Robotics

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Topics covered :

- **Part 1 Manipulators**
  1. Spatial descriptions and transformations
  2. Manipulator kinematics
  3. Inverse manipulator kinematics
  4. Jacobians: Velocities and static forces
  5. Manipulator dynamics and Trajectory generation

- **Part II Mobile robots**
  1. Introduction
  2. Locomotion and sensors
  3. kinematics

What is a robot?

- Many different definitions for robots exist.

- A robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks." (Robot Institute of America).

Automation vs. robots

Automation: Machinery designed to carry out a specific task

-Bottling machine

-Dishwasher

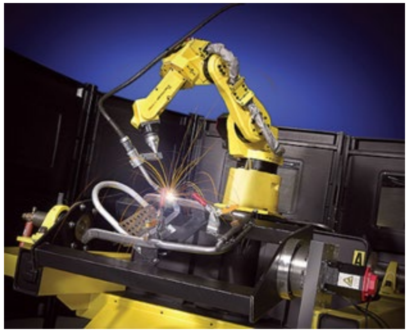
Robots: machinery designed to carry out a variety of tasks

-Pick and place arms

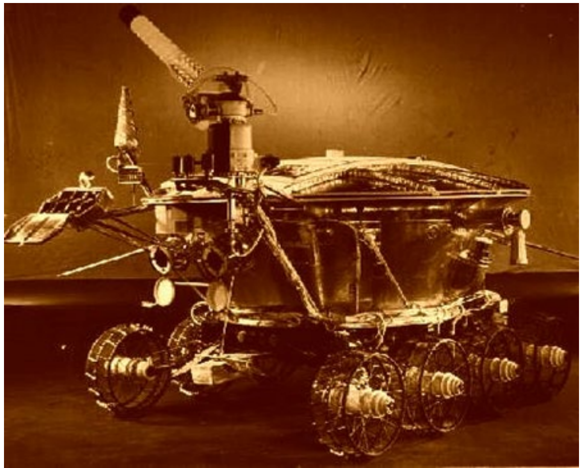
-Mobile robots

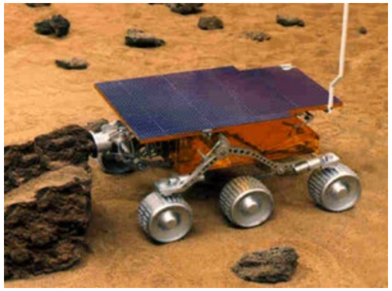
Robots Classification

- Manipulators: robotic arms. These are most commonly found in industrial settings. https://www.jabil.com/blog/ten-popular-industrial-robot-applications.html



- Mobile Robots: unmanned vehicles
- Hybrid Robots: mobile robots with manipulators
- Humanoid robot https://www.bostondynamics.com/atlas





Applications

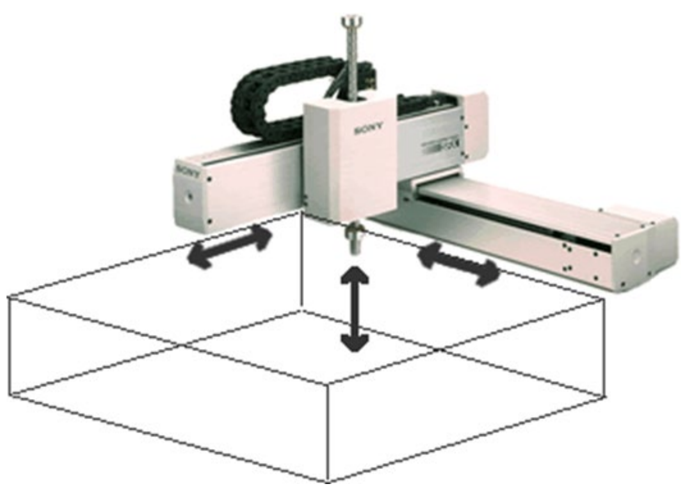
Dangerous:
-Space exploration
-chemical spill cleanup
-disarming bombs
-disaster cleanup

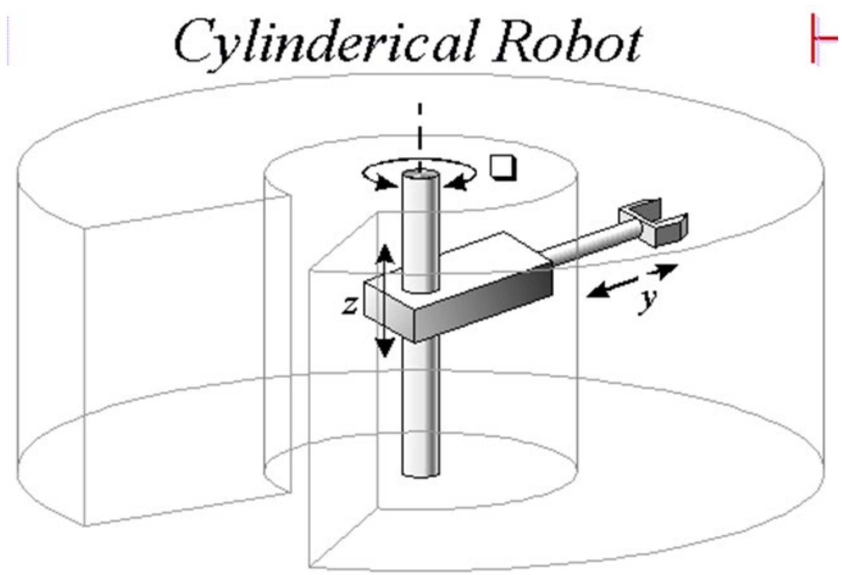
Repetitive
-Welding car frames
-part pick and place
-manufacturing parts.

High precision or high speed
-Electronics chips
-Surgery
-precision machining

Measures of performance

- Work space
  - The space within which the robot operates.
  - Larger volume costs more but can increase the capabilities of a robot





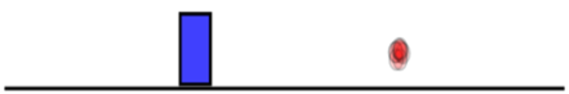
Measures of performance

- Speed and acceleration
- ➢ Faster speed often reduces resolution or increases cost
- ➢ Varies depending on position, load.
- ➢ Speed can be limited by the task the robot performs (welding, cutting)

Measures of performance

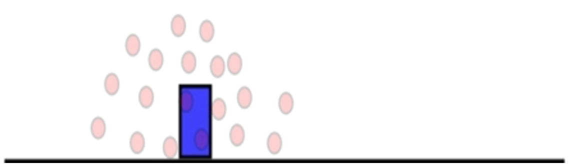
- Accuracy

➢The difference between the actual position of the robot and the programmed position

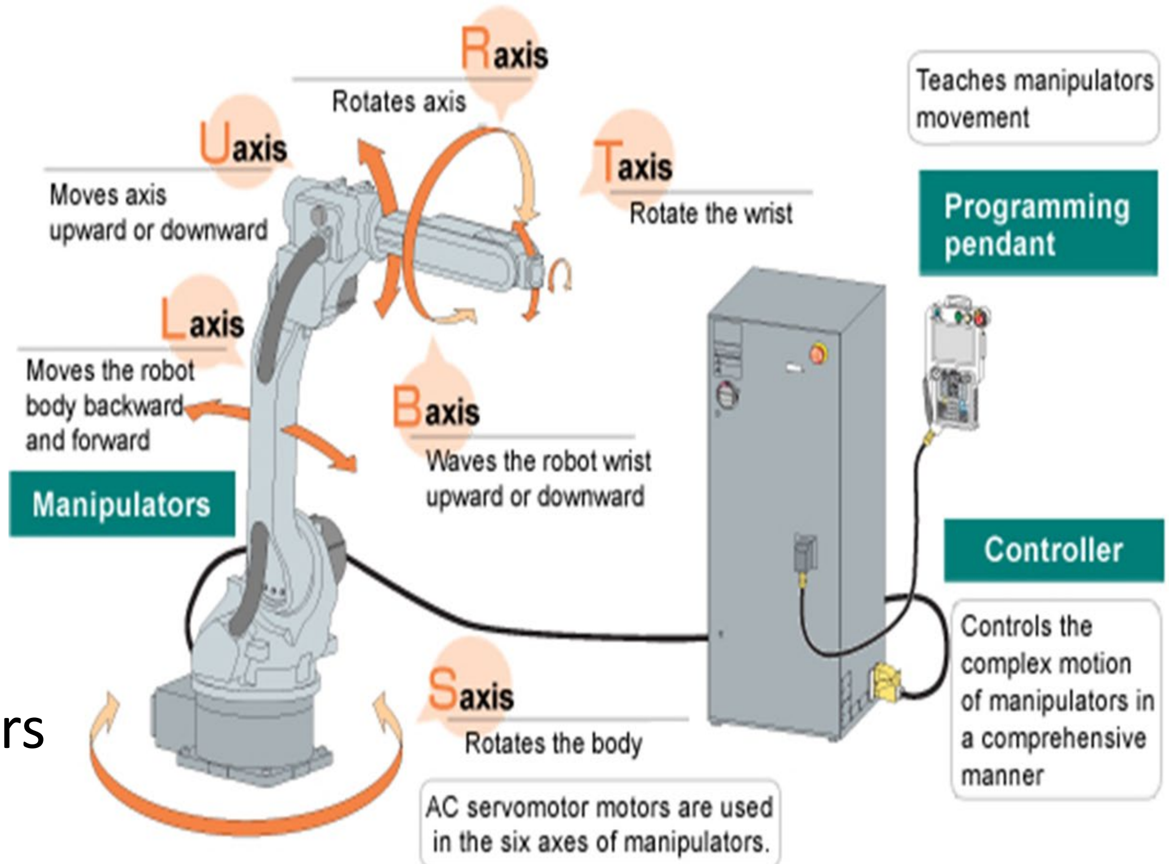


- Repeatability

➢Will the robot always return to the same point under the same conditions?



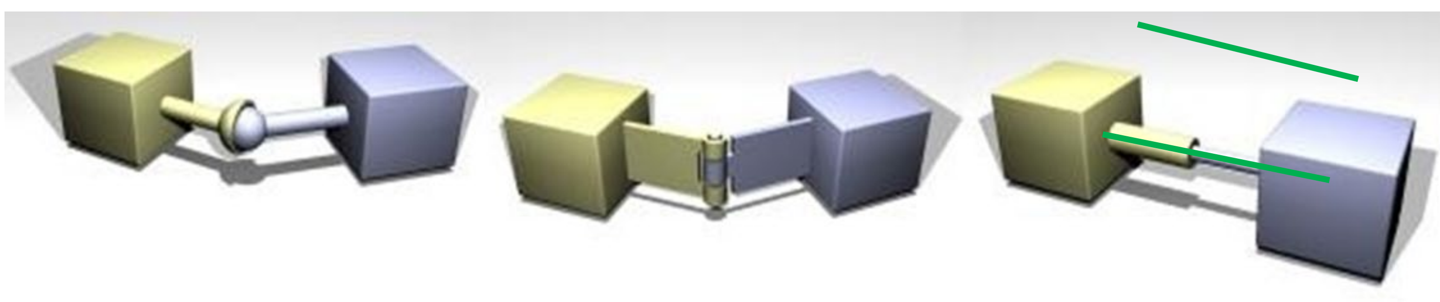
Robot Components



- Body
- End Effectors
- Actuators
- Sensors
- Controller
- Software

Robot: Body

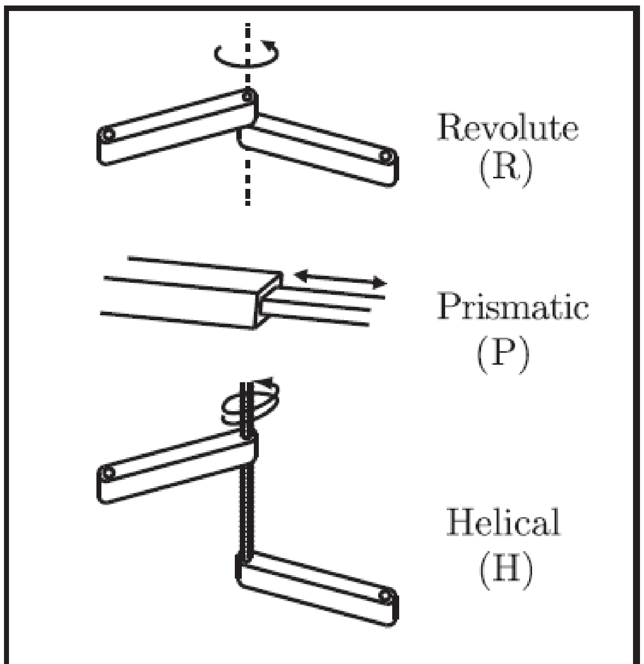
- Consists of links and joints
- A link is a part, a shape with physical properties.
- A joint is a constraint on the spatial relations of two or more links.
- These are just a few examples…

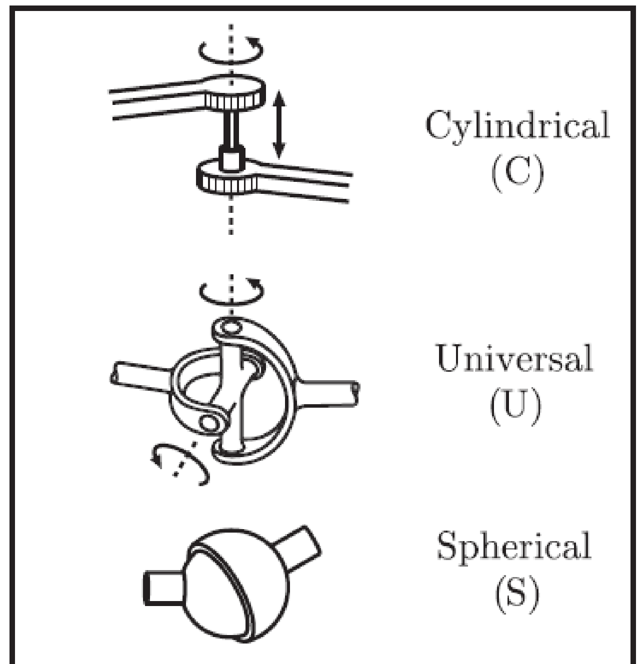


Ball joint | Revolute (hinge) joint | Prismatic (slider) joint

Degrees of Freedom

- Joints constraint free movement, measured in "Degrees of Freedom" (DOFs).
- Joints reduce the number of DOFs by constraining some translations or rotations.
- Robots classified by total number of DOFs





Degrees of Freedom

Joint type	dof f	Constraints c between two planar rigid bodies	Constraints c between two spatial rigid bodies
Revolute (R)	1	2	5
Prismatic (P)	1	2	5
Helical (H)	1	N/A	5
Cylindrical (C)	2	N/A	4
Universal (U)	2	N/A	4
Spherical (S)	3	N/A	3

Grübler's formula for the number of degrees of freedom of the robot is

$$\begin{aligned}\text{dof} &= \underbrace{m(N-1)}_{\text{rigid body freedoms}} - \underbrace{\sum_{i=1}^{J} c_i}_{\text{joint constraints}} \\ &= m(N-1) - \sum_{i=1}^{J}(m - f_i) \\ &= m(N-1-J) + \sum_{i=1}^{J} f_i.\end{aligned}$$

N links
J the number of joints
m be the number of degrees of freedom of a rigid body (m = 3 for planar mechanisms and m = 6 for spatial mechanisms)
fi be the number of freedoms provided by joint **i**

Degrees of Freedom: example

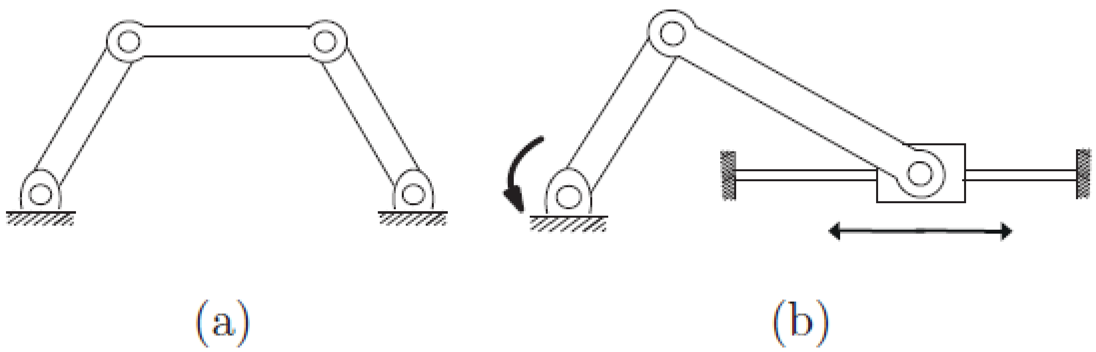


Figure 2.4: (a) Four-bar linkage. (b) Slider–crank mechanism.

Example 2.3 (Four-bar linkage and slider-crank mechanism). The planar four bar linkage shown in Figure 2.4(a) consists of four links (one of them ground) arranged in a single closed loop and connected by four revolute joints.

Degrees of Freedom: example

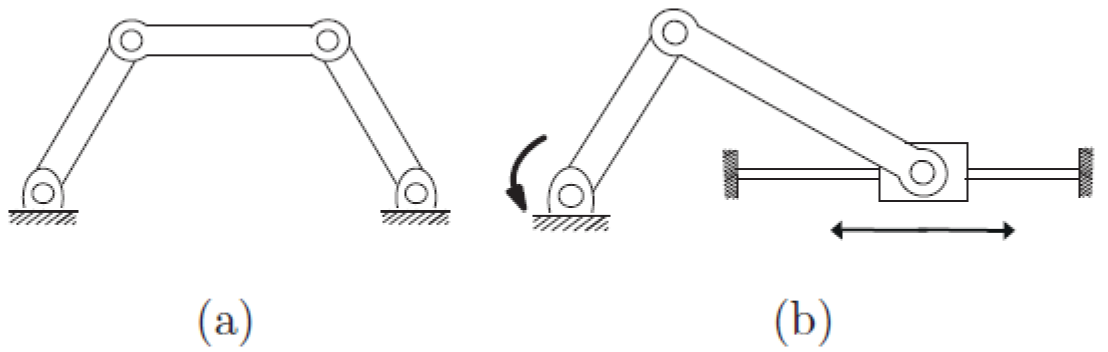


Figure 2.4: (a) Four-bar linkage. (b) Slider–crank mechanism.

DOF= $m(N-1-J)+\sum_{i=1}^{J} f_i.$

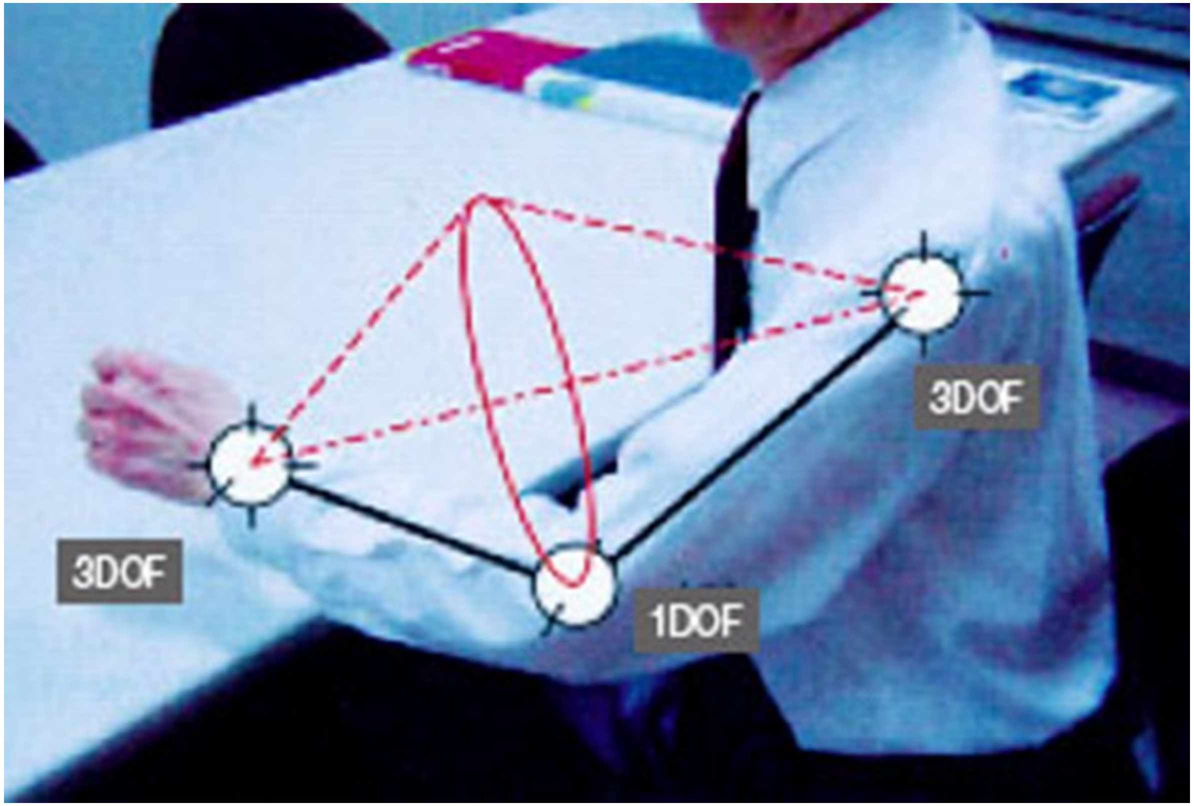
Since all the links are conned to move in the same plane, we have m = 3. Substituting N = 4, J = 4, and f_i = 1, i = 1; 4, into Grubler's formula,

DOF= 3(4-1-4)+4=3(-1)+4=1 (one DOF)

What about figure(b)?

Degrees of Freedom

How many DOFs can you identify in your arm?



Robot: End Effectors

- Component to accomplish some desired physical function
- Examples:
  - ✓ Hands
  - ✓ Torch
  - ✓ Wheels
  - ✓ Legs

Robot: Actuators

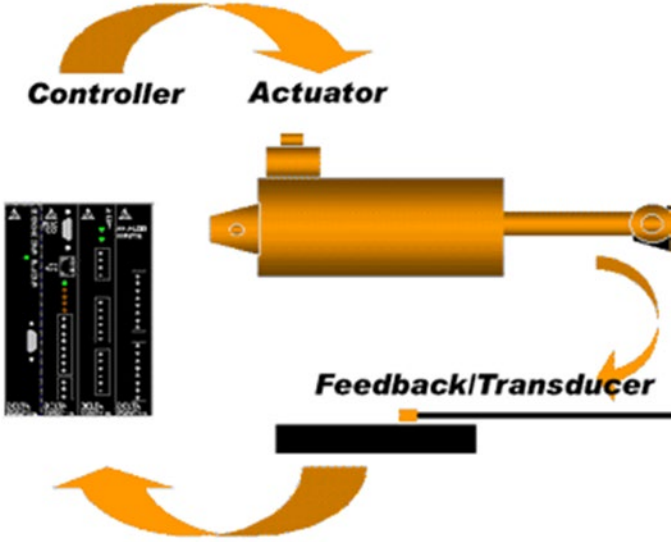
- Actuators are the “muscles” of the robot.
- These can be electric motors, hydraulic systems, pneumatic systems, or any other system that can apply forces to the system.

Robot: Sensors

- Rotation encoders
- Cameras
- Pressure sensors
- Limit switches
- Optical sensors
- Sonar

Robot: Controller

- Controllers direct a robot how to move.
- There are two controller paradigms
  - Open-loop controllers execute robot movement without feedback.
  - Closed-loop controllers execute robot movement and judge progress with sensors. They can thus compensate for errors.

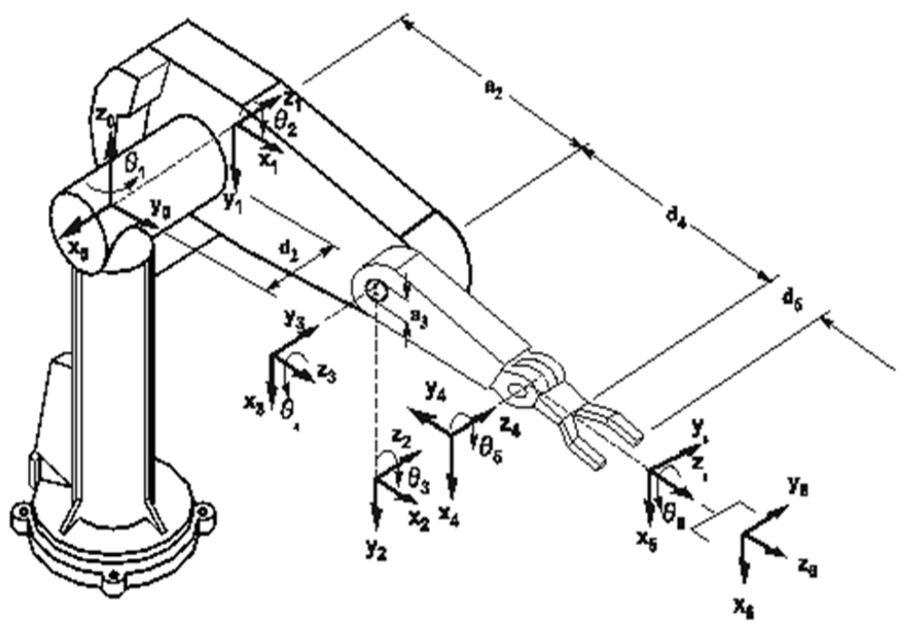


Kinematics

- Kinematics is the study of motion without regard for the forces that cause it.
- It refers to all time-based and geometrical properties of motion.
- It ignores concepts such as torque, force, mass, energy, and inertia.

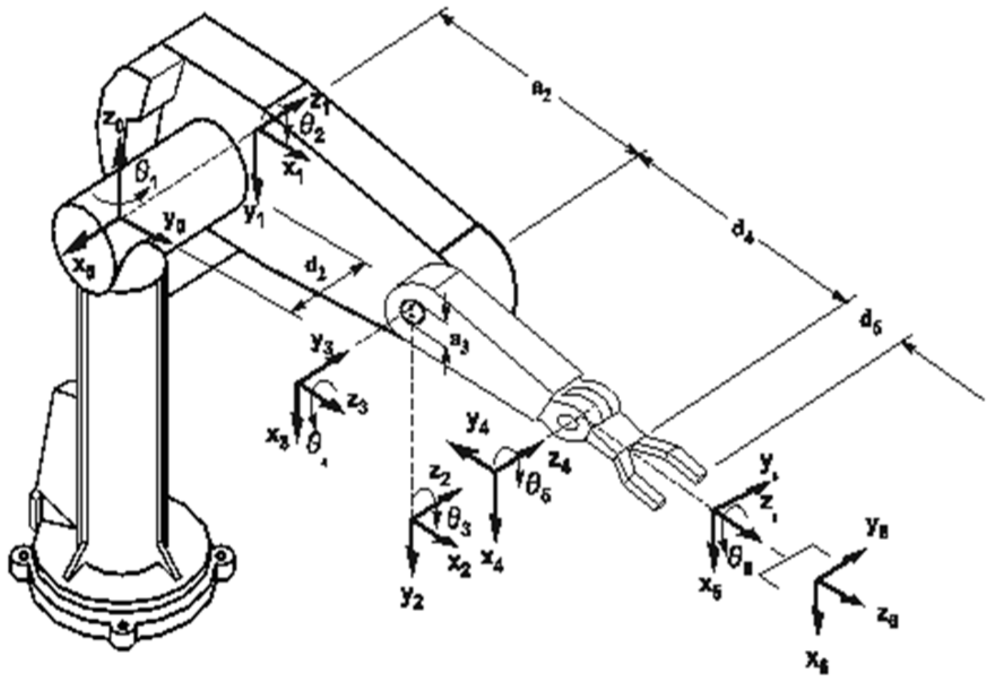
Forward Kinematics

- For a robotic arm, this would mean calculating the position and orientation of the end effector given all the joint variables.



Inverse Kinematics

- Inverse Kinematics is the reverse of Forward Kinematics.
- It is the calculation of joint values given the positions, orientations, and geometries of mechanism's parts.
- It is useful for planning how to move a robot in a certain way.



Dynamics

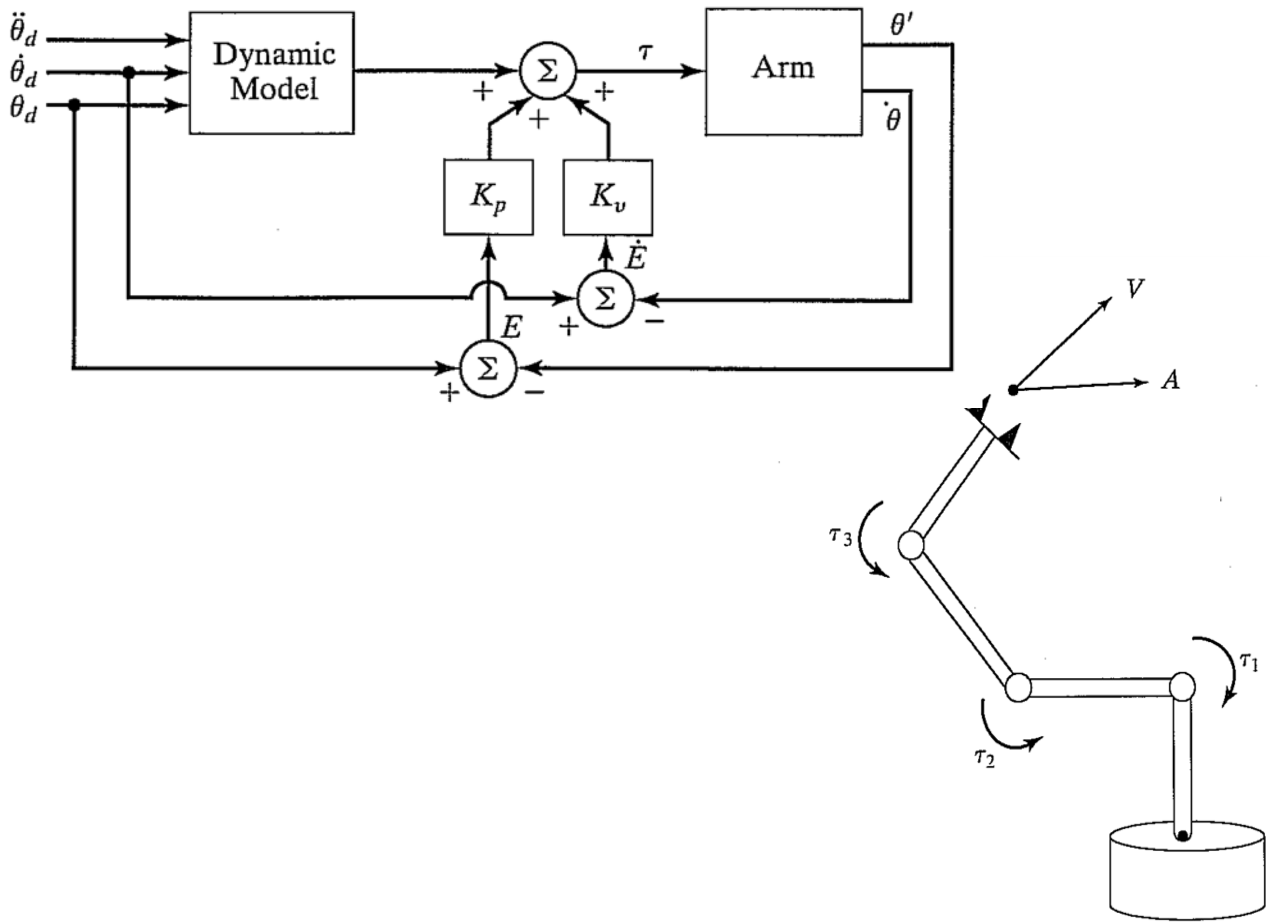
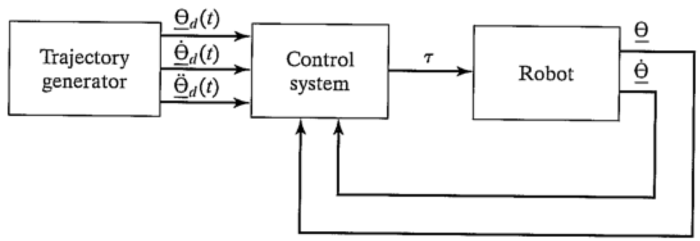


FIGURE 1.10:The relationship between the torques applied by the actuators and the resulting motion of the manipulator is embodied in the dynamic equations.

Trajectory generating



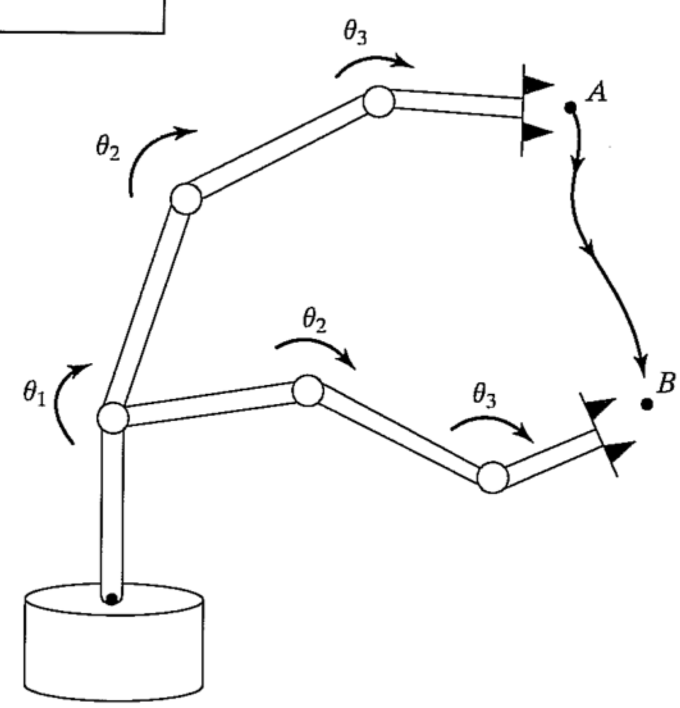


FIGURE 1.11:In order to move the end-effector through space from point A to point B , we must compute a trajectory for each joint to follow.

Position Control

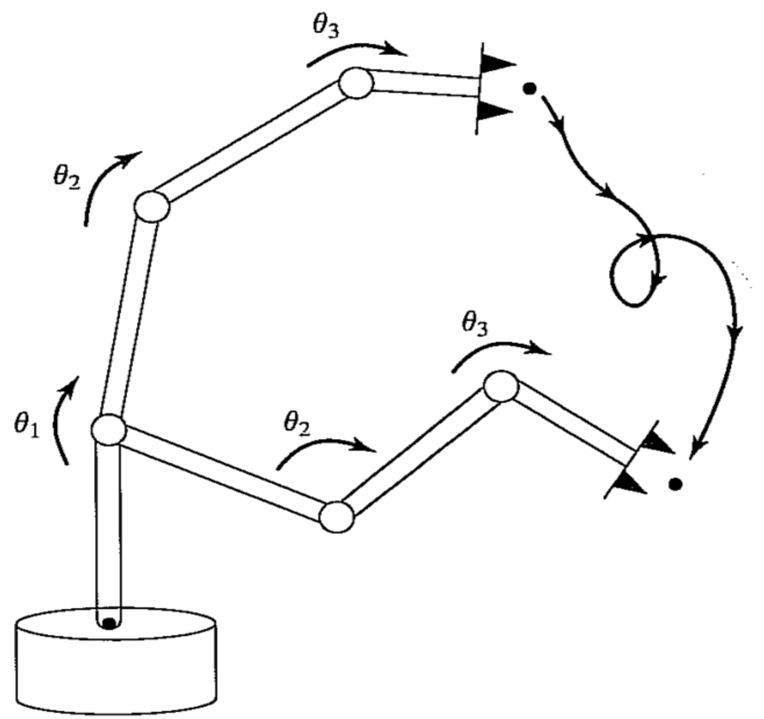


FIGURE 1.13: In order to cause the manipulator to follow the desired trajectory , a position-control system must be implemented. Such a system uses feedback from joint sensors to keep the manipulator on course.

Force Control

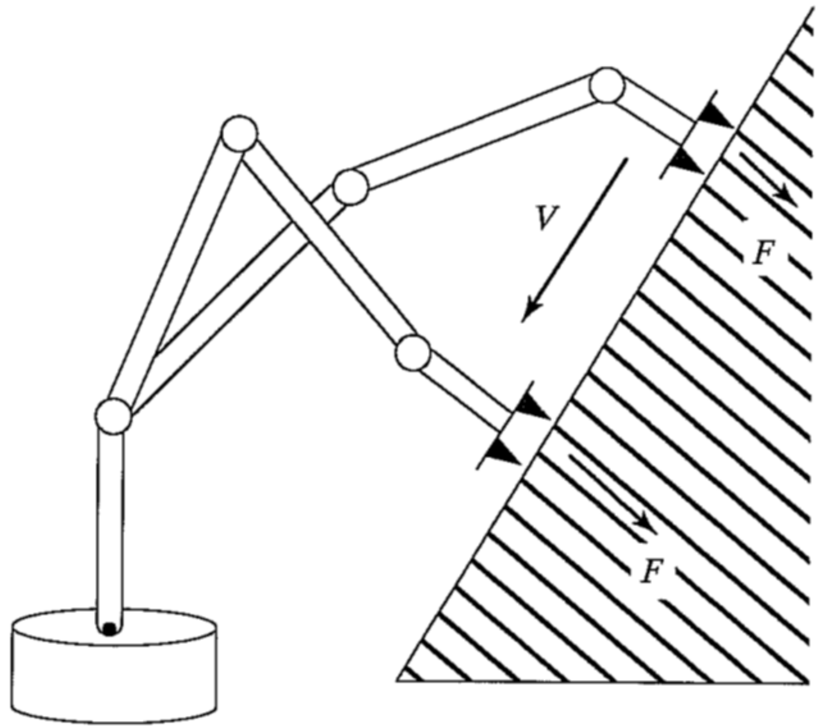
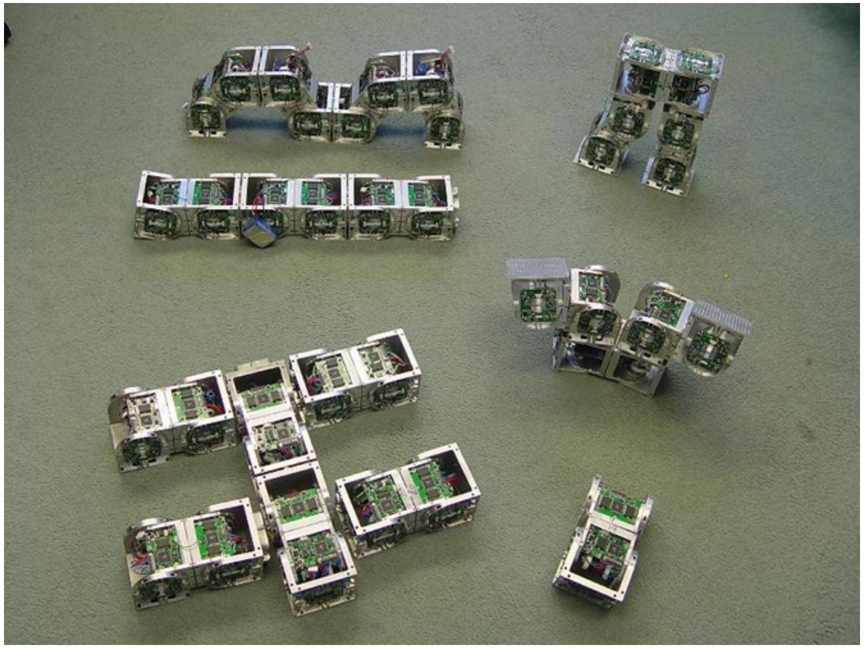


FIGURE 1.14: In order for a manipulator to slide across a surface while applying a constant force , a hybrid position-force control system must be used.

New direction

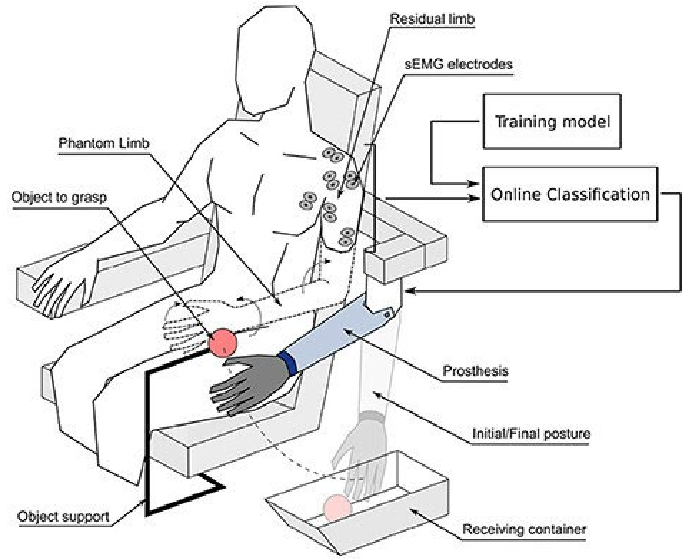
- Nanobots

Powered exoskeleton



- Reconfigurable Robot

Powered exoskeleton (Robotic suit) and robotics prosthetic limb



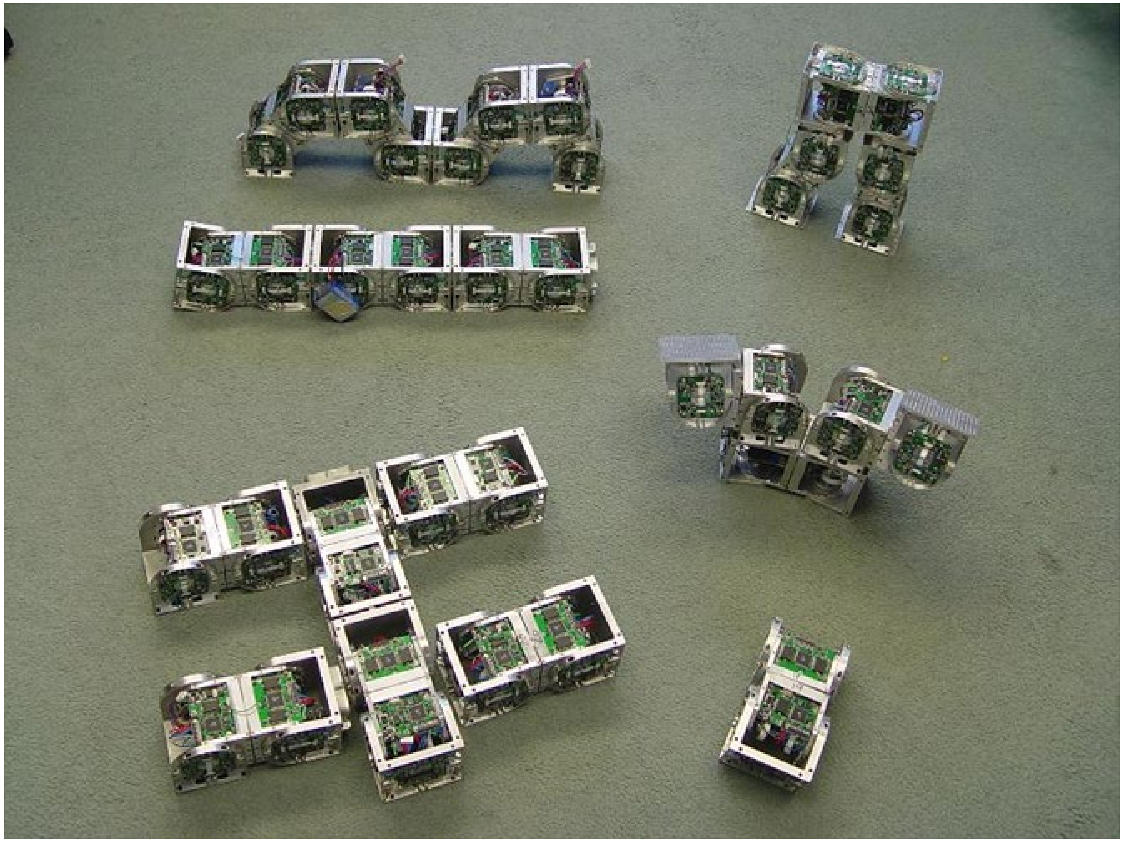
https://www.weforum.org/agenda/2018/12/a-new-prosthetic-arm-takes-the-place-of-a-phantom-limb

hybrid assistive limb
https://youtu.be/RCWw6LSuRCo?t=17

- Nanobots

https://edition.cnn.com/videos/tv/2015/01/29/spc-make-create-innovate-nanobots.cnn

- Reconfigurable Robot



https://www.wevolver.com/wevolver.staff/superbot/