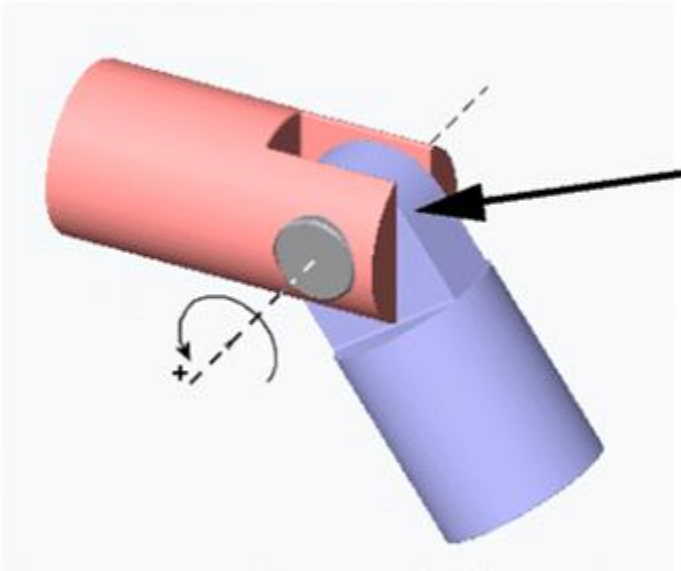


Joints(مفصل)

- A joint is the connection between two or more links at their nodes.
- It constrains the motions of the connected links.
- A joint can be classified as:
  - One-DOF
  - Two-DOF
  - Three-DOF

One-DOF Joint

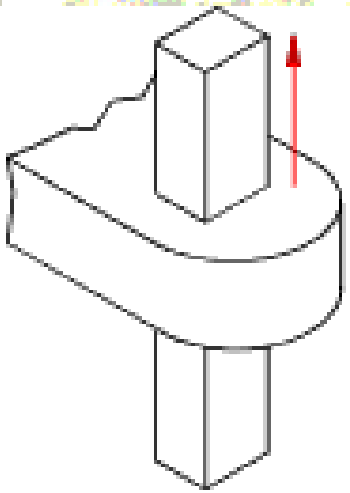
- ***Revolute joint***
- Imposes a rotational motion



- **Symbol R**

One-DOF Joint

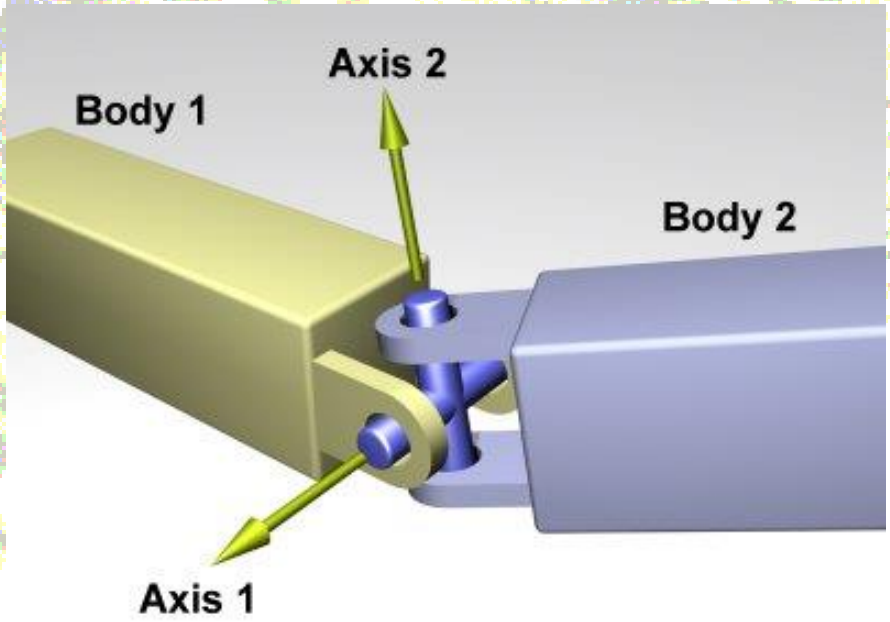
- ***Prismatic joint***
- Imposes a translational motion



- **Symbol: *P***

Two-DOF Joint

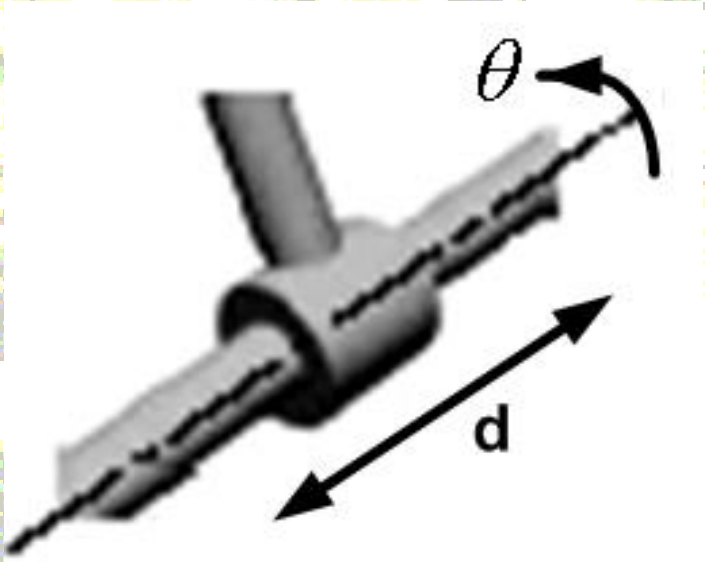
- ***Universal joint***



- **Symbol *U***

Two-DOF Joint

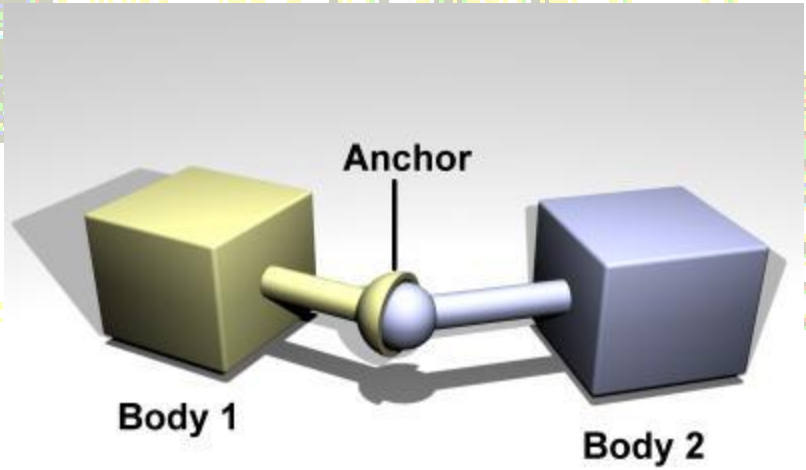
- **Cylindrical *joint***

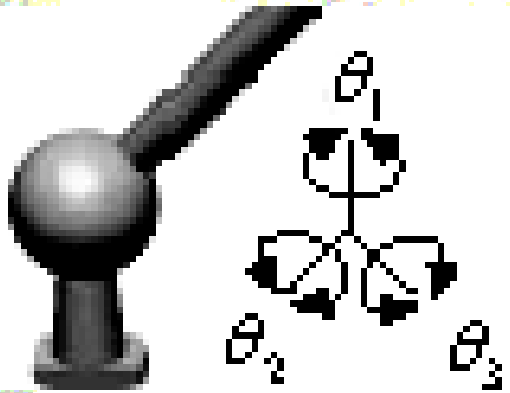


- **Symbol *C***

Three DOF Joint

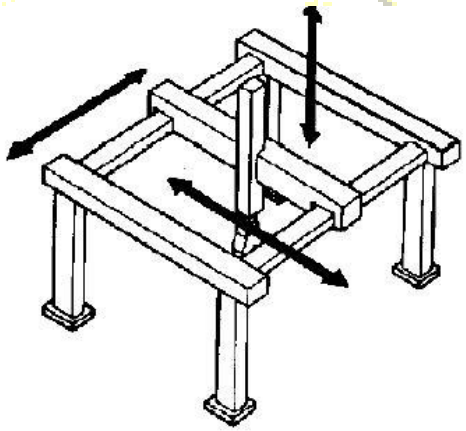
- Ball-and-socket (**spherical joint**)

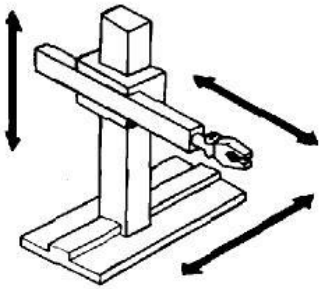


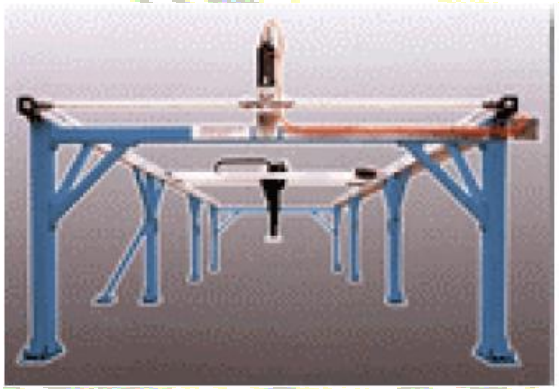


- **Symbol *S***

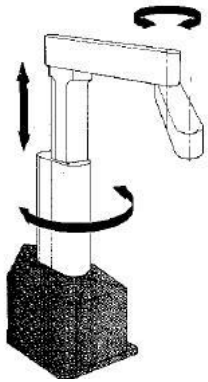
Manipulators

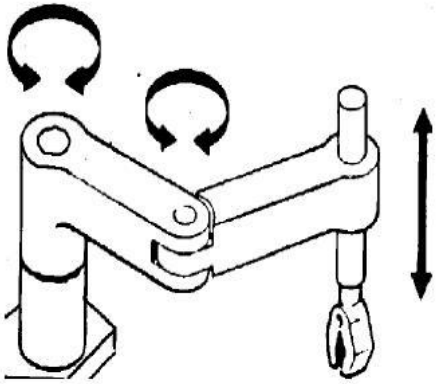


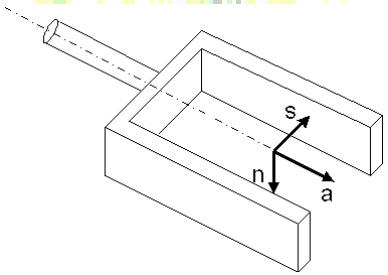




Cartesian: PPP







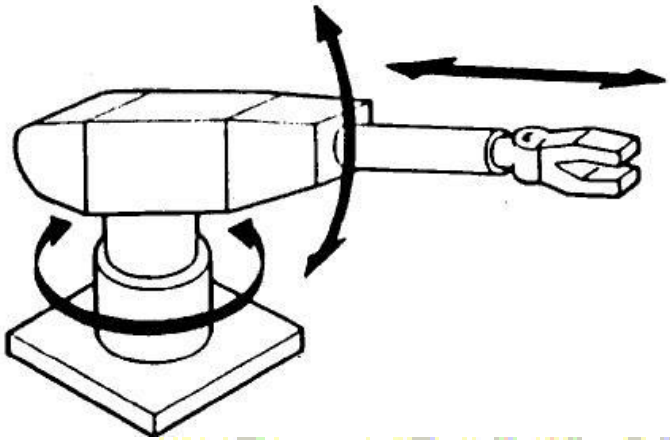
SCARA: RPR, RRP

Hand coordinate:

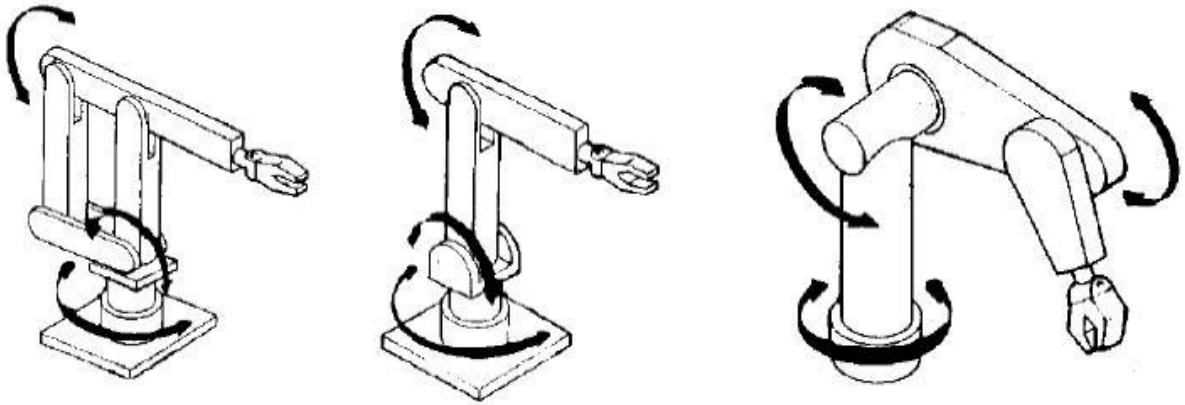
n: normal vector; **s**: sliding vector;

a: approach vector, normal to the tool mounting plate

Manipulators



Spherical: RRP



Articulated: RRR

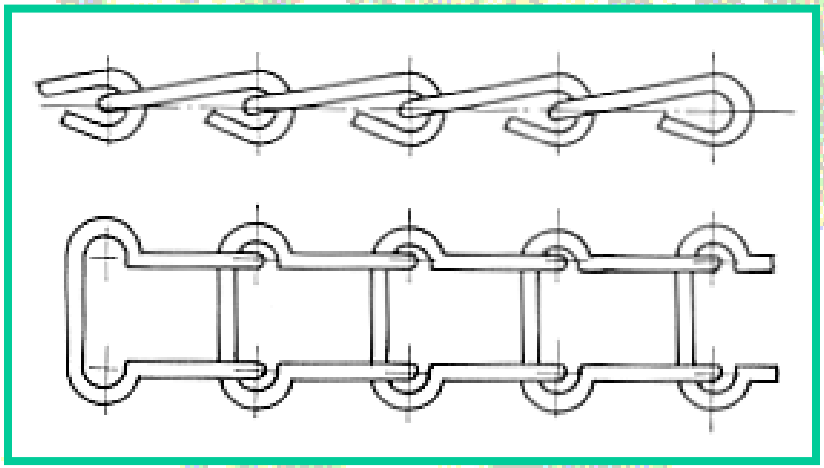
Configuration

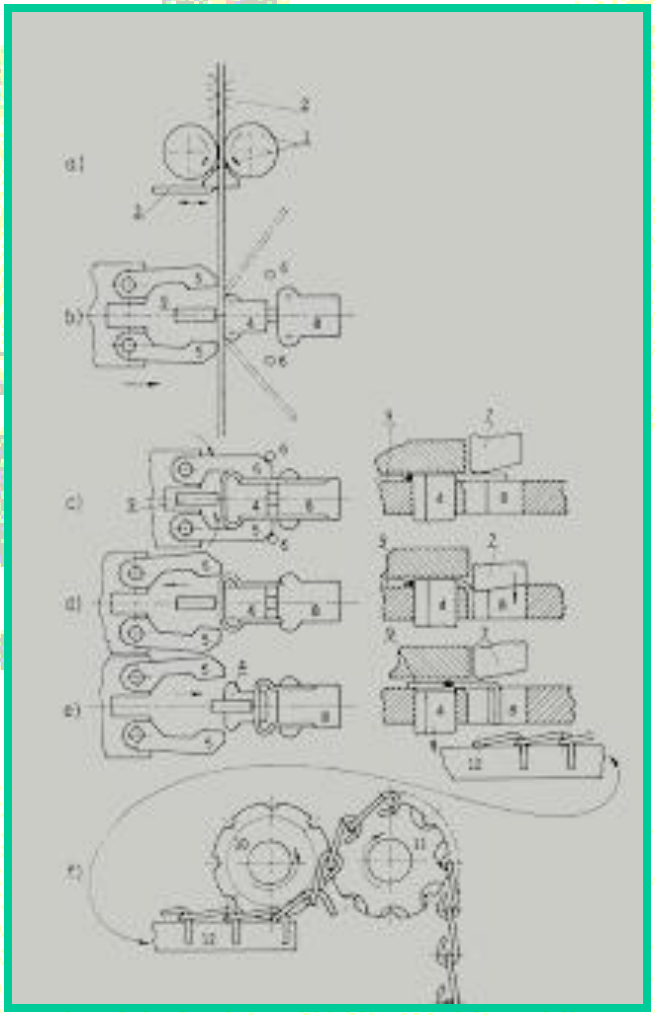
- A ***configuration*** of the manipulator is a complete specification of the location of every point on the manipulator.
- If you know the values for the **joint variable** *(joint angle for revolute joints or joint offset for prismatic joints), it is straightforward to infer the position of any point on the manipulator.*
- *A configuration is represented by a set of values for the joint variable*

Automation: Technology concerned with the use of mechanical, electronic, and computer-based systems in the operation and control of production. (The technique of making a process automatic or self-controlling).

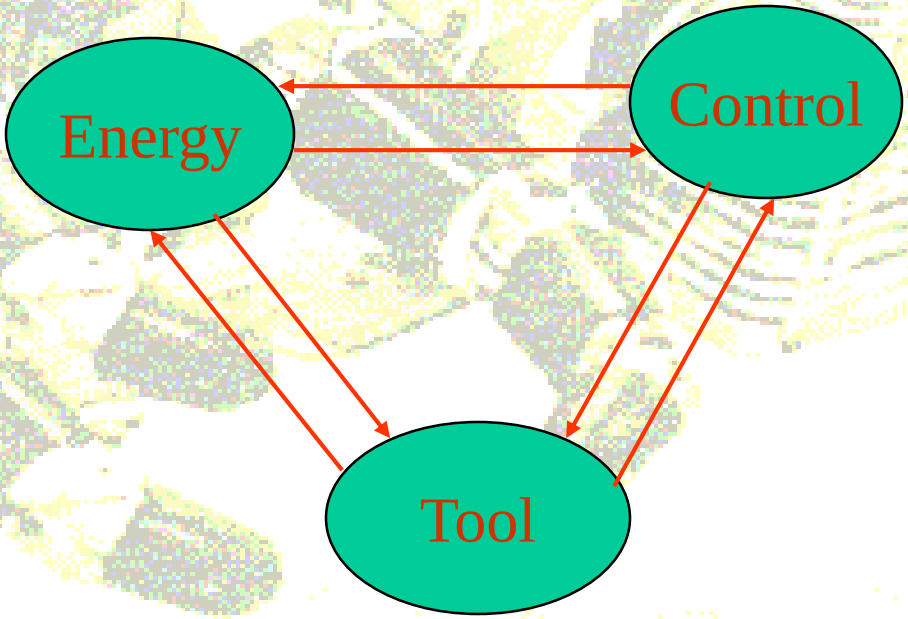
- **Fixed (Hard) Automation**: Specialized machines are designed for high-volume production of parts (i.e. mechanical, electrical, etc.). Can not be adapted (i.e. programmed) to perform variable–type work. (Efficient only when we have mass production $\cong >$ 10000).
- **Programmable Automation**: The production volume is rather low (<1000), and various parts are needed to be produced. Hence, specialized devices are designed to be flexible and adaptable to variations in production. Parts are produced in a batch (group), and when the batch is completed, the system is reprogrammed to produce the next batch. Robots are occasionally used in the production of parts.
- **Flexible (Soft) Automation**: When the production volume is medium (1000 to 10000). Sometimes robots are applied for spot welding, spray painting, material handling, and component assembly. Variation of parts/products is more limited than the programmable automation.

Processing Layout of an Automatic Machine for Manufacturing a Chain

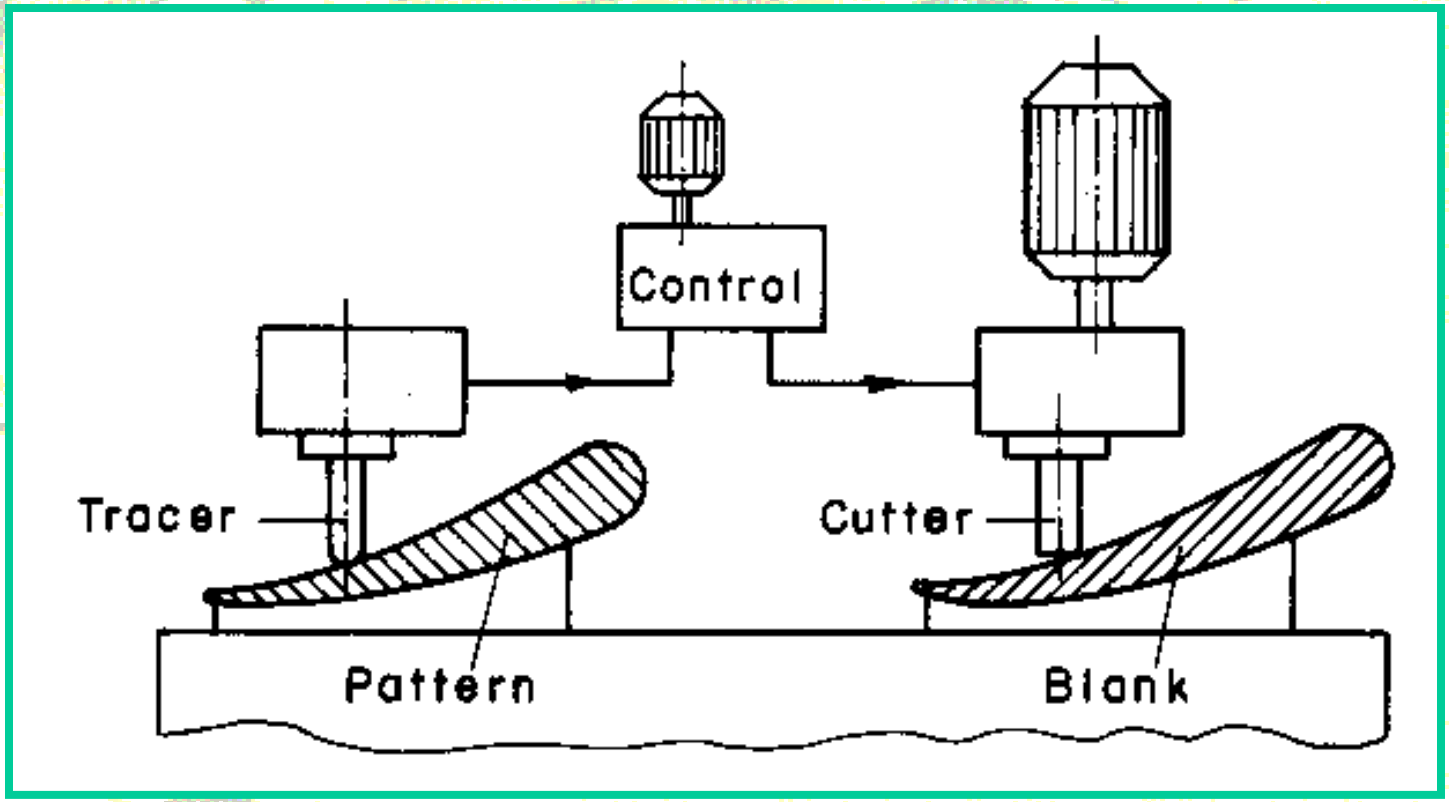




Every instrument used by us can be described in a general form by an Energy Source, a Control Unit, and the Tool that are connected in some way.



Layout of a Tracing System (i.e. key copy instrument)



Robot Subsystems

- **A Mechanical Structure**:
  - For manipulators this structure consists of a set of rigid bodies (**links**), connected by means of articulations (**joints**). Links and joints can also be described in terms of an **arm** (for mobility), a **wrist** (for dexterity) and an **end-effector** (for performing the task).
  - For mobile robots, the structure consists of a chassis with a locomotion mechanism, in the form of legs, wheels, rotor blades, etc.
- **Actuators**: These set the robot in motion through actuation of its joints, and are typical electric, pneumatic or hydraulic.
- **Sensors**: These measure the status of the manipulator (propriceptive sensors) and the status of the environment (heteroceptive sensors).
- **A control system**: This enables control and supervision of the robot, and is usually a computer with a graphical user interface, and/or a teach pendant.