Universidad Autónoma del Estado de México
Centro Universitario UAEM Valle de México

Ingeniería en Computación

Unidad de Aprendizaje: Fundamentos de Robótica

Tema: Industrial Robots

Elaboró: Dr. en C. Héctor Rafael Orozco Aguirre
Marzo de 2018

Universidad Autónoma del Estado de México
UAEM

Secretaría de Docencia
Dirección de Estudios Profesionales

PROGRAMA DE ESTUDIO POR COMPETENCIAS
FUNDAMENTOS DE ROBOTICA

I. IDENTIFICACIÓN DEL CURSO

Espacio Educativo: Facultad de Ingeniería

Licenciatura: Licenciatura de Ingeniería en Computación **Año de aprobación por el Consejo Universitario:**	**Área de docencia:** Interacción Hombre-Máquina

Aprobación por los H.H. Consejos Académico y de Gobierno	**Fecha:**	**Programa elaborado por:** **Adriana H. Vilchis González**	**Programa revisado por:**
		Fecha de elaboración : 20 Septiembre del 2009	

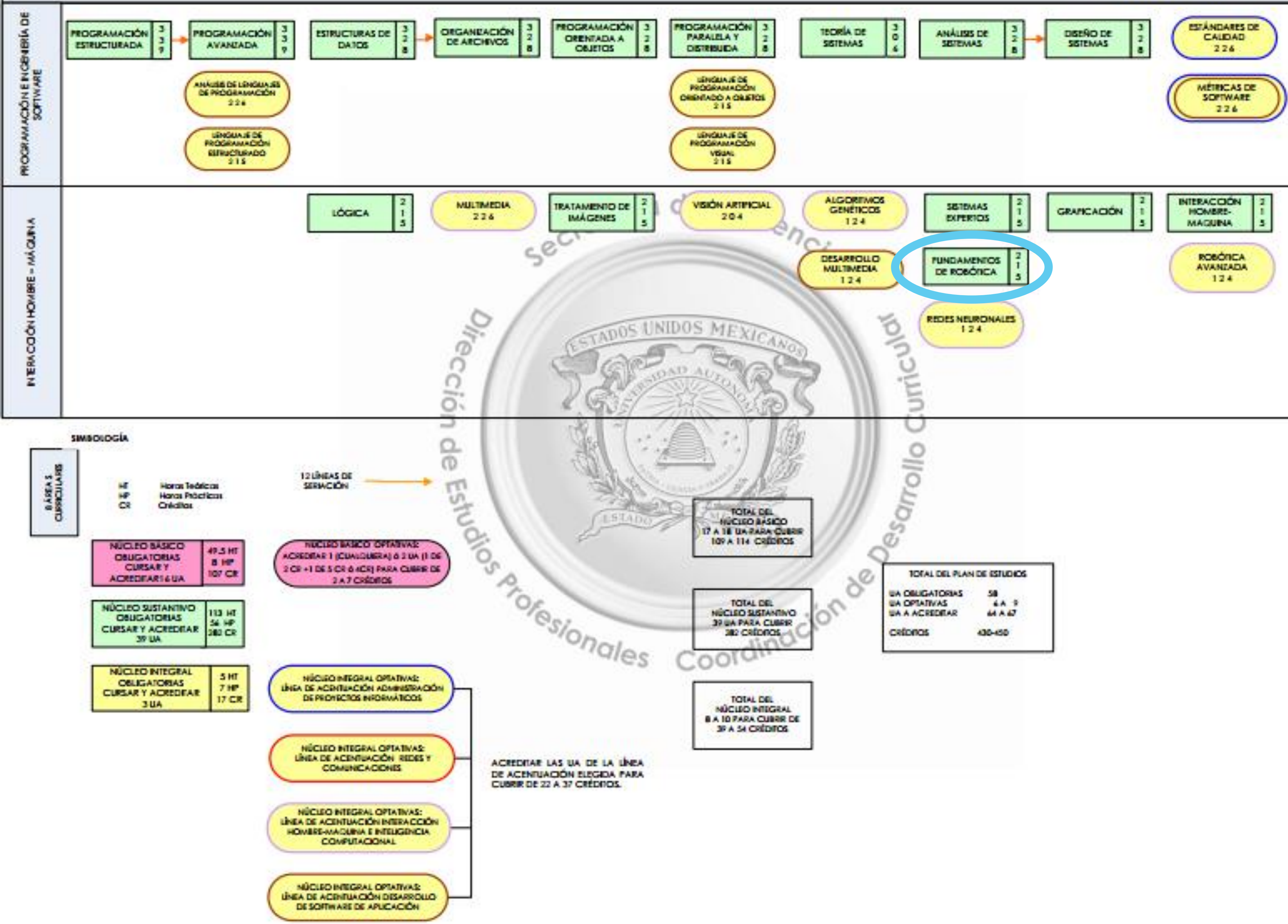
Clave	Horas de teoría	Horas de práctica	Total de horas	Créditos	Tipo de curso	Núcleo de formación
L41067	2	1	3	5	Curso	Sustantivo

Unidad de Aprendizaje Antecedente Ninguna	**Unidad de Aprendizaje Consecuente** Ninguna

Programas educativos o espacios académicos en los que se imparte:
Licenciatura en Ingeniería en Computación (Facultad. de Ingeniería, Centros Universitarios: Atlacomulco, Ecatepec, Texcoco, Valle de Chalco, Valle de México, Valle de Teotihuacán, Zumpango)

MAPA CURRICULAR DE LA LICENCIATURA DE INGENIERÍA EN COMPUTACIÓN 2004

CRÉDITOS TOTALES: 430 - 450



Propósito de la Unidad de Aprendizaje

Programar en lenguaje ensamblador aplicaciones de software o hardware para tener el control total de un sistema de cómputo utilizando para dicho aprendizaje un equipo de cómputo (PC) o un microcontrolador/microprocesador comercial.

El alumno desarrollará programas en lenguaje ensamblador de uso práctico para manejar los componentes básicos de un sistema de cómputo, usando las instrucciones y las metodologías propias del la estructura del lenguaje ensamblador.

El alumno deberá realizar, explicar, documentar cada programa realizado, de tal forma que realce la comprensión de las instrucciones individuales y el estilo de programación

Contenido

- Robot industrial
- Anatomía de un robot
- Articulaciones de un robot
- Sistemas de coordenadas
- Control y programación de un robot
- Grados de libertad
- Espacio de trabajo

Guión explicativo

- Esta presentación tiene como fin dar a conocer lo siguiente:
  - ¿Qué es un robot industrial?, sus anatomía, tipos de articulaciones y notaciones empleadas.
  - Sistemas de coordenadas robóticas, sus ventajas y desventajas.
  - Grados de libertad y espacio de trabajo de los robots.

Guión explicativo

- El contenido de esta presentación contiene temas de interés contenidos en la Unidad de Aprendizaje Fundamentos de Robótica.
- El material va en Inglés para reforzar la práctica de esta lengua y fomentar el uso de la misma en UDAs avanzadas y especializadas.
- Las diapositivas deben explicarse en orden, y deben revisarse aproximadamente en 6 horas, además de realizar preguntas a la clase sobre el contenido mostrado.

Industrial Robot

A general-purpose, programmable machine possessing certain anthropomorphic characteristics, such as:

- Hazardous work environments
- Repetitive work cycle
- Consistency and accuracy
- Difficult handling task for humans
- Multishift operations
- Reprogrammable, flexible
- Interfaced to other computer systems

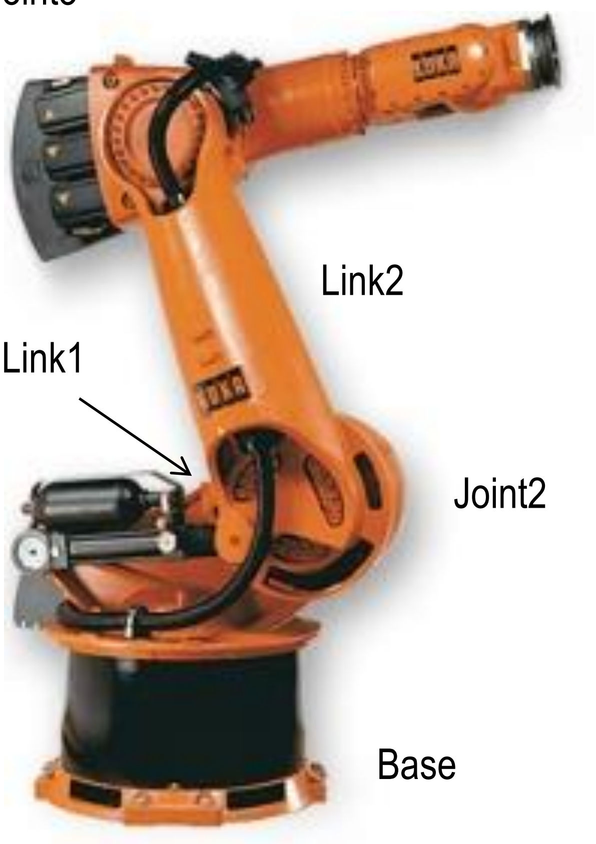
Robot Anatomy

- Manipulator consists of joints and links:
  - Joints provide relative motion
  - Links are rigid members between joints
  - Various joint types: linear and rotary
  - Each joint provides a "degree-of-freedom"
  - Most robots possess five or six degrees-of-freedom

Robot Anatomy

- Robot manipulator consists of two sections:
  - Body-and-arm – for positioning of objects in the robot's work volume
  - Wrist assembly – for orientation of objects

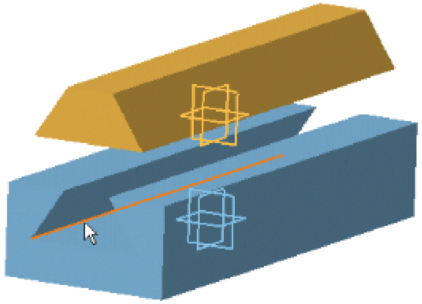
Robot Anatomy

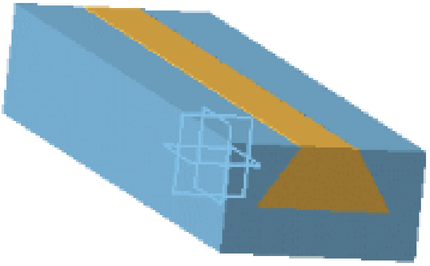


Robot Joints

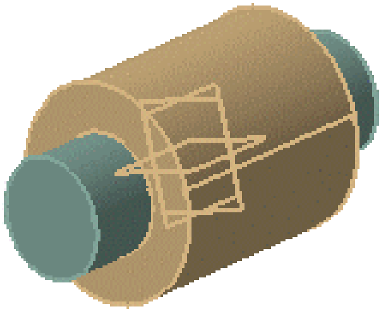
Prismatic Joint: Linear, No rotation involved.

(Hydraulic or pneumatic cylinder)



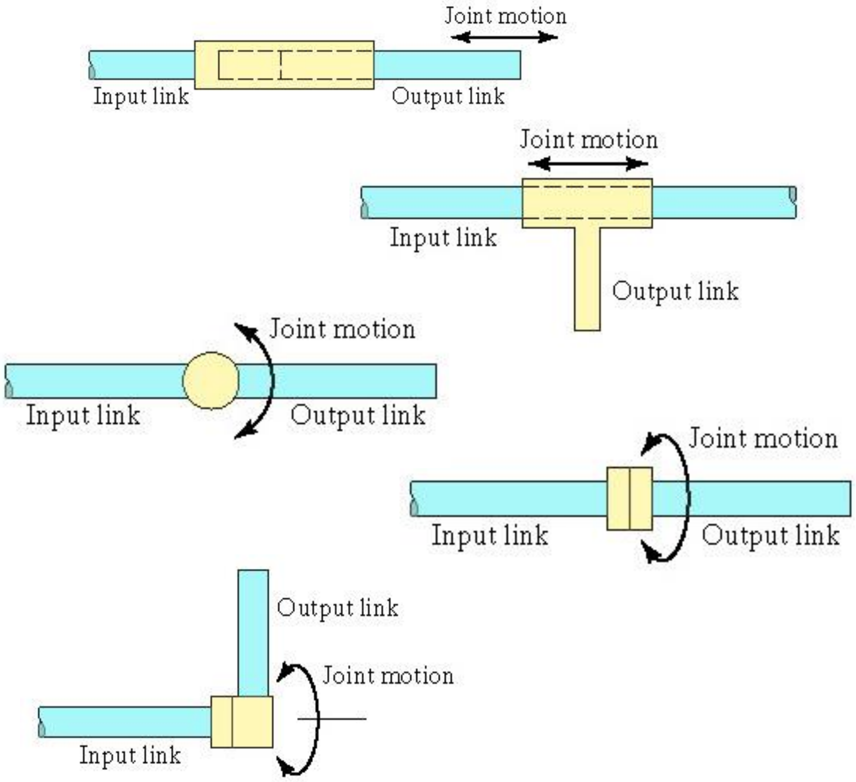


Revolute Joint: Rotary, (electrically driven with stepper motor, servo motor)



Manipulator Joints

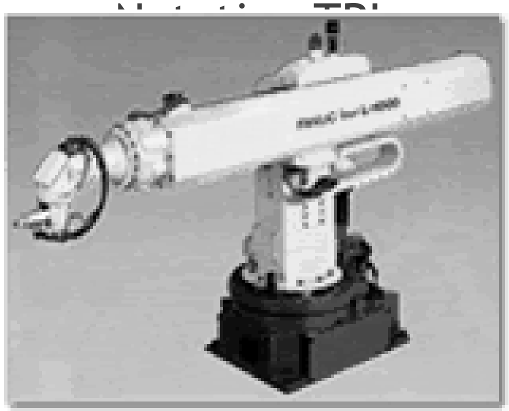
- Translational motion
  - Linear joint (type L)
  - Orthogonal joint (type O)
- Rotary motion
  - Rotational joint (type R)
  - Twisting joint (type T)
  - Revolving joint (type V)

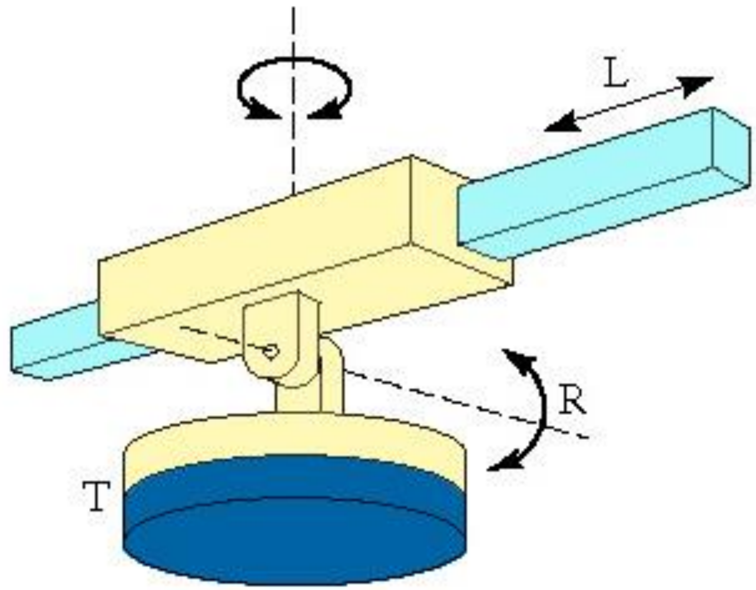


Joint Notation Scheme

- Uses the joint symbols (L, O, R, T, V) to designate joint types used to construct robot manipulator
- Separates body-and-arm assembly from wrist assembly using a colon (:)
- Example: TLR : TR
- Common body-and-arm configurations …

Polar Coordinate
Body-and-Arm Assembly

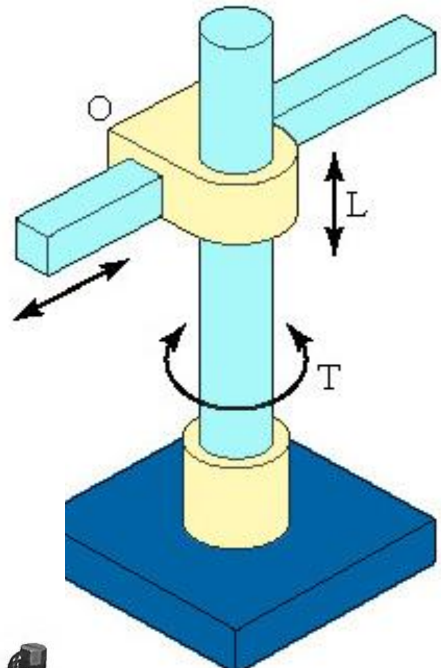




- Consists of a sliding arm (L joint) actuated relative to the body, which can rotate about both a vertical axis (T joint) and horizontal axis (R joint)

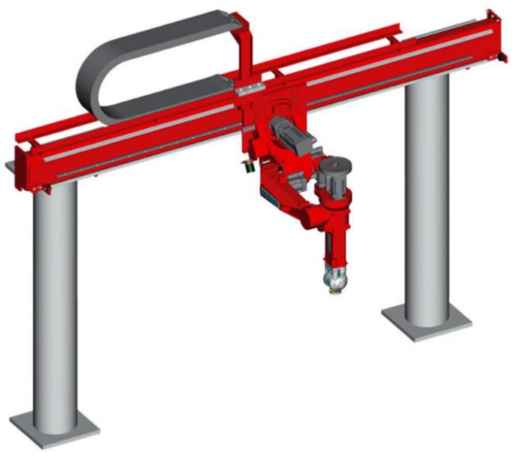
Cylindrical
Body-and-Arm Assembly

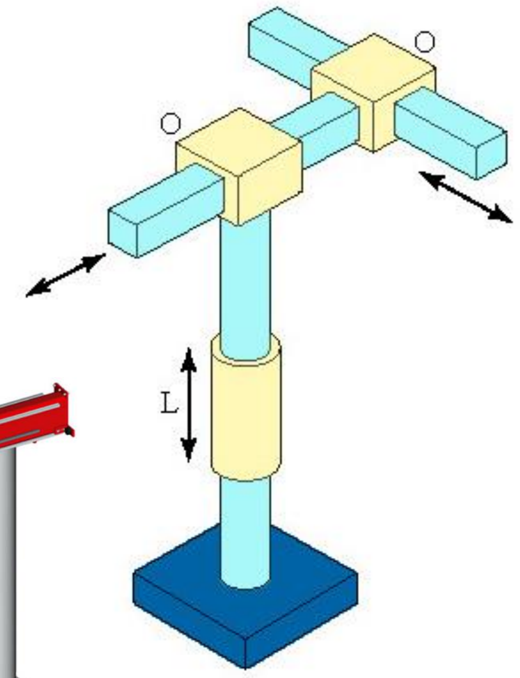
- Notation TLO:
  - Consists of a vertical column, relative to which an arm assembly is moved up or down
  - The arm can be moved in or out relative to the column



Cartesian Coordinate Body-and-Arm Assembly

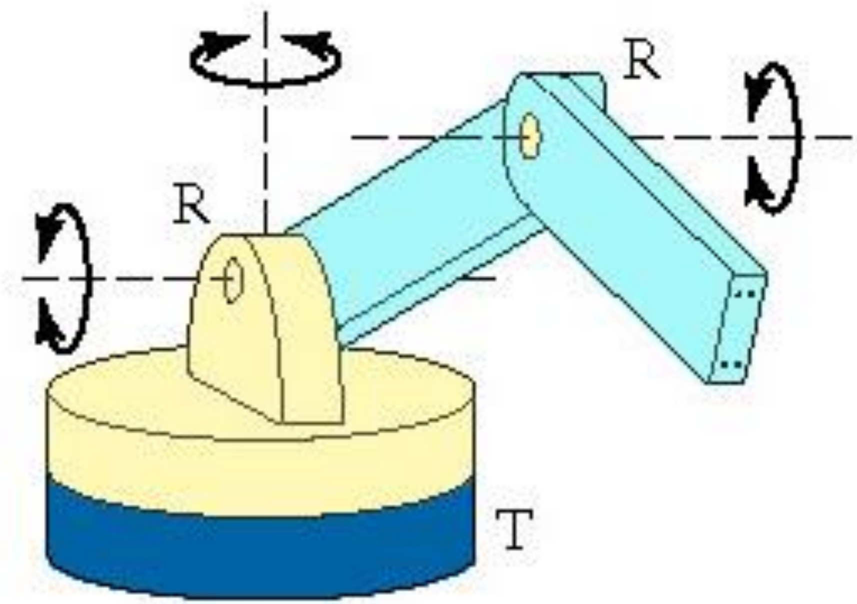
- Notation LOO:
  - Consists of three sliding joints, two of which are orthogonal
  - Other names include rectilinear robot and x-y-z robot





Jointed-Arm Robot

- Notation TRR:



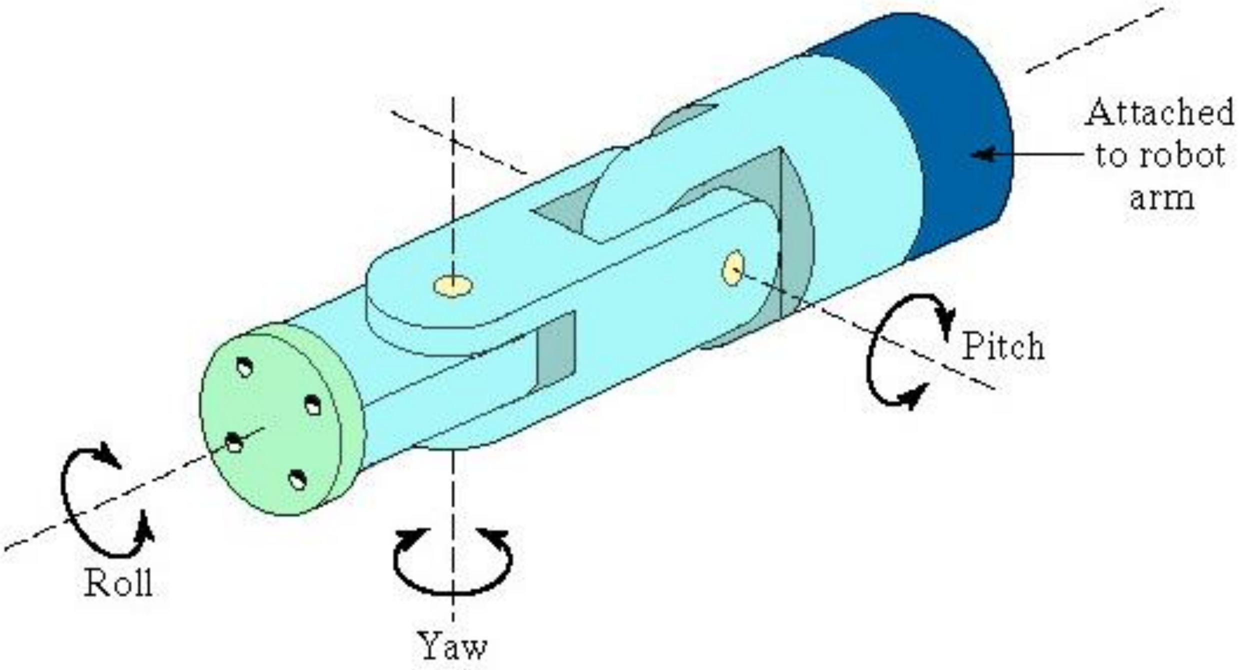
Wrist Configurations

- Wrist assembly is attached to end-of-arm
- End effector is attached to wrist assembly
- Function of wrist assembly is to orient end effector
  - Body-and-arm determines global position of end effector

- Two or three degrees of freedom:
  - Roll
  - Pitch
  - Yaw

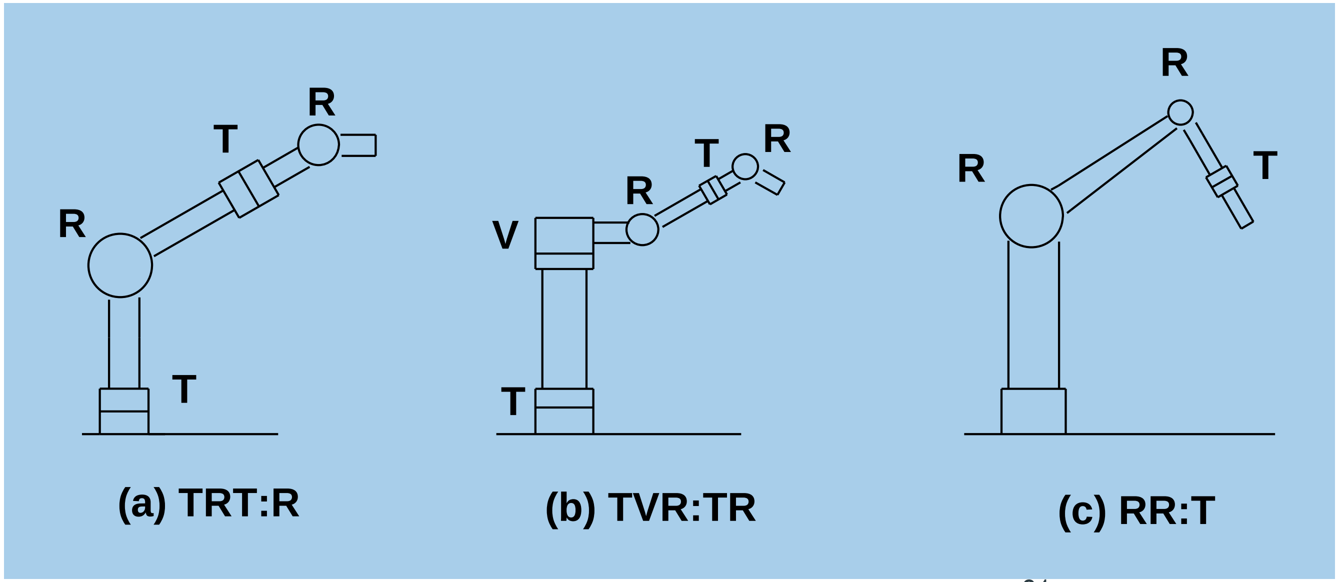
- Notation :RRT

Wrist Configurations



Example

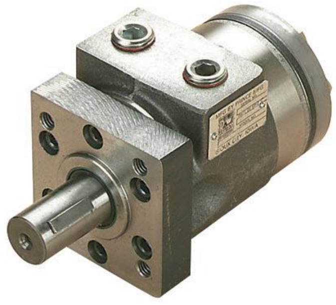
- Sketch following manipulator configurations
  - a) TRT:R
  - b) TVR:TR
  - c) RR:T



Joint Drive Systems

- Electric:
  - Uses electric motors to actuate individual joints
  - Preferred drive system in today's robots

- Hydraulic:
  - Uses hydraulic pistons and rotary vane actuators
  - Noted for their high power and lift capacity



- Pneumatic:
  - Typically limited to smaller robots and simple material transfer applications

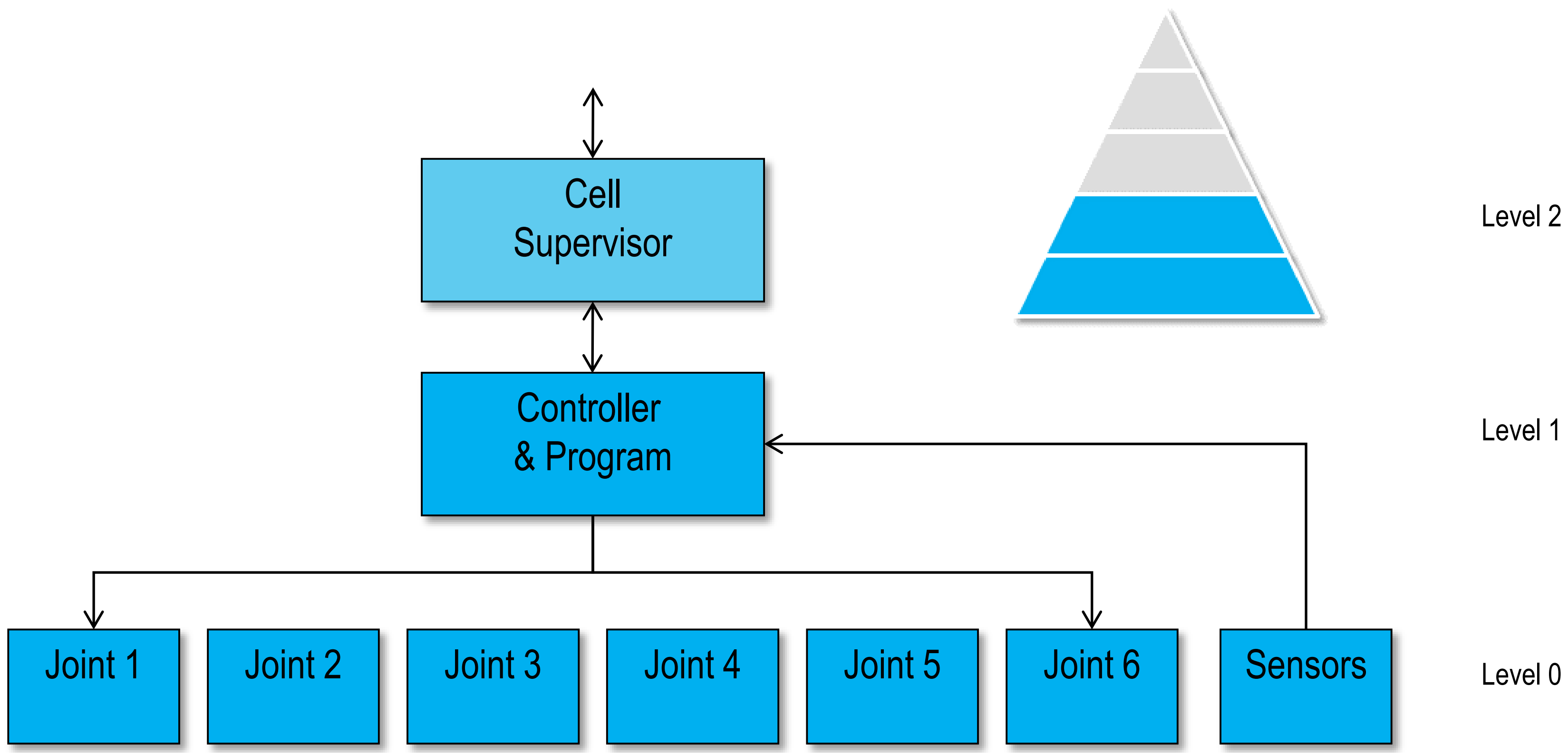
Robot Control Systems

- **Limited sequence control**
  - pick-and-place operations using mechanical stops to set positions
- **Playback with point-to-point control**
  - records work cycle as a sequence of points, then plays back the sequence during program execution

Robot Control Systems

- **Playback with continuous path control**
  - greater memory capacity and/or interpolation capability to execute paths (in addition to points)
- **Intelligent control**
  - exhibits behavior that makes it seem intelligent, e.g., responds to sensor inputs, makes decisions, communicates with humans

Robot Control System



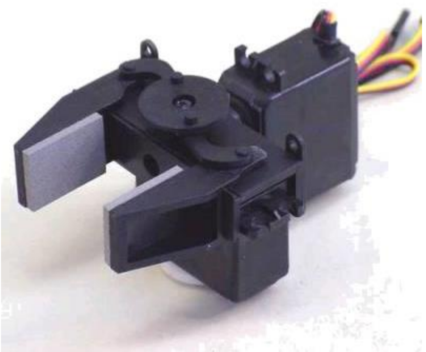
End Effectors

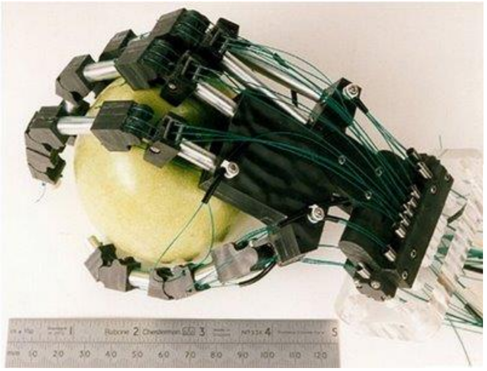
- The special tooling for a robot that enables it to perform a specific task

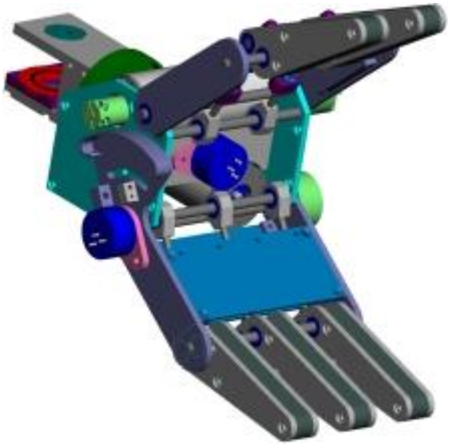
End Effectors

- Two types:
  - Grippers – to grasp and manipulate objects (e.g., parts) during work cycle
  - Tools – to perform a process, e.g., spot welding, spray painting

Grippers and Tools



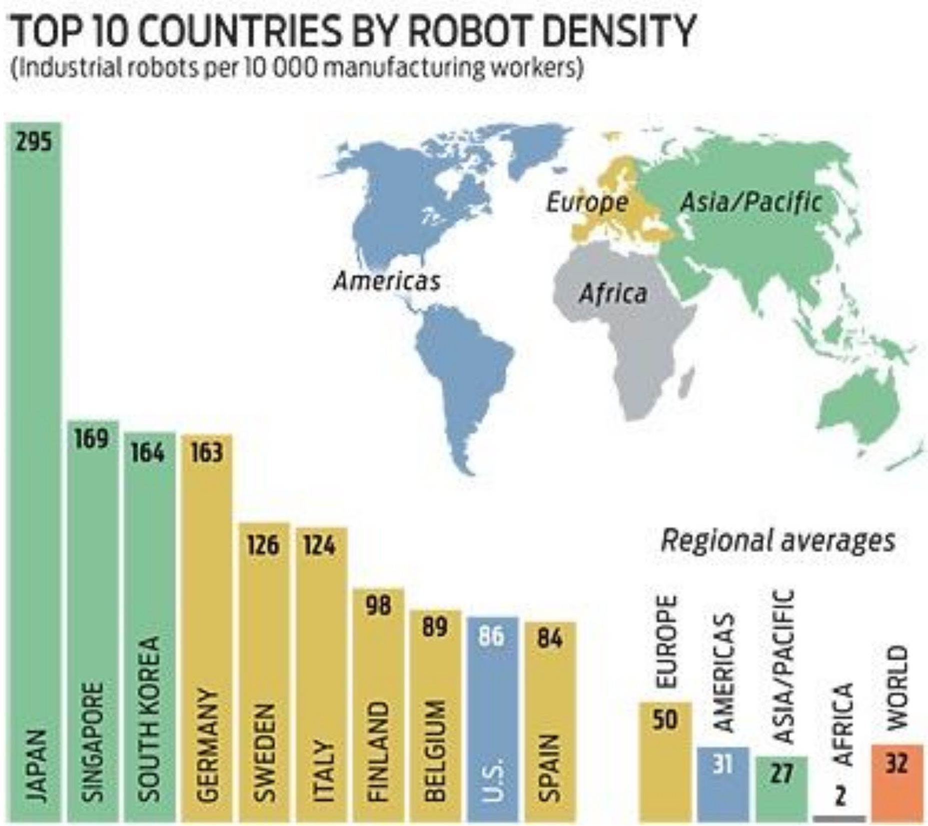




Industrial Robot Applications

1. Material handling applications
    - Material transfer – pick-and-place, palletizing
    - Machine loading and/or unloading
2. Processing operations
    - Welding
    - Spray coating
    - Cutting and grinding
3. Assembly and inspection

Industrial Robot Applications



Robot Programming

- Leadthrough programming
  - Work cycle is taught to robot by moving the manipulator through the required motion cycle and simultaneously entering the program into controller memory for later playback

Robot Programming

- Robot programming languages
  - Textual programming language to enter commands into robot controller
- Simulation and off-line programming
  - Program is prepared at a remote computer terminal and downloaded to robot controller for execution without need for leadthrough methods

Leadthrough Programming

- Powered leadthrough
  - Common for point-to-point robots
  - Uses teach pendant
- Manual leadthrough
  - Convenient for continuous path control robots
  - Human programmer physical moves manipulator

Leadthrough Programming Advantages

- Advantages:
  - Easily learned by shop personnel
  - Logical way to teach a robot
  - No computer programming
- Disadvantages:
  - Downtime during programming
  - Limited programming logic capability
  - Not compatible with supervisory control

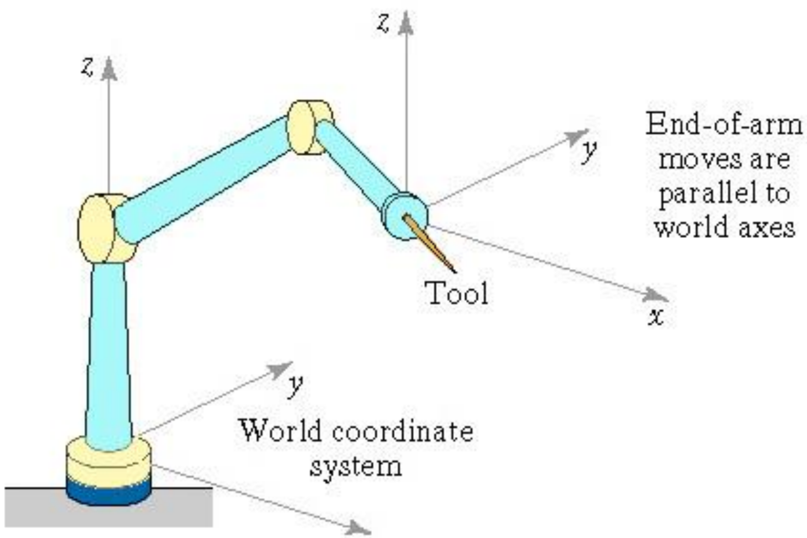
Robot Programming

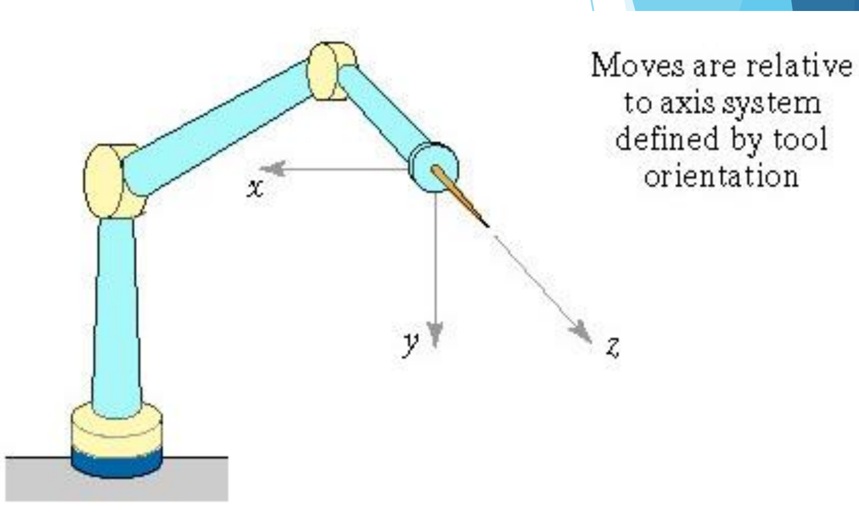
- Textural programming languages
- Enhanced sensor capabilities
- Improved output capabilities to control external equipment
- Program logic
- Computations and data processing
- Communications with supervisory computers

Arm Geometry

- A robot must be able to reach a point in space within three axes by moving:
  - forward and backward
  - to the left and right, and,
  - up and down.
- A robot manipulator may be classified according to the type of movement needed to complete the task.

Coordinate Systems





World coordinate system

Tool coordinate

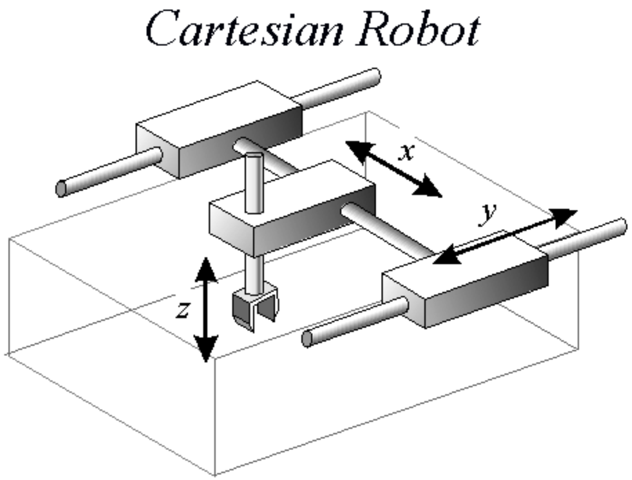
system

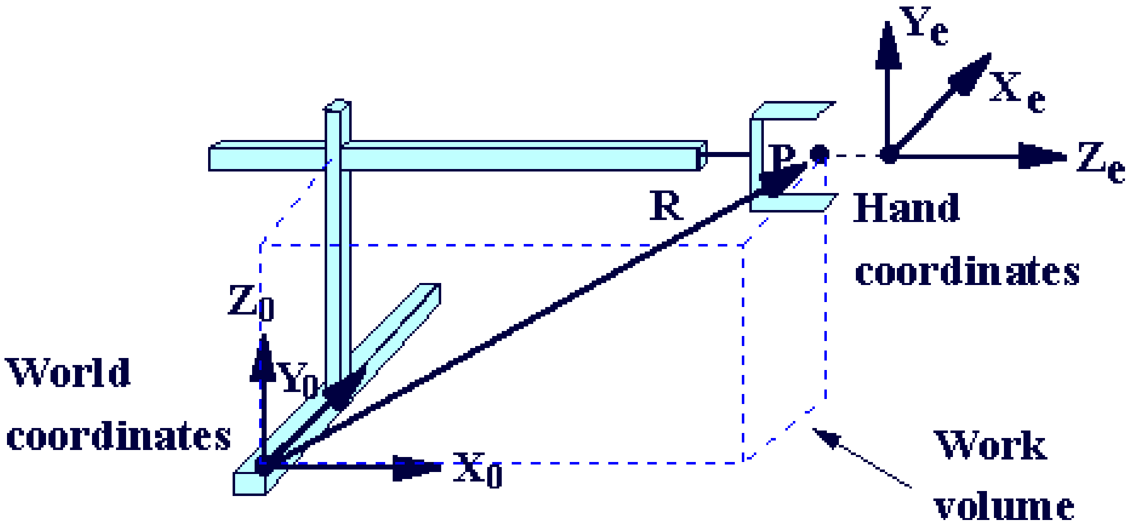
Rectangular-Coordinated Robots

- **A rectangular-coordinated robot is described by the following:**
  - **has three linear axes of motion.**
  - **x represents left and right motion.**
  - **y describes forward and backward motion.**
  - **z is used to depict up-and-down motion.**

- ***Note: The work envelope of a rectangular robot is a cube or rectangle, so that any work performed by robot must only involve motions inside the space.***

Rectangular-Coordinated Robots





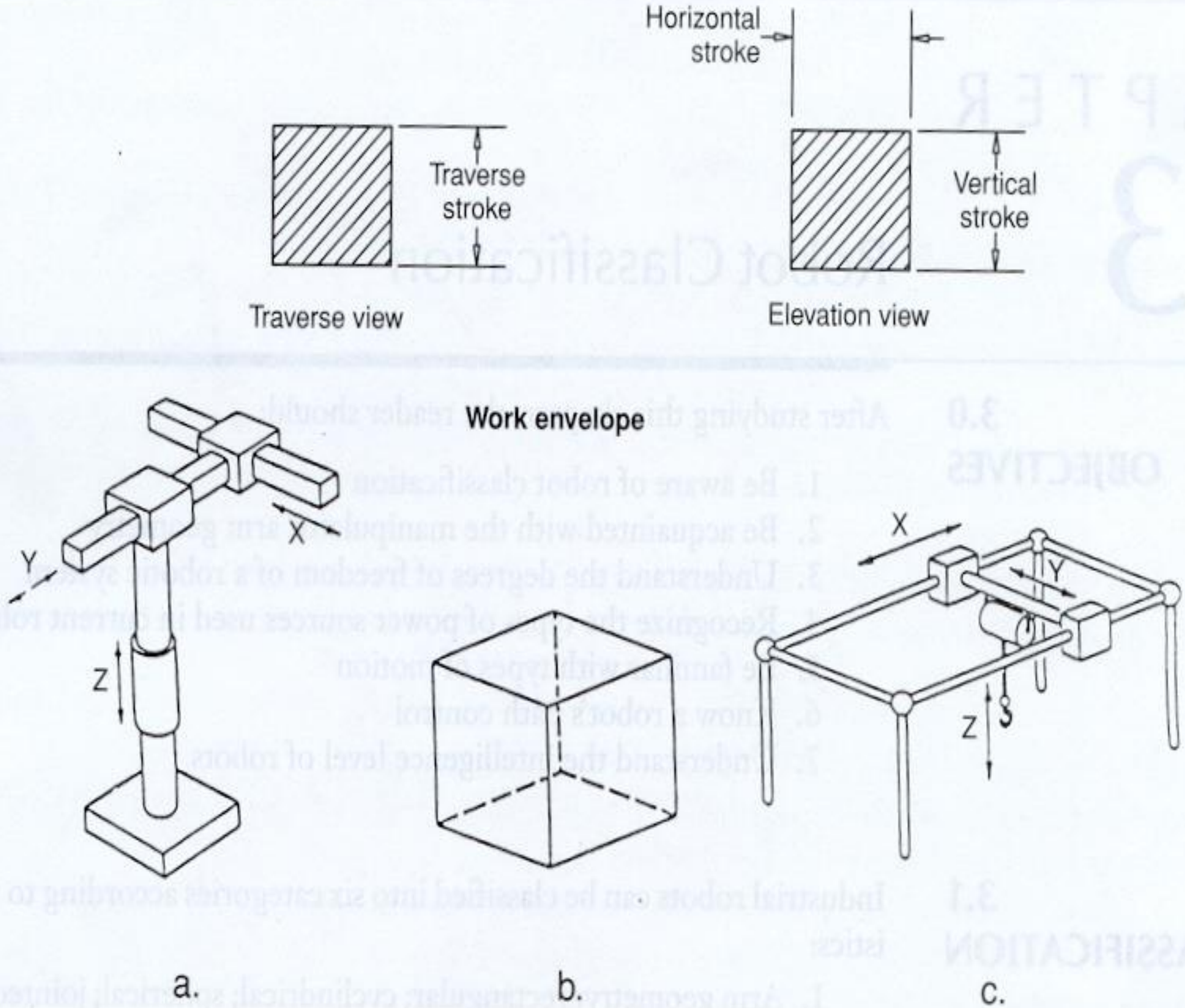


Figure 3.2.1 Rectangular or Cartesian-coordinated robot: (a) A rectangular coordinated arm moves in three linear axes. (b) The box-shaped work envelope within which a rectangular manipulator operates. (c) Overhead crane movements are similar to those of a rectangular-coordinated arm.

Rectangular-Coordinated Robots

- Applications:
  - pick-and-place operations.
  - adhesive applications(mostly long and straight).
  - advanced munition handling.
  - assembly and subassembly.
  - welding,
  - among others.

Rectangular-Coordinated Robots

- Advantages:
  - they can obtain large work envelope because ravelling along the x-axis, the volume region can be increased easily.
  - their linear movement allows for simpler controls.
  - they have high degree of mechanical rigidity, accuracy, and repeatability due o their structure.
  - they can carry heavy loads because the weight-lifting capacity does not vary at different locations withing the work envelope.

Rectangular-Coordinated Robots

- Disadvantages:
  - they makes maintenance more difficult for some models with overhead drive mechanisms and control equipment.
  - access to the volume region by overhead crane or other material-handling equipment may be impaired by the robot-supporting structure.
  - their movement is limited to one direction at a time.

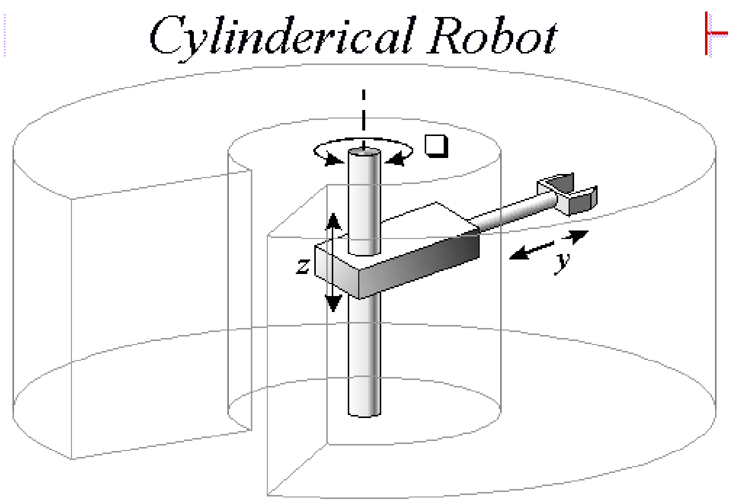
Cylindrical-Coordinated Robots

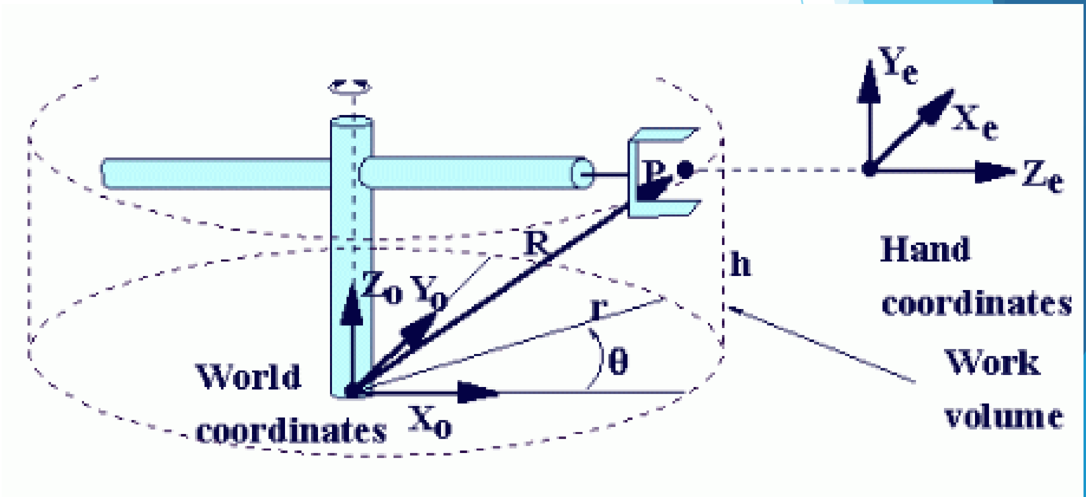
- A cylindrical-coordinated robot is one that can described in terms of the following:
  - has two linear motions and one rotary motion.
  - robots can achieve variable motion.
  - the first coordinate describe the angle theta of base rotation--- about the up-down axis.
  - the second coordinate correspond to a radical or y--- in out motion at whatever angle the robot is positioned.

Cylindrical-Coordinated Robots

- the final coordinate again corresponds to the up-down z position.
- rotational ability gives the advantage of moving rapidly to the point in z plane of rotation.
- results in a larger work envelope than a rectangular robot manipulator.
- suited for pick-and-place operations.

Cylindrical-Coordinated Robots





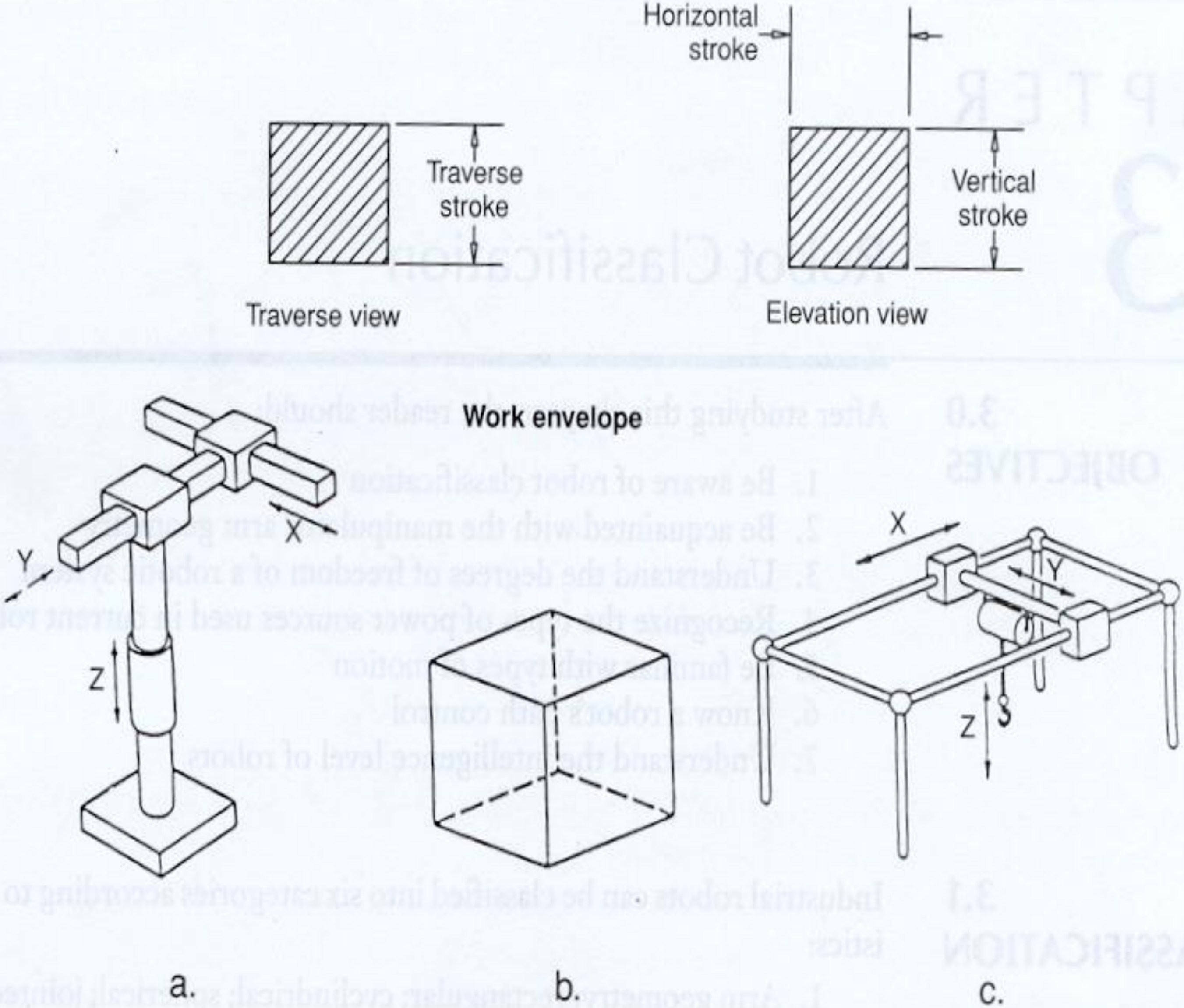


Figure 3.2.1 Rectangular or Cartesian-coordinated robot: (a) A rectangular coordinated arm moves in three linear axes. (b) The box-shaped work envelope within which a rectangular manipulator operates. (c) Overhead crane movements are similar to those of a rectangular-coordinated arm.

Cylindrical-Coordinated Robots

- Applications:
  - assembly.
  - coating applications.
  - conveyor pallet transfer.
  - die casting.
  - foundary and forging applications.
  - inspection moulding.
  - investment casting.
  - machine loading and unloading,
  - among others.

Cylindrical-Coordinated Robots

- Advantages:
  - their vertical structure conserves floor space.
  - their deep horizontal reach is useful for far-reaching operations.
  - their capacity is capable of carrying large payloads.

Cylindrical-Coordinated Robots

- Disadvantages:
  - their overall mechanical rigidity is lower than that of the rectilinear robots because their rotary axis must overcome inertia.
  - their repeatability and accuracy are also lower in the direction of rotary motion.
  - their configuration requires a more sophisticated control system than the rectangular robots.

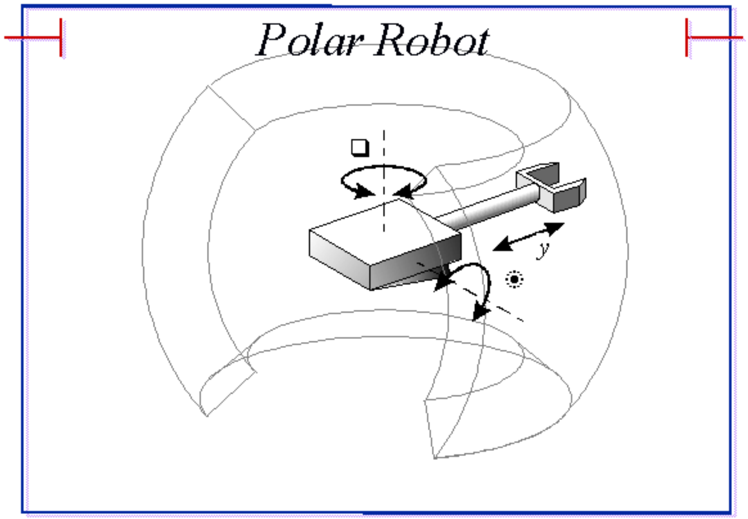
Spherical-Coordinated Robots

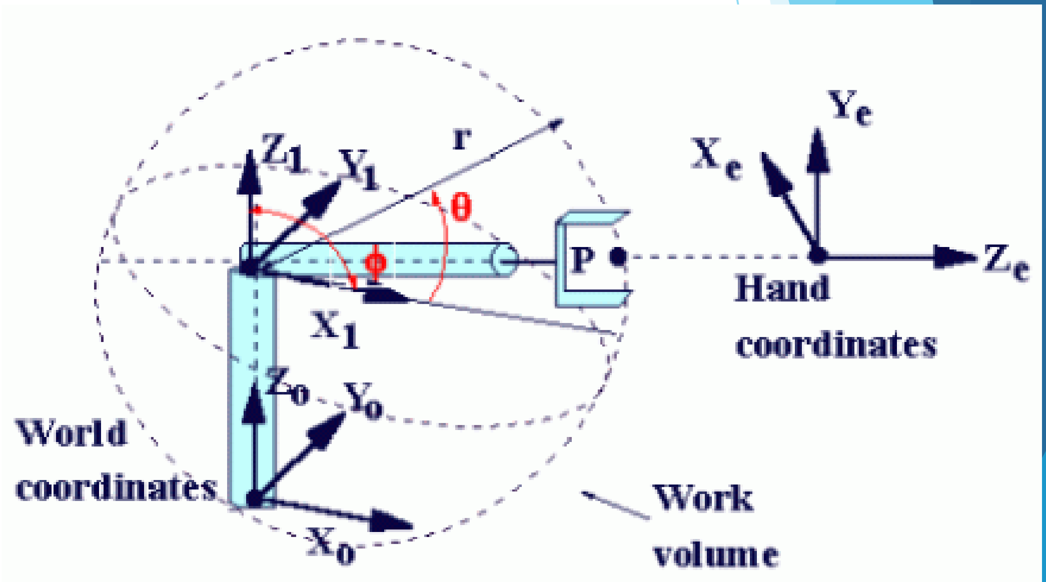
- A spherical-coordinated robot is defined by the following:
  - has one linear motion and two rotary motions.
  - the work volume is like a section of sphere.
  - the first motion corresponds to a base rotation about a vertical axis.
  - the second motion corresponds to an elbow rotation.

Spherical-Coordinated Robots

- the third motion corresponds to a radial, or in-out, translation.
- a spherical-coordinated robots provides a larger work envelope than the rectilinear or cylindirical robot.
- design gives weight lifting capabilities.
- advantages and disadvantages same as cylindirical-coordinated design.

Spherical-Coordinated Robots





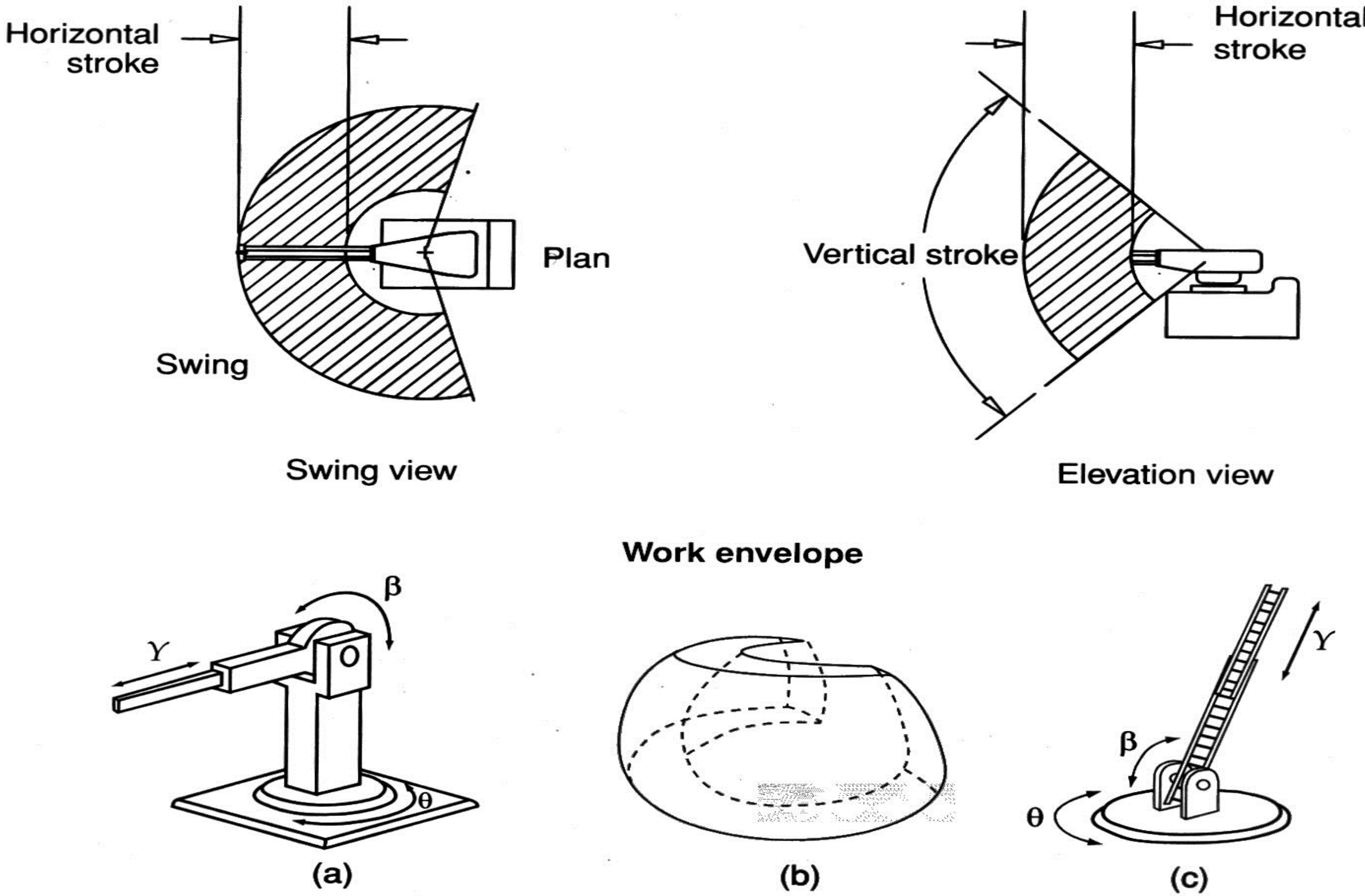
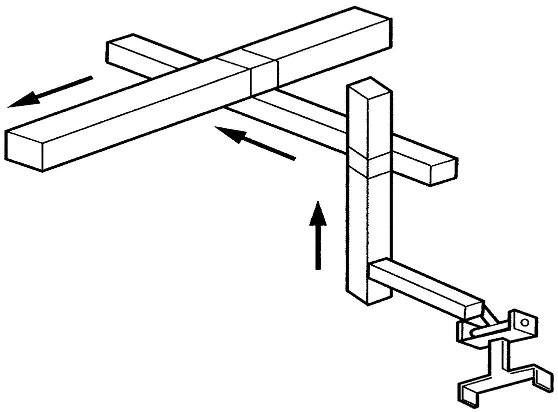


Figure 3.2.5 Spherical- or polar-coordinated robot: (a) A polar- or spherical-coordinated manipulator rotates about its base and shoulder and moves linearly in and out. (b) The work envelope of a polar-coordinated manipulator is the space between the two hemispheres. (c) A ladder on a hook-and-ladder truck has movements similar to those of a polar-coordinated manipulator.

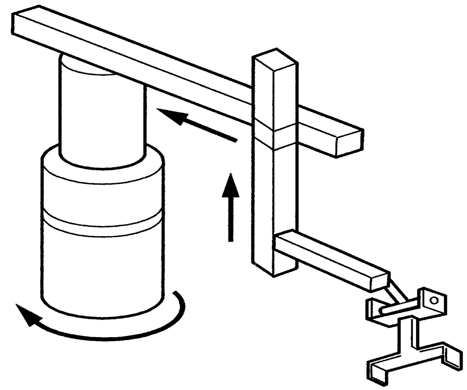
Spherical-Coordinated Robots

- Applications:
  - die casting, dip coating, forging.
  - glass handling, heat treating.
  - injection molding, machine tool handling.
  - material transfer, parts cleaning
  - press loading, stacking and unsticking,
  - among others.

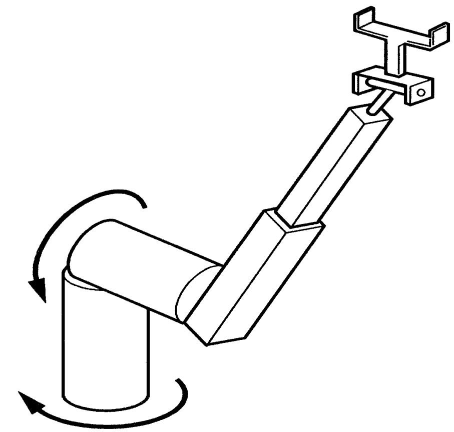
Robot Coordinates



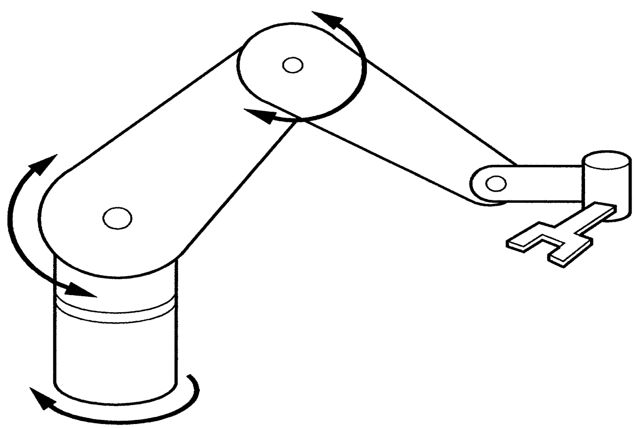
Cartesian



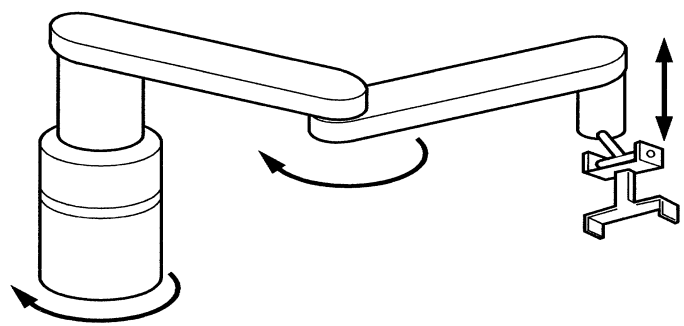
Cylindrical



Spherical



Articulated



SCARA

Robot Coordinates

- Cartesian/rectangular/gantry (3P) : 3 cylinders joint
- Cylindrical (R2P) : 2 Prismatic joint and 1 revolute joint
- Spherical (2RP) : 1 Prismatic joint and 2 revolute joint
- Articulated/anthropomorphic (3R) : All revolute(Human arm)
- Selective Compliance Assembly Robot Arm (SCARA):

2 paralleled revolute joint and 1 additional prismatic joint

Degrees of Freedom

- Number of independent position variables which would has to be specified to locate all parts of a mechanism.

- In most manipulators this is usually the number of joints.

Degrees of Freedom

- The degree of freedom (DOF) or grip of a robotic system can be compared to the way in which the human body moves:
  - for each degree of freedom a joint is required.
  - the degrees of freedom located in the arm define the configuration.
  - three degrees of freedom located in the wrist give the end effector all the flexibility.

Degrees of Freedom

- A total of six degrees of freedom is needed to locate a robot's hand at any point in its work space.

- Although six degrees of freedom are needed for maximum flexibility, most robot employee only three to five degrees of freedom.

- The more the degrees of freedom, the greater is the complexity of motions encountered.

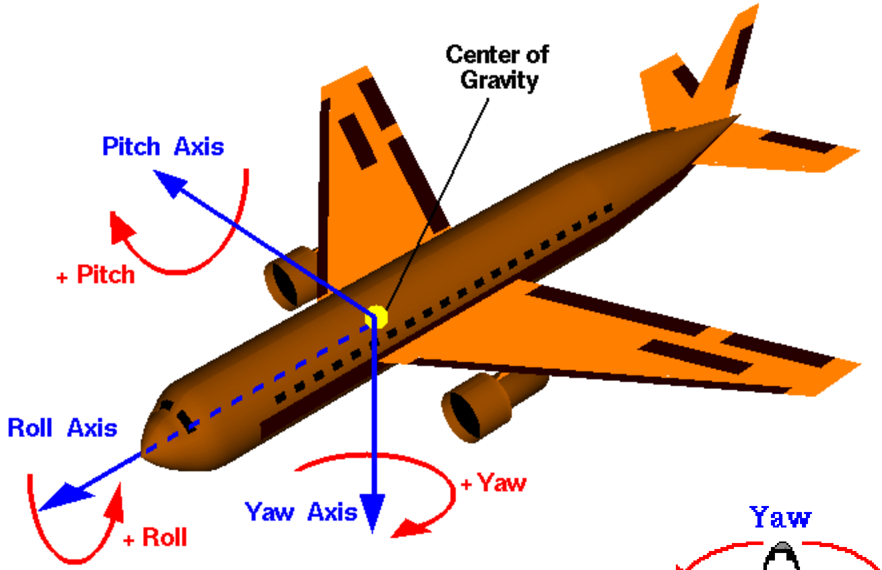
Degrees of Freedom

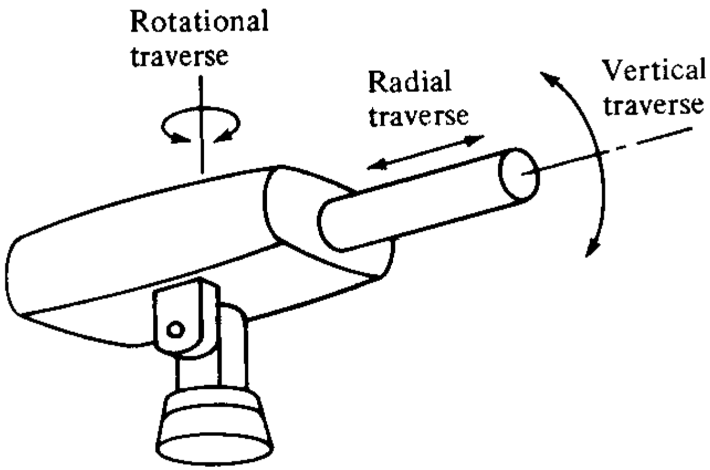
- The three degrees of freedom located in the arm of a robotic system are:
  - the rotational reverse: is the movement of the arm assembly about a rotary axis, such as left-and-right swivel of the robot’s arm about a base.
  - the radial traverse: is the extension and retraction of the arm or the in-and-out motion relative to the base.
  - the vertical traverse: provides the up-and-down motion of the arm of the robotic system.

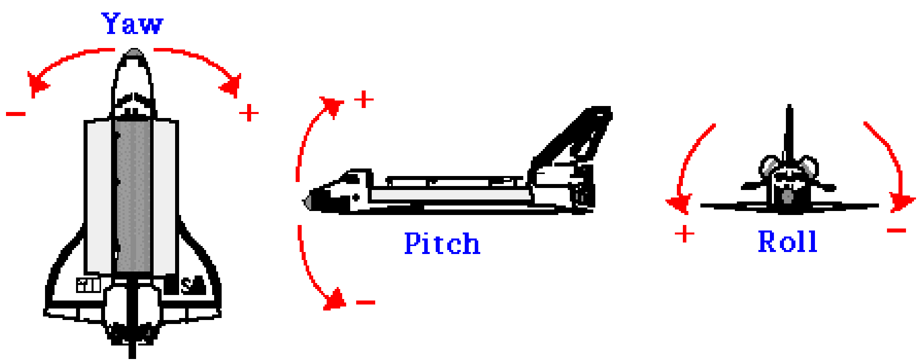
Degrees of Freedom

- The three degrees of freedom located in the wrist, which bear the names of aeronautical terms, are:
  - pitch or bend: is the up-and-down movement of the wrist.
  - yaw: is the right-and-left movement of the wrist.
  - roll or swivel: is the rotation of the hand.

Degrees of Freedom







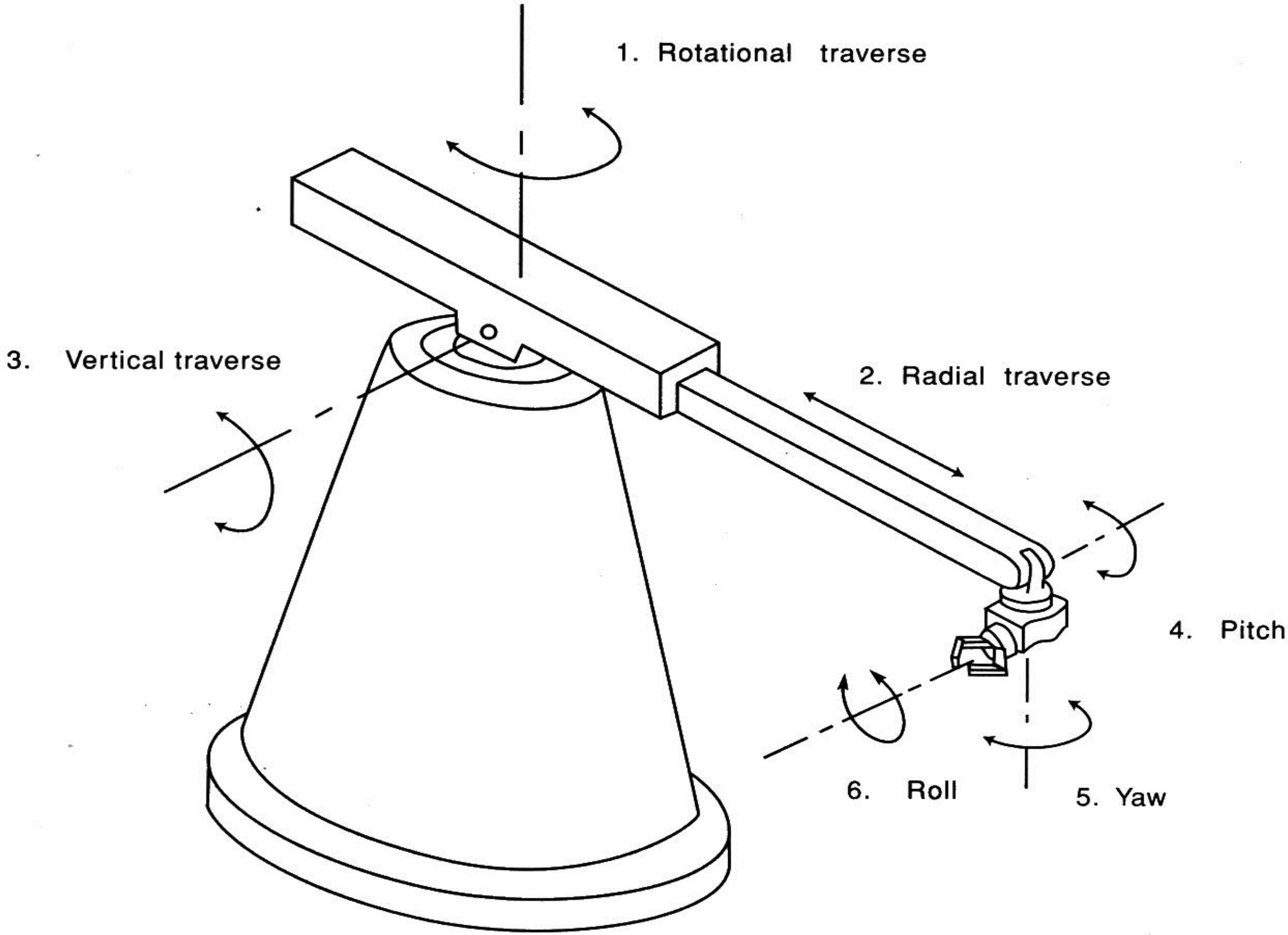
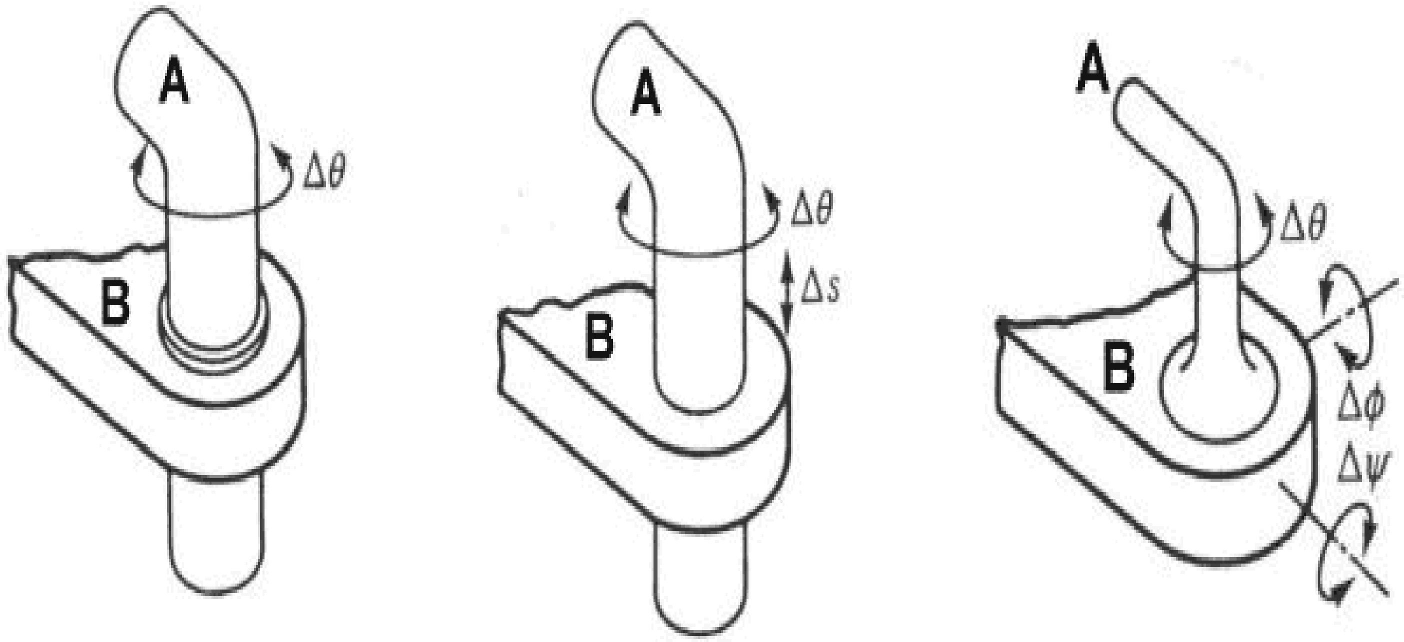
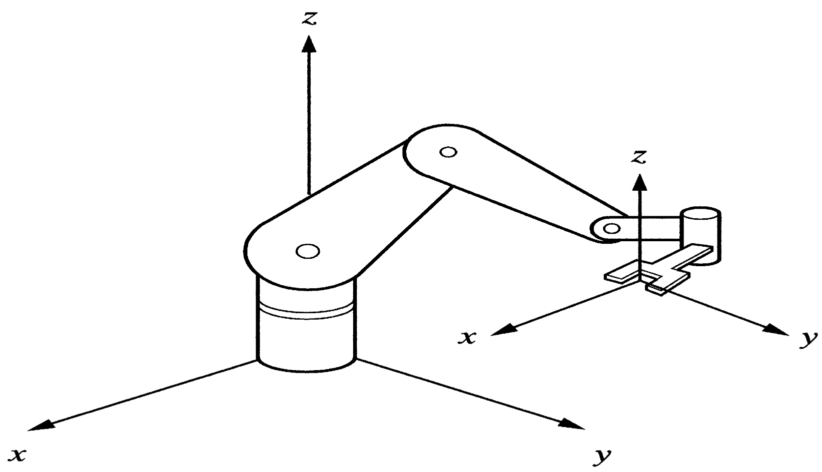


Figure 3.3.2 Six major degrees of freedom of a robotic system

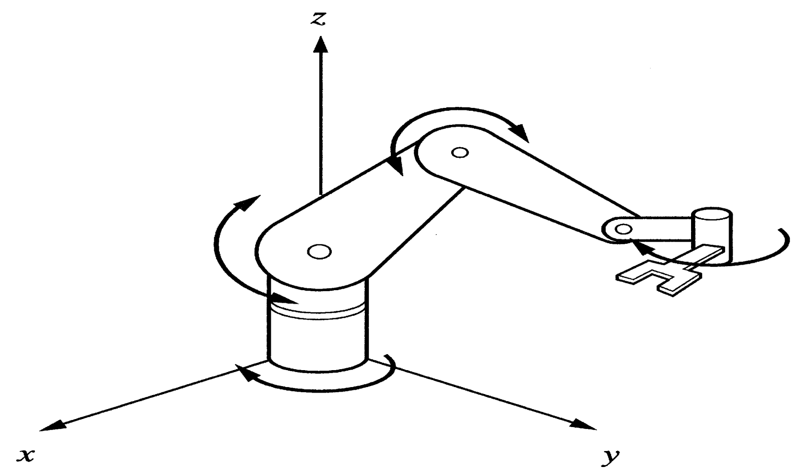
Degrees of Freedom



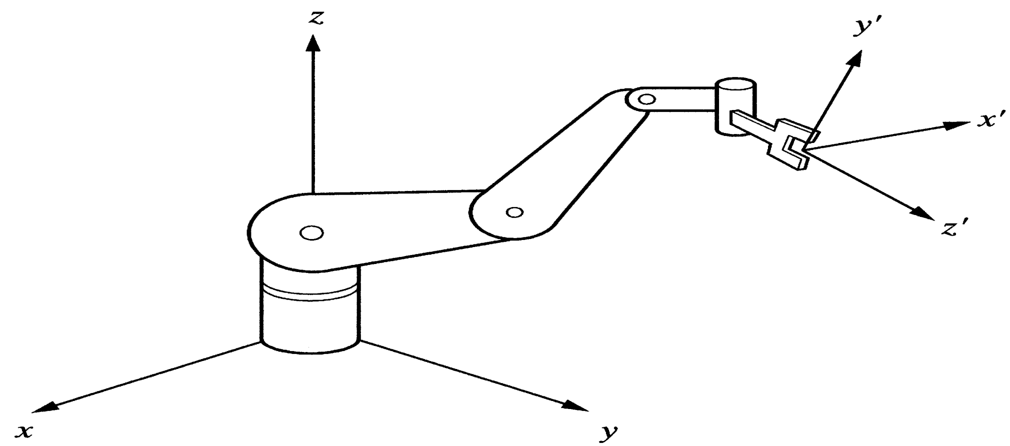
Robot Reference Frames



World reference frame

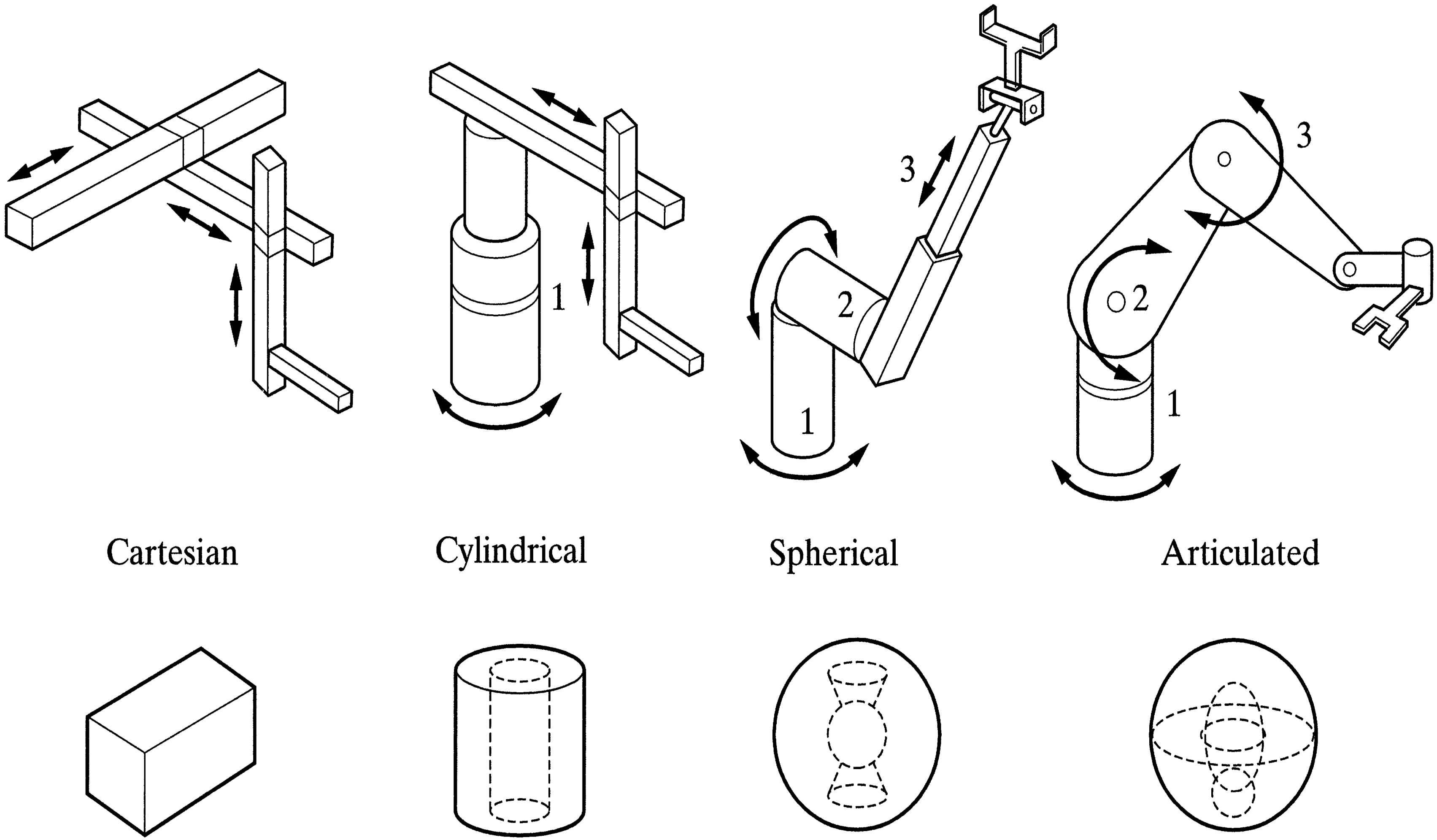


Joint reference frame



Tool reference frame

Robot Workspace



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