Introduction to Robotics

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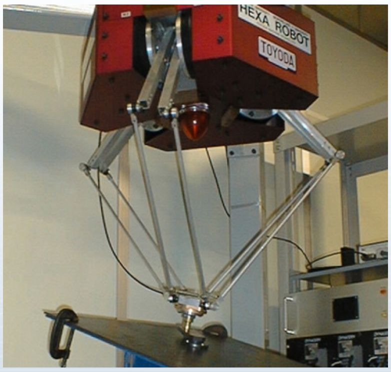
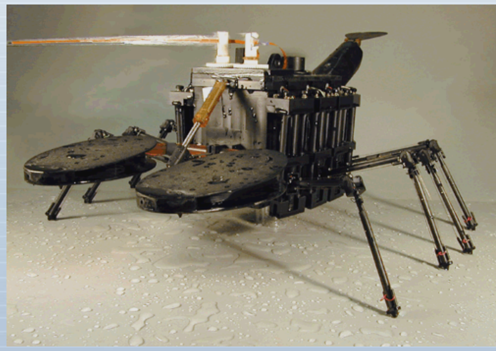
What is Robot ?

Robots in our Imagination

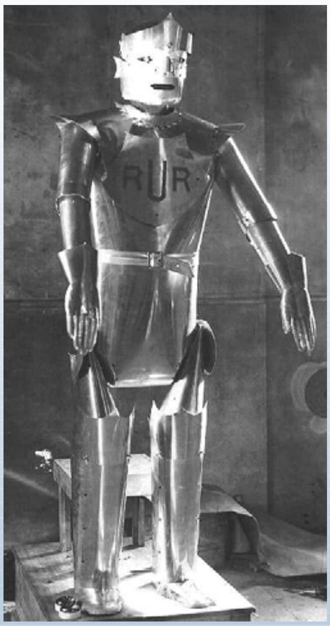
What is Robot Like in Our Real Life ?





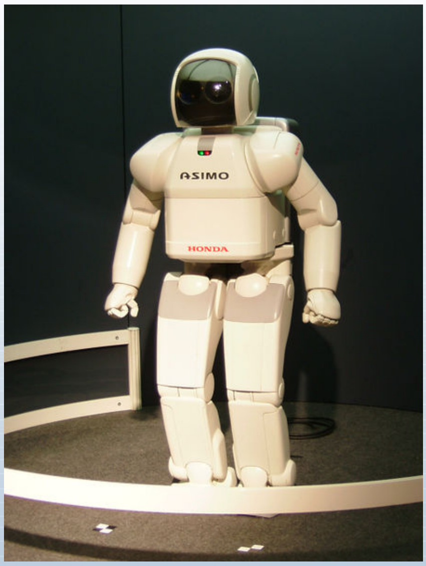
Origin of the Term ROBOT

- The term "robot" was first introduced by the Czech playwright ***Karel Capek*** in his 1920 play *Rossum's Universal Robots*.
- The word *robota* being the Czech word for work.



Definition of a Robot from Wikipedia

- A robot is a mechanical device that can perform preprogrammed physical tasks. A robot may act under the direct control of a human (eg. the robotic arm of the space shuttle) or autonomously under the control of a pre-programmed computer. Robots may be used to perform tasks that are too dangerous or difficult for humans to implement directly (e.g. the space shuttle arm) or may be used to automate repetitive tasks that can be performed more cheaply by a robot than by the employment of a human (e.g. automobile production).
- The word robot is also used to describe an intelligent mechanical device in the form of a human. This form of robot (culturally referred to as androids) is common in science fiction stories. However, such robots are yet to become common-place in reality and much development is yet required in the field of artificial intelligence before they even begin to approach the robots of science fiction.



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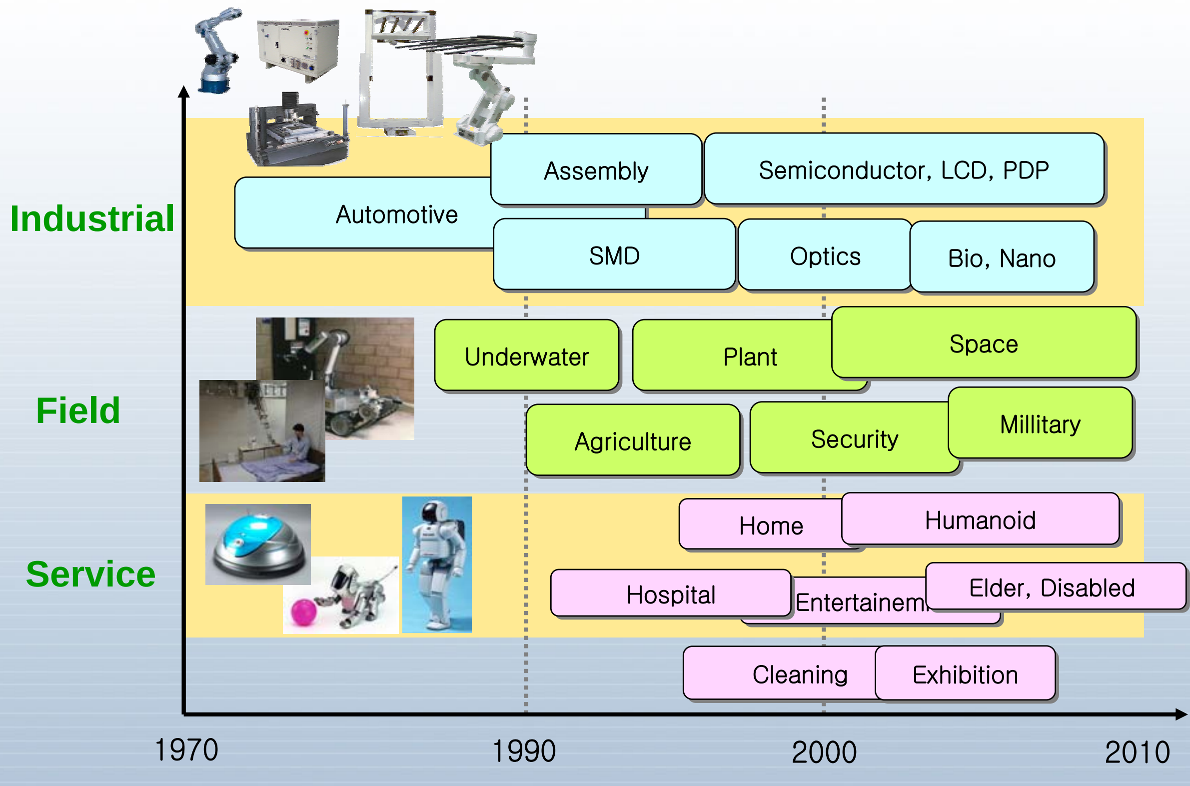
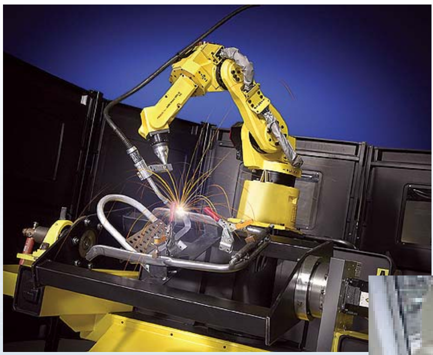
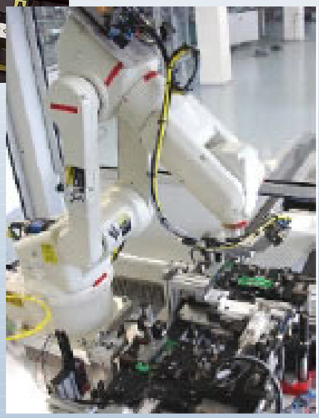
Application Areas of Robots



Industrial Robots



Welding



Assembling

LCD Transfer

Painting

Field Robots: Surgery and Exploration

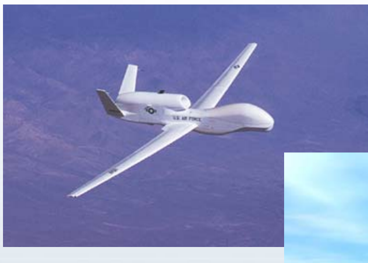
MIS

Exploration

Undewater

Mars Exploration

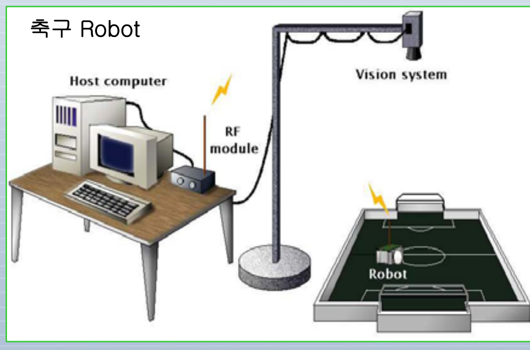
Filed Robots: Military



Service Robots: Entertainment

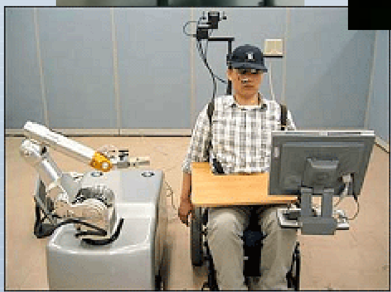
Sony AIBO

Pubby(미)



Service Robots: Elder and Disabled People

경비용



노약자 보조용

청소용

가정용 교육/서비스

Types of Robots

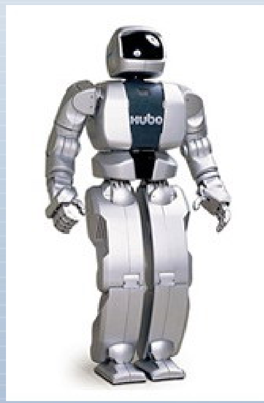
Serial Type

Mobile Type

Parallel Type

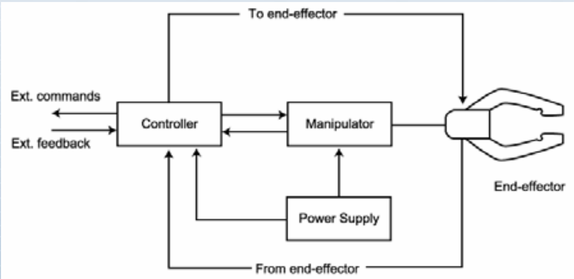
Fig. 1: Motion base by Hydra-Power Systems, Inc.

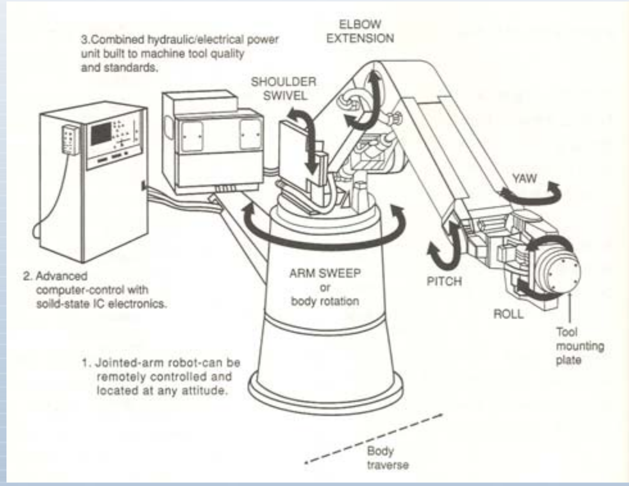
Walking Type



Elements of Robot

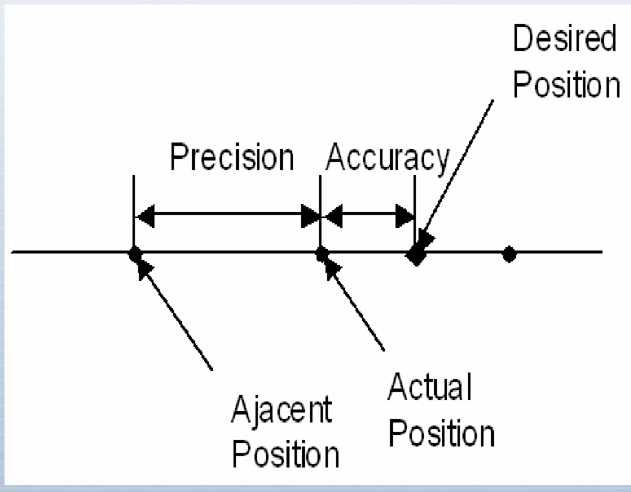
- manipulator
- end effectors, Gripper
- power supply
- controller





Teminologies

- **Accuracy:** How well a robot can move to an arbitrary point in space
- **Precision:** The smallest increment with which a robot can be positioned.

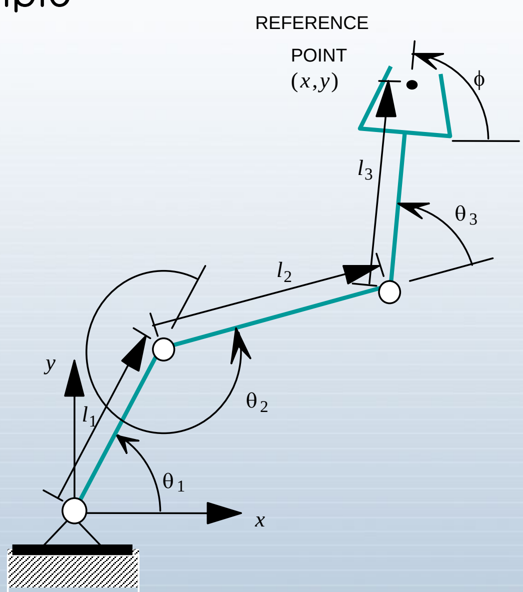


Teminologies

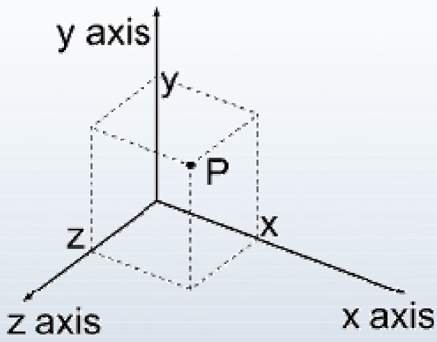
- **Repeatability:** How well a robot can return to the same point.
- **Workspace:** A volume of space which the end-effector of the manipulator can reach
  - **Dexterous workspace** is the volume of space which the robot can reach with all orientations. That is, at each point in the dexterous workspace, the end-effector can be arbitrarily oriented.
  - **The reachable workspace** is the volume of space which the robot can reach in at least one orientation

Serial Type Robot

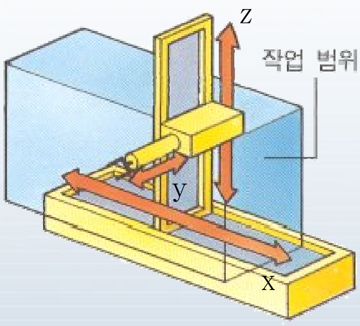
- Structure : Open Chain, Simple
- Accuracy : Low
- Payload : Low
- Workspace : Large



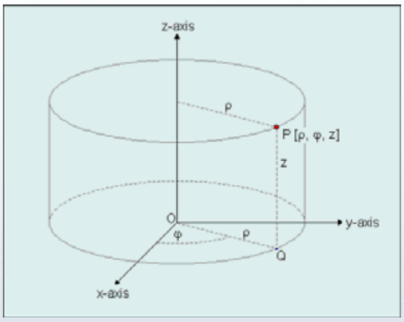
Cartesian Robot



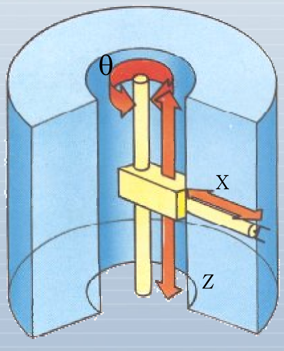
Cartesian Coordinate



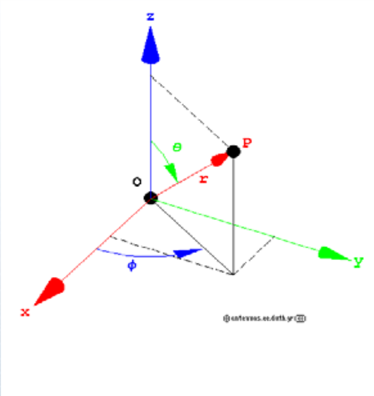
Cylindrical Robot



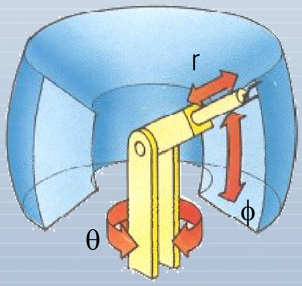
Cylindrical Coordinate



Spherical Robot



Spherical Coordinate



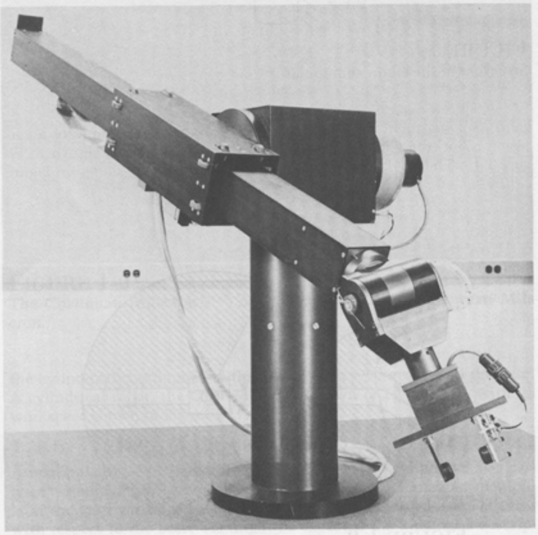
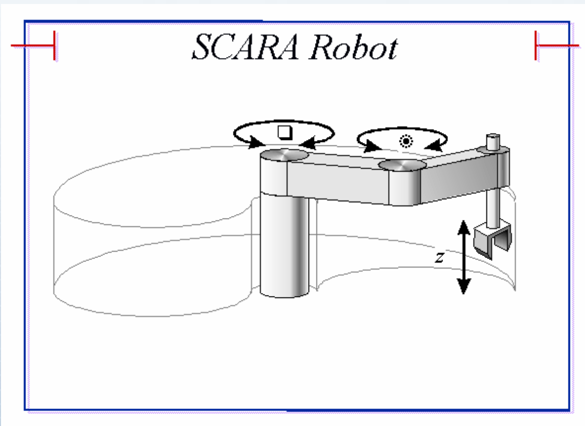
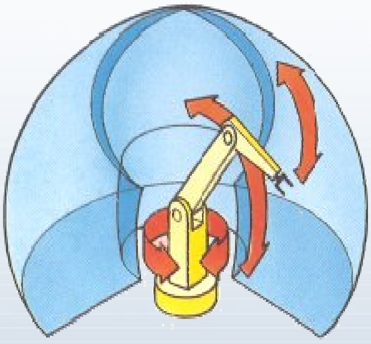


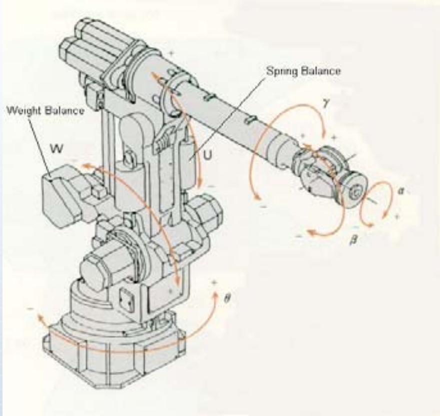
FIGURE 1-10
The Stanford manipulator (Courtesy of the Coordinated Science Laboratory, University of Illinois)

SCARA ROBOT



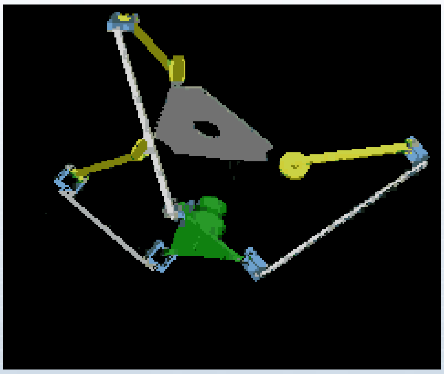
Articulated Robot

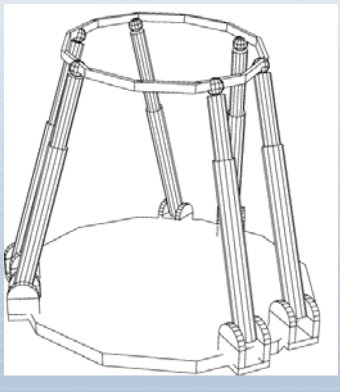


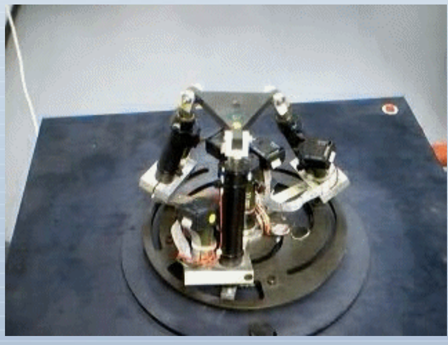


Parallel Robot

- Structure: Closed Chain, Complex
- Accuracy: High
- Payload : High
- Workspace: Small





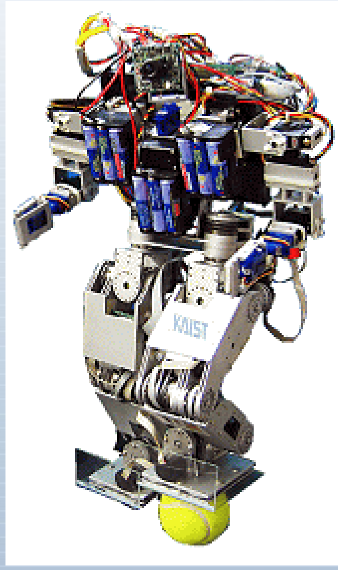


Parallel Robot

Fig. 1: Motion base by Hydra-Power Systems, Inc.

Mobile Robot

Walking



How to accomplish a given task ?

- Wish to move the manipulator from its home position to position A, from which point the robot is to follow the contour of the surface S to the point B, at constant velocity, while maintaining a prescribed force F normal to the surface.

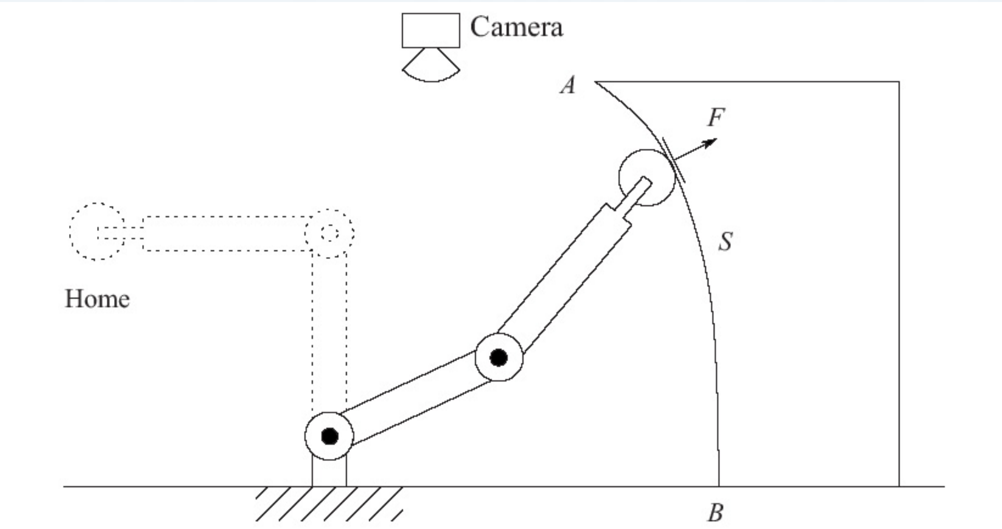


Figure 1.19: Two-link planar robot example. Each chapter of the text discusses a fundamental concept applicable to the task shown.

Forward Kinematics

- Problem
  - How to describe both the position of the tool and the location A and B with respect to a common coordinate system
- Determine the position and orientation of the end effector or tool in terms of the joint variables.

Forward Kinematic Analysis

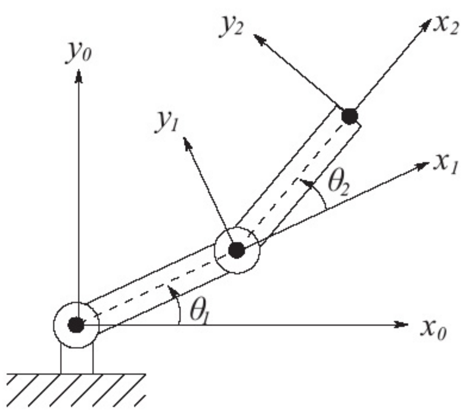


Figure 1.20: Coordinate frames attached to the links of a two-link planar robot. Each coordinate frame moves as the corresponding link moves. The mathematical description of the robot motion is thus reduced to a mathematical description of moving coordinate frames.

$$x = a_1 \cos\theta_1 + a_2 \cos(\theta_1 + \theta_2)$$

$$y = a_1 \sin\theta_1 + a_2 \sin(\theta_1 + \theta_2)$$

Inverse Kinematics

- Need the joint variables in terms of the *x* and *y* coordinates of A.

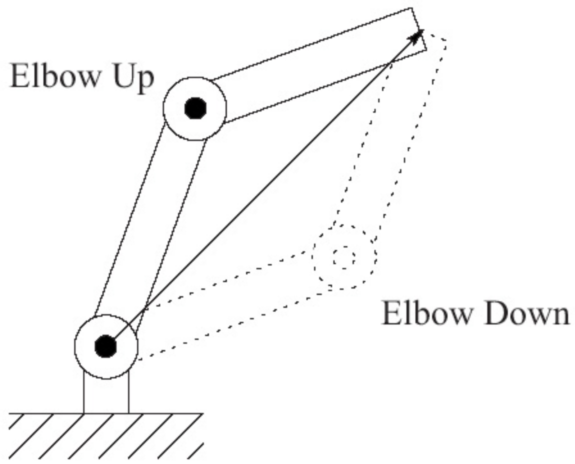


Figure 1.21: The two-link elbow robot has two solutions to the inverse kinematics except at singular configurations, the elbow up solution and the elbow down solution.

Inverse Kinematic Analysis

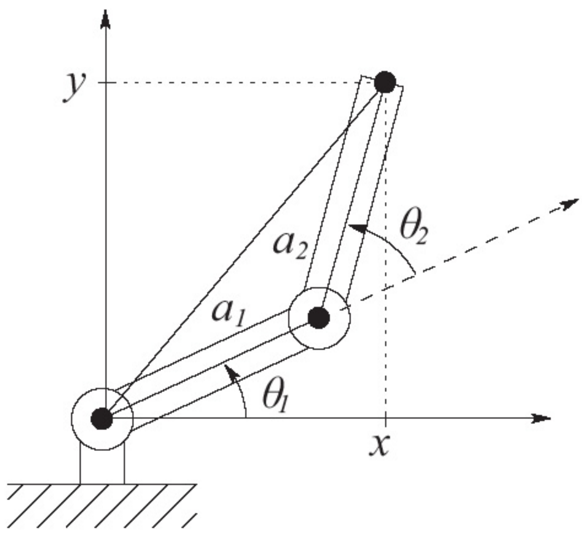


Figure 1.22: Solving for the joint angles of a two-link planar arm.

$$\theta_2 = \tan^{-1}\frac{\pm\sqrt{1-D^2}}{D} \qquad \theta_1 = \tan^{-1}\left(\frac{y}{x}\right) - \tan^{-1}\left(\frac{a_2\sin\theta_2}{a_1 + a_2\cos\theta_2}\right)$$

Velocity Kinematics

- To follow a contour at constant velocity, or at any prescribed velocity, we must know the relationship between the tool velocity and the joint velocities.

$$\dot{x} = -a_1 \sin\theta_1 \cdot \dot{\theta}_1 - a_2 \sin(\theta_1 + \theta_2)(\dot{\theta}_1 + \dot{\theta}_2)$$
$$\dot{y} = a_1 \cos\theta_1 \cdot \dot{\theta}_1 + a_2 \cos(\theta_1 + \theta_2)(\dot{\theta}_1 + \dot{\theta}_2)$$

$$\left[\dot{X}\right] = J(\theta)\left[\dot{\theta}\right] \qquad \dot{\theta} = J^{-1}\dot{X}$$

Singular Configuration

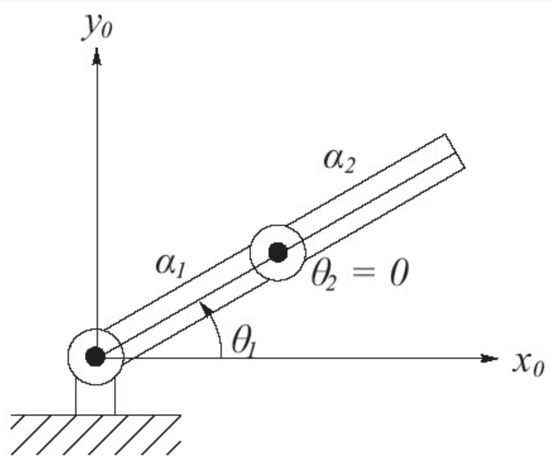
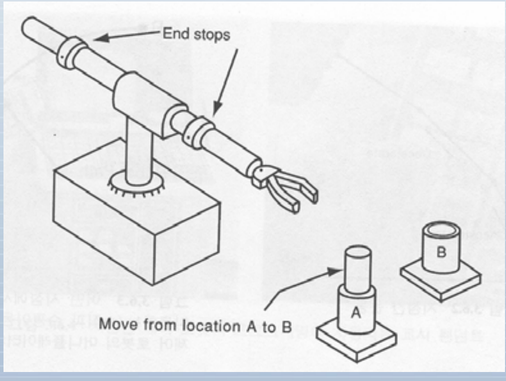


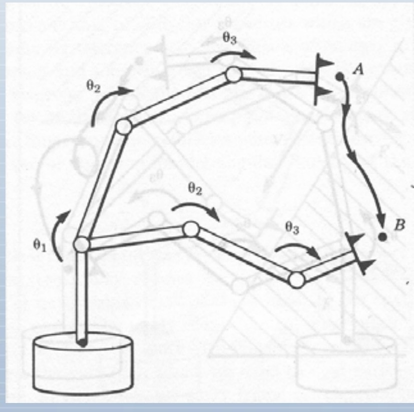
Figure 1.23: A singular configuration results when the elbow is straight. In this configuration the two-link robot has only one DOF.

When there is no inverse Jacobian

Path Planning and Trajectory Generation

- Path planning: determine a path in task space to move the robot to a goal position while avoiding collision with objects in its workspace, without time considerations, that is, without considering velocities and accelerations.
- Trajectory generation: determine the time history of the manipulator along a given path





Independent Joint Control

- Make the robot follow the reference trajectory

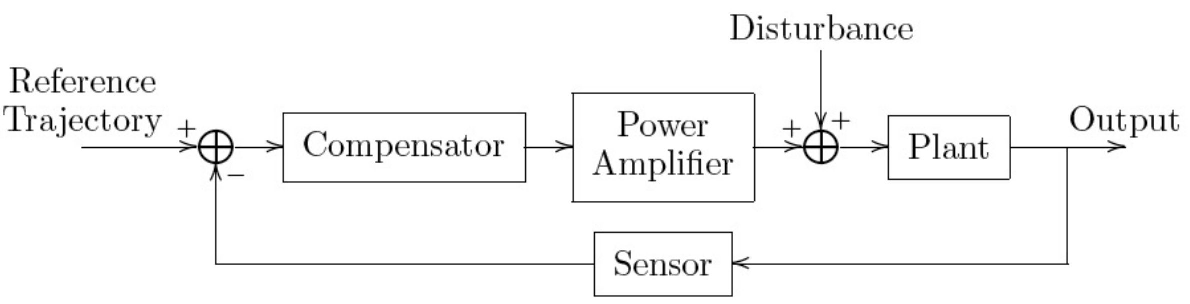


Figure 1.24: Basic structure of a feedback control system. The compensator measures the error between a reference and a measured output and produces a signal to the plant that is designed to drive the error to zero despite the

Dynamics

- Dynamics give the relationship between the robot's position (and its derivatives) and forces.
  - Inverse Dynamics
    - Given robots desired hand position, velocity and acceleration what are the required joint torques
  - Forward Dynamics
    - Given the joint torque, what will the velocity of the end-effector

Force Control

- Position Control
- Force Control
- Hybrid Control