



## Chapter 2

# Fundamentals of Robotics

# Objectives

By the end of this lesson the learner should be able to:

- Define “Degrees of Freedom” (DOF)
- Identify three primary DOF and their respective Cartesian coordinate identifiers
- Identify the three DOF of the end effector wrist used in many industrial robots
- Identify three basic methods used to classify industrial robots
- Define “work envelope” for an industrial robot
- Define and discuss “servo” and “non-servo” control systems

# Key Technical Terms

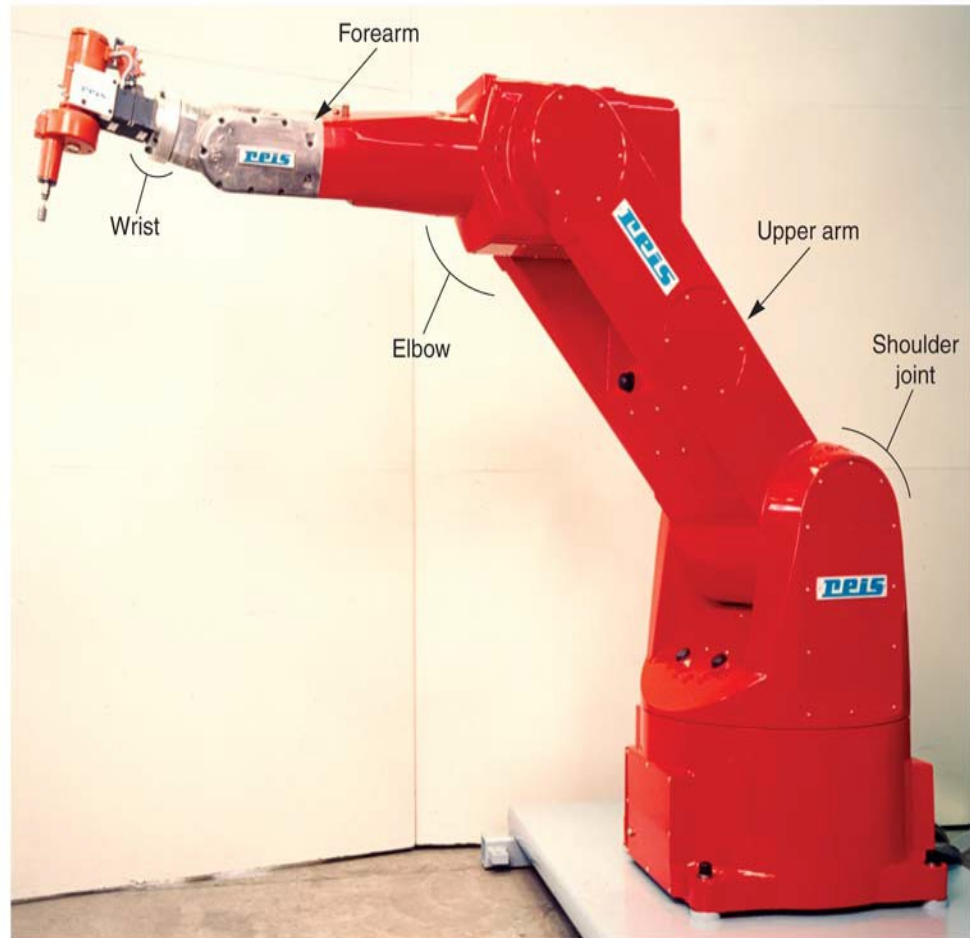
Rotary actuators	Linear actuators	Hydraulic drives	Pneumatic drives
Closed-loop system	Open-loop system	Servo robot	Non-servo robot
Cartesian configuration	SCARA configuration	Spherical configuration	Cylindrical configuration
Revolute configuration	Rotational traverse	Vertical traverse	Radial traverse
Degrees of freedom	Pitch	Yaw	Roll
Manipulator	Controller	Power supply	Teach pendant
Program	Work envelope	Hierarchical control	End effector
Error signal	Tachometer	Direct-drive motor	Trajectory

By the end of this lesson the learner should be able to define and explain characteristics / actions related to these technical terms

# Robot Designed for Precise Path-oriented Tasks

## *Components of an Industrial Robot*

- Shoulder
- Upper arm
- Elbow
- Forearm
- Wrist

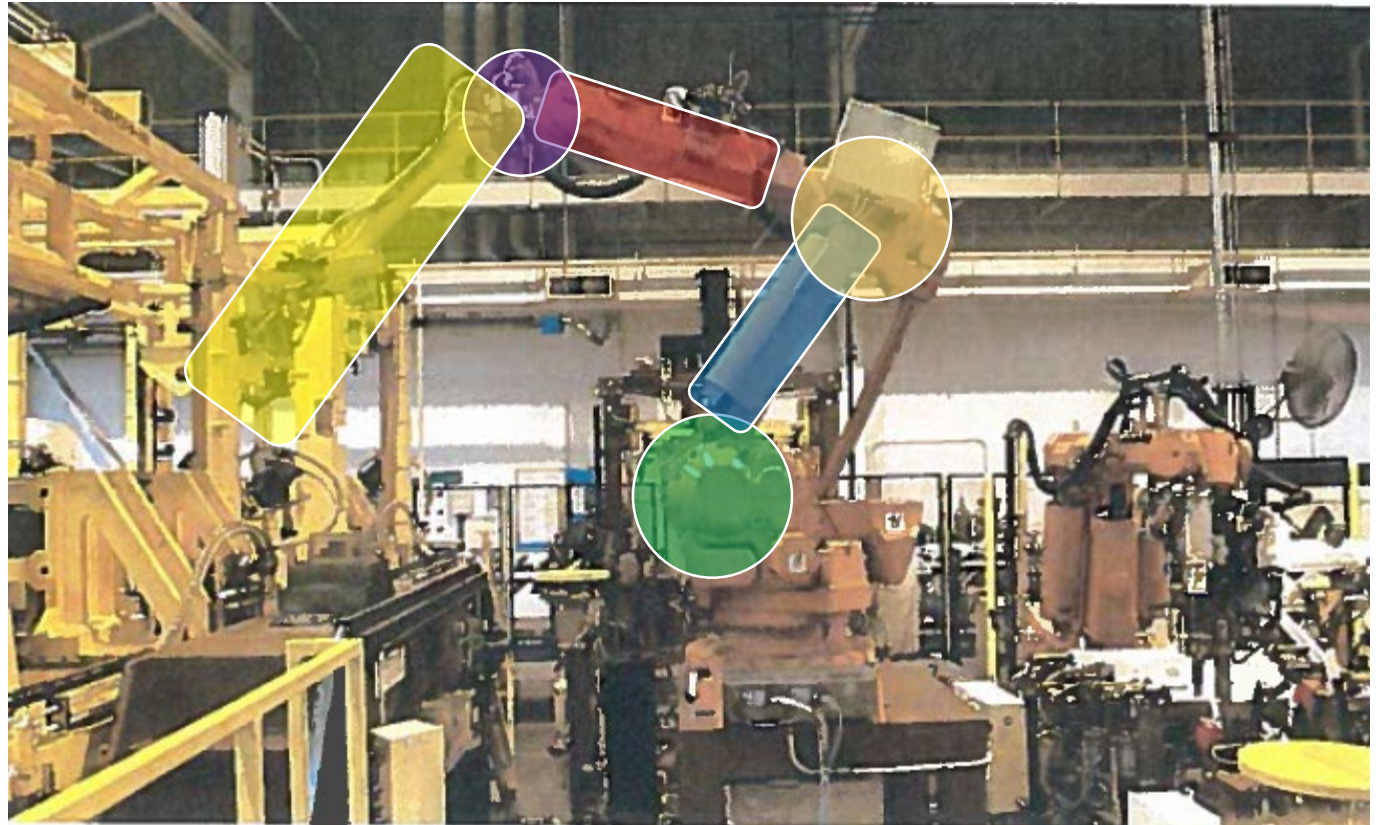


(Reis Machines, Inc.)

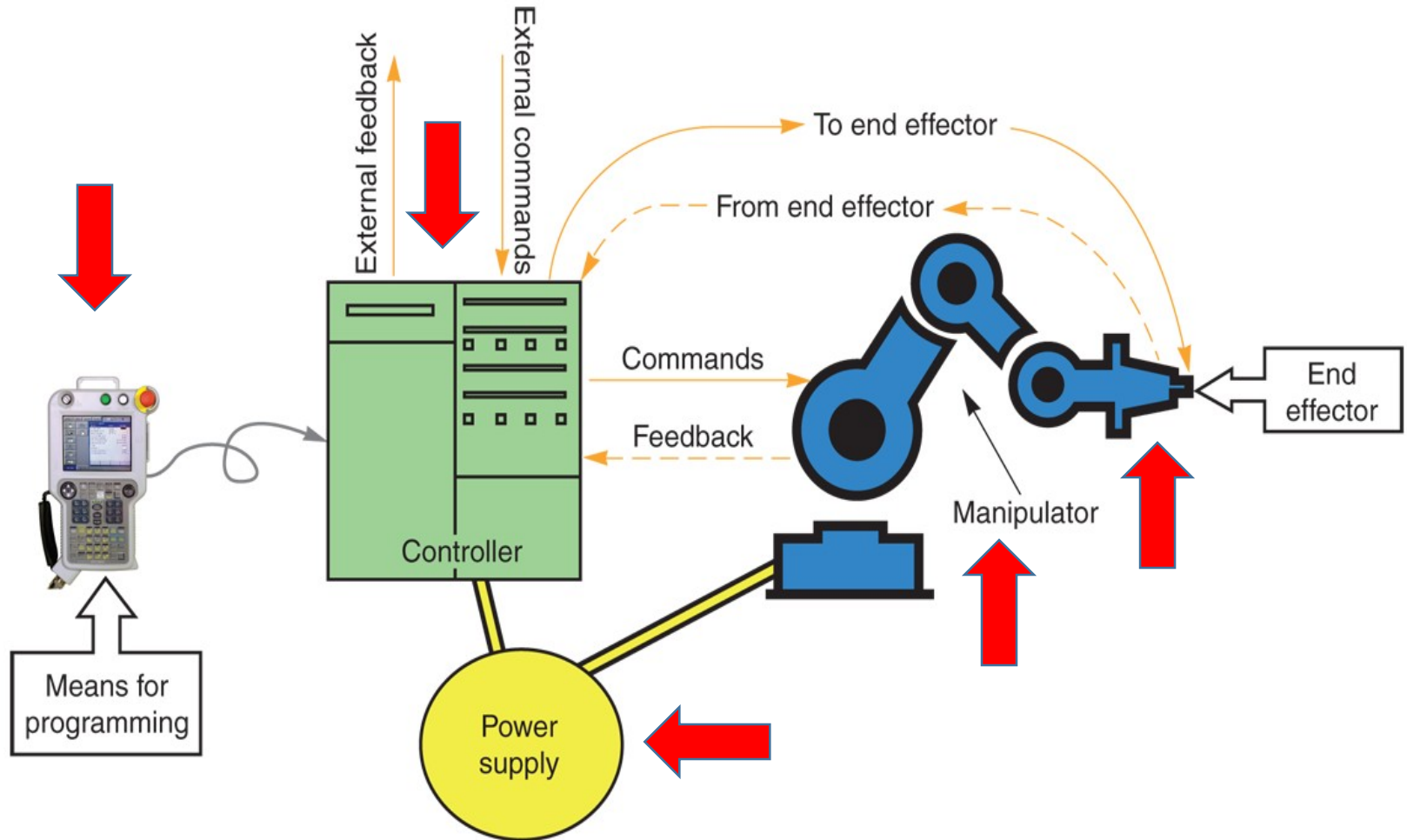
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# Robot Components on an Industrial Robot

- Shoulder
- Upper arm
- Elbow
- Forearm
- Wrist



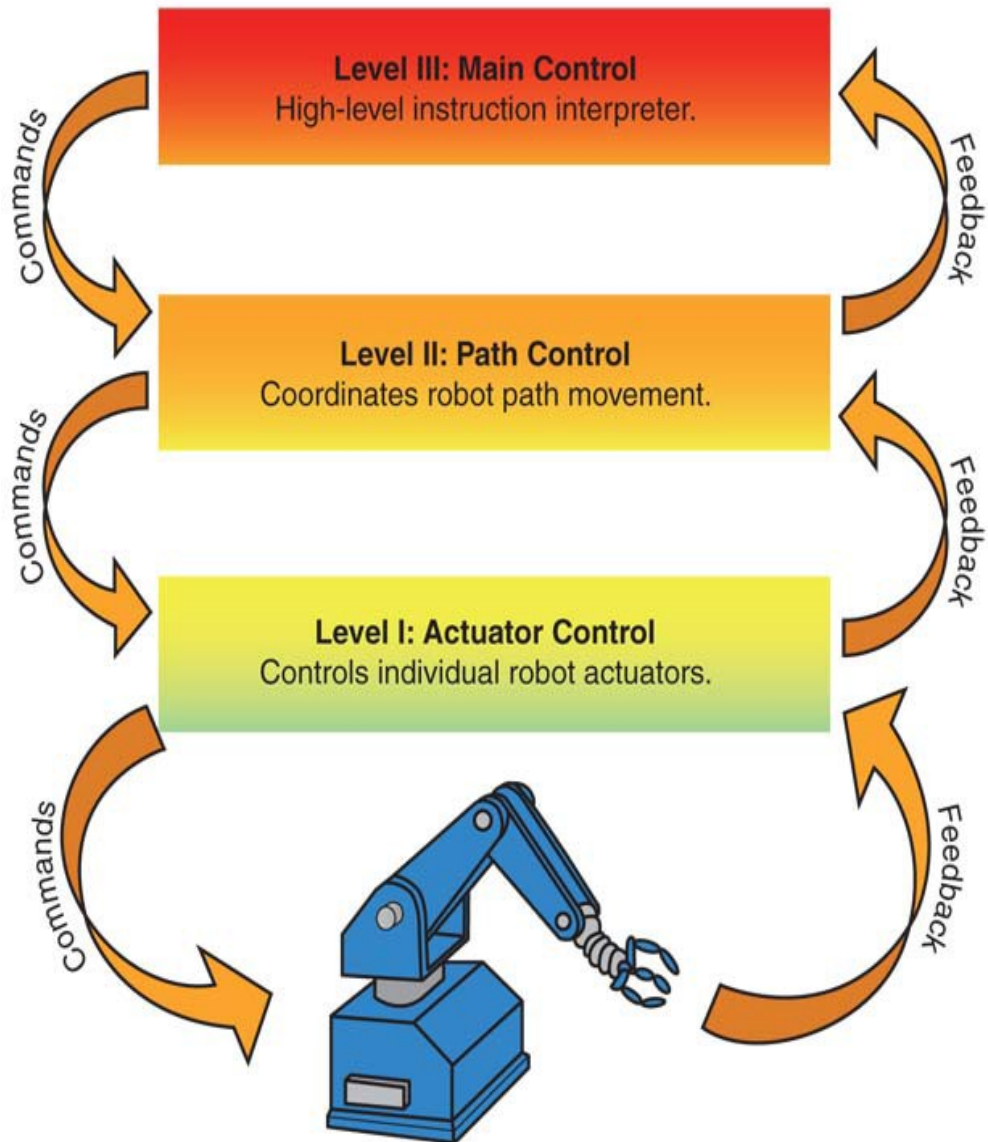
# Relationship of Robot Systems



# Industrial Robot Controller

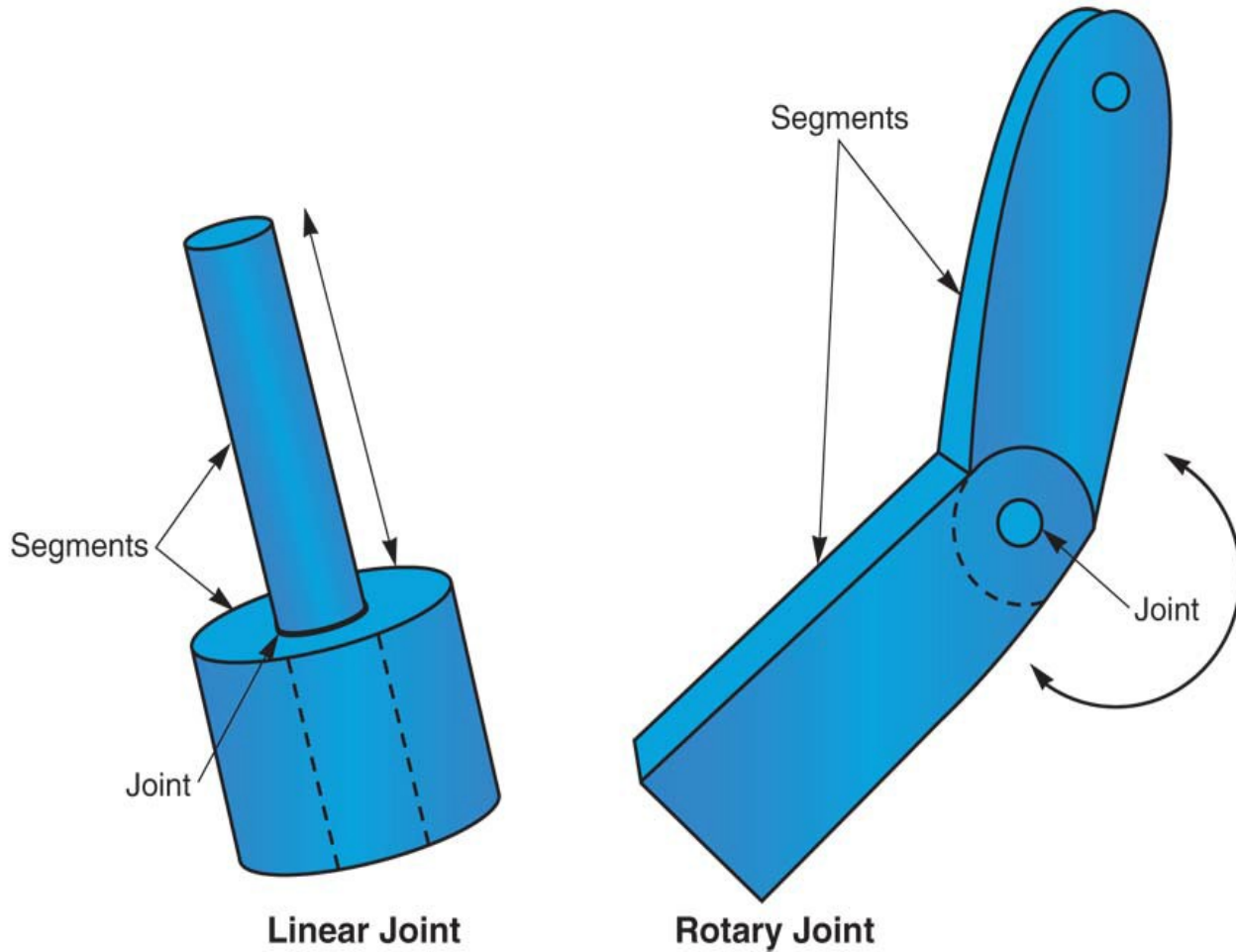


# Hierarchical Control

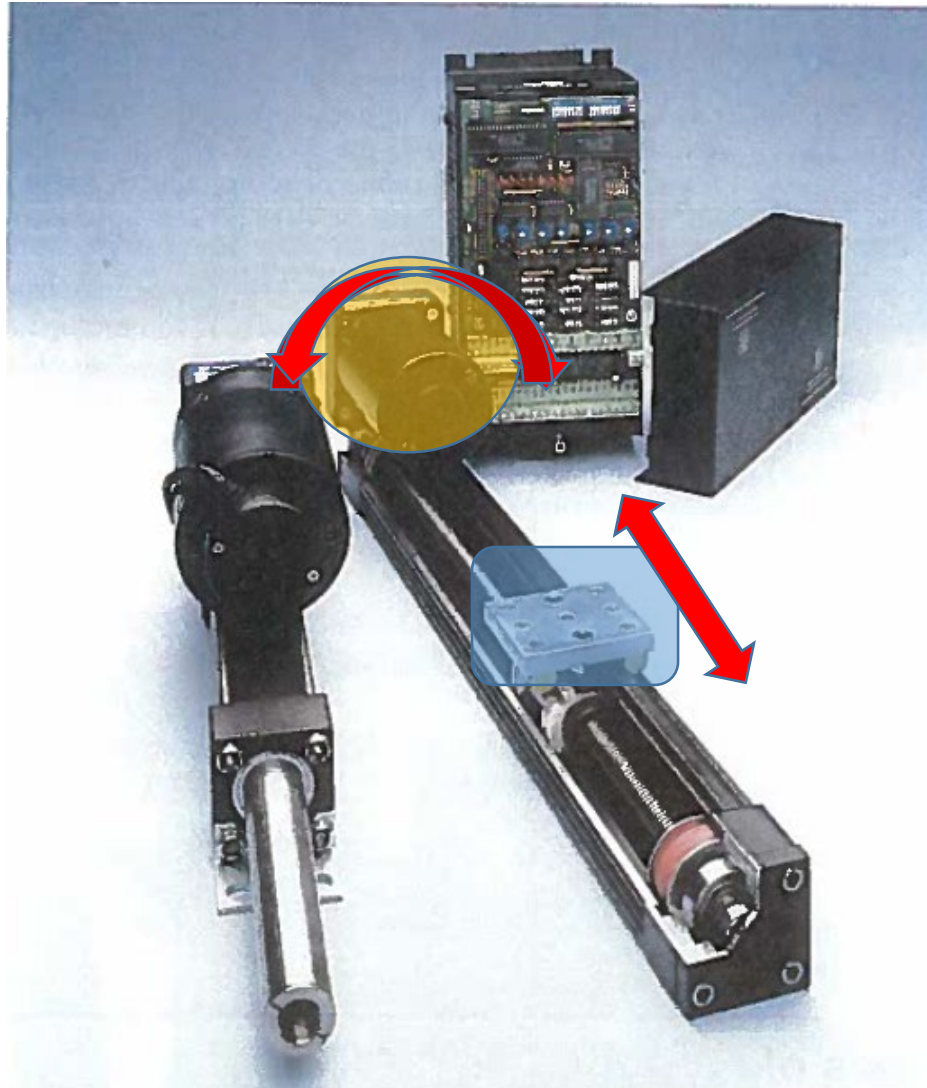




# Types of Motion Provided by Actuators



# Rotary Motion to Linear Motion



# End Effector



# Power Supply



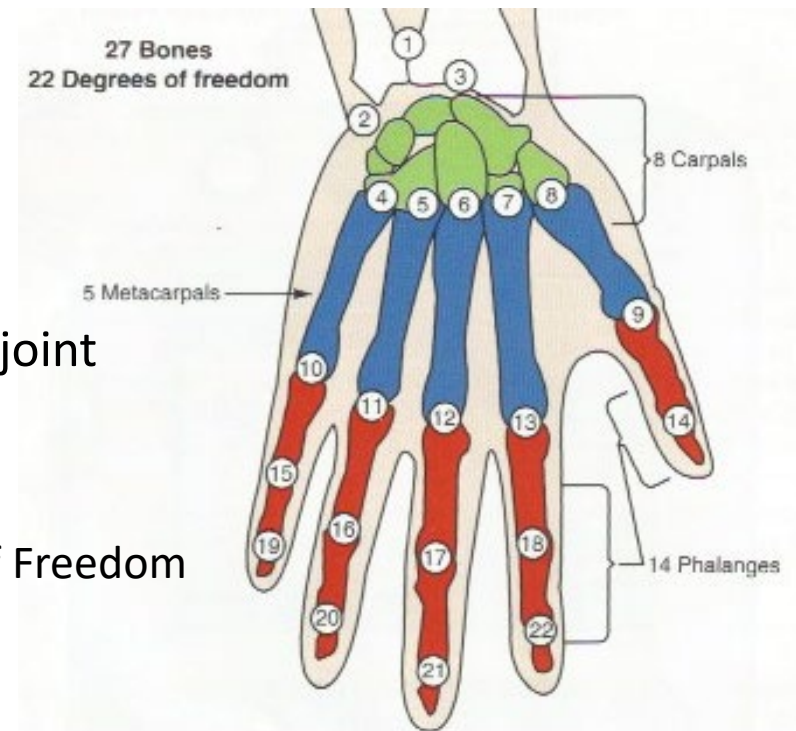
# Teach Pendant



# Degrees of Freedom

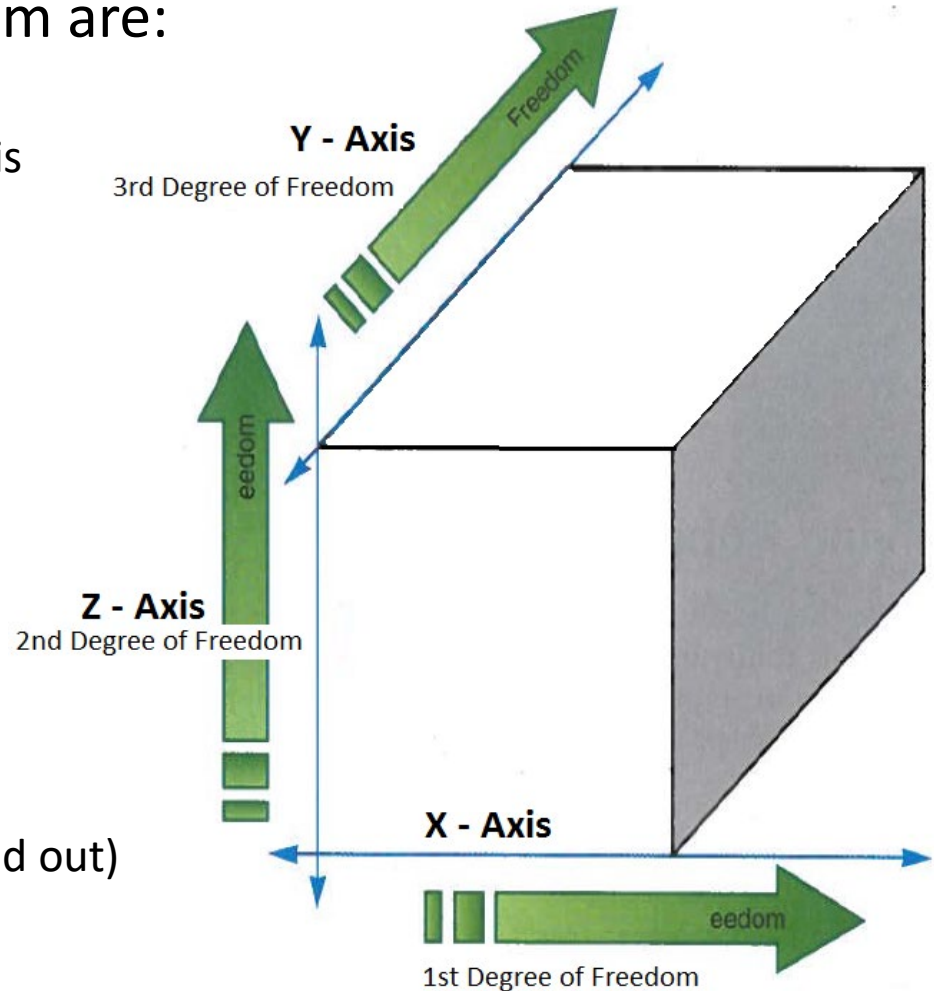
## ***Degrees of Freedom:***

- Describes the robots freedom to move in 3-D space, more specifically to move:
  - Forward and backward
  - Up and down
  - Left and right
- Each degree of freedom requires a joint
- Point of interest:
  - The human hand has 22 Degrees of Freedom



# Degrees of Freedom

- 3 basic degrees of freedom are:
  - Rotational traverse
    - Movement on a vertical axis
    - 'X' axis
    - Left to right (side to side)
  - Vertical traverse
    - Up and down
    - 'Z' axis
  - Radial traverse
    - Extension and retraction
    - 'Y' axis
    - Forward & Backward (In and out)

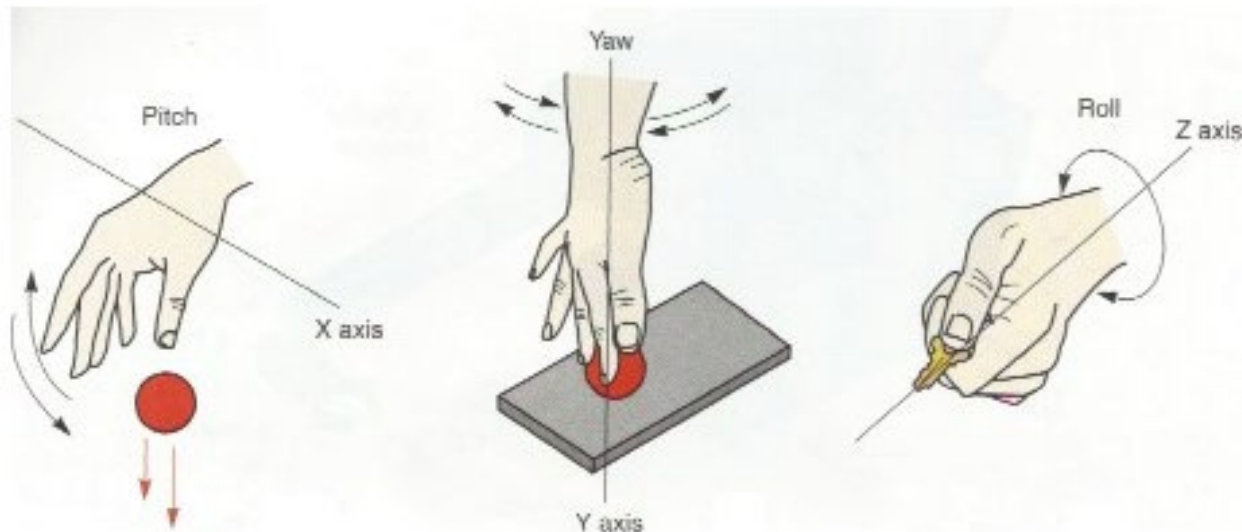


# Degrees of Freedom

## Three Minor Degrees of Freedom (“wrist”)

### The robot wrist:

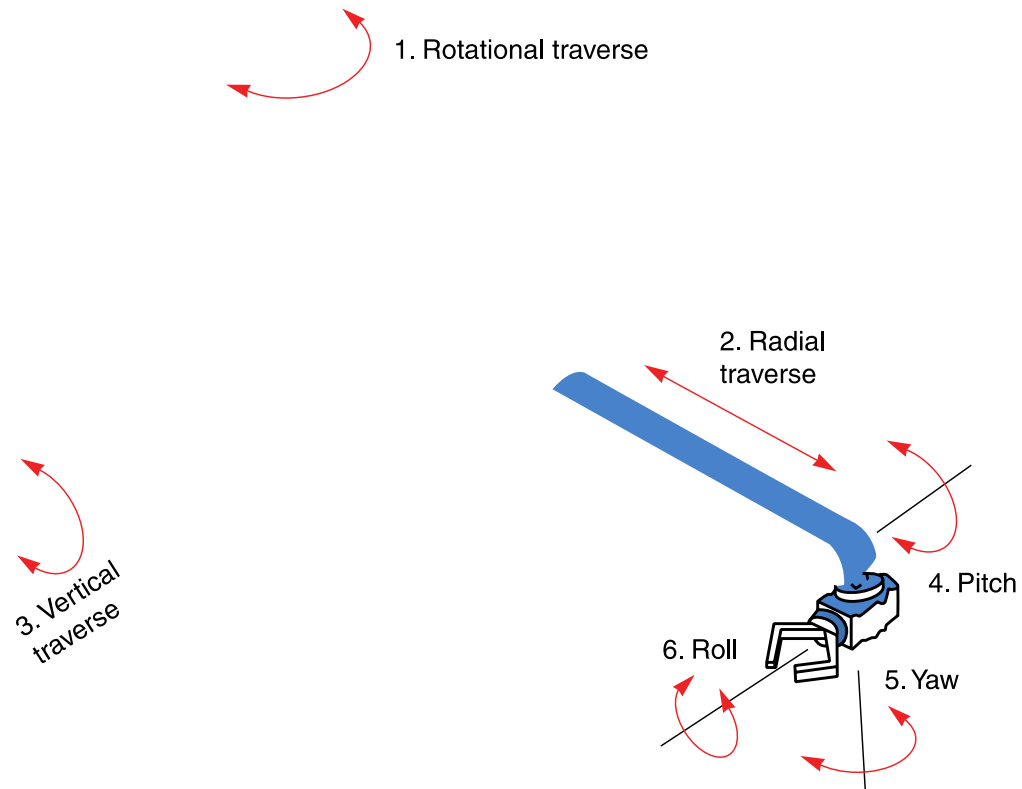
- Increases the end effector (end-of-arm tooling) flexibility
- The wrist uses three additional degrees of freedom
  - Pitch – the bend or up and down movement of wrist
  - Yaw – the side to side movement of the wrist
  - Roll – the swivel or rotation of the wrist





# Degrees of Freedom

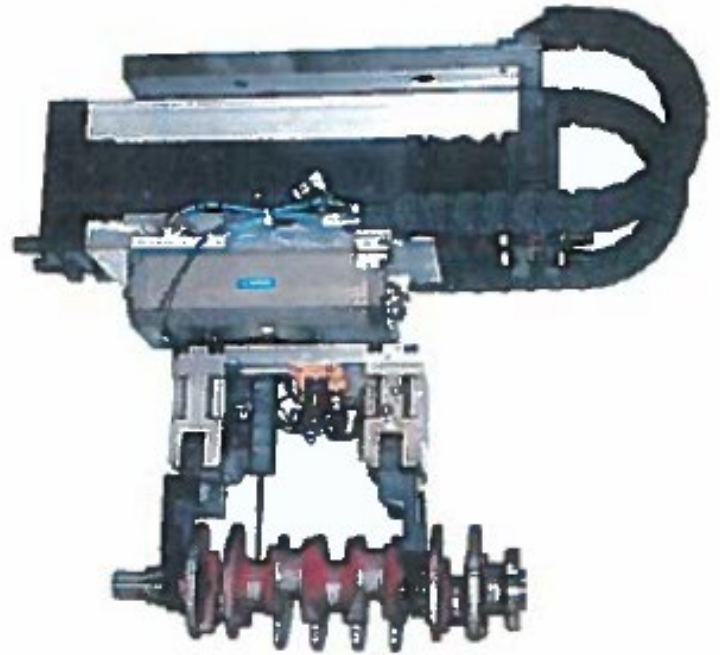
## Robot's Six Degrees of Freedom



# Gantry Robot



A



B

# Rack-mounted Robot with Eight DOF

Rotational traverse

Left to right

Vertical traverse

Up and down

Radial traverse

Forward & Backward

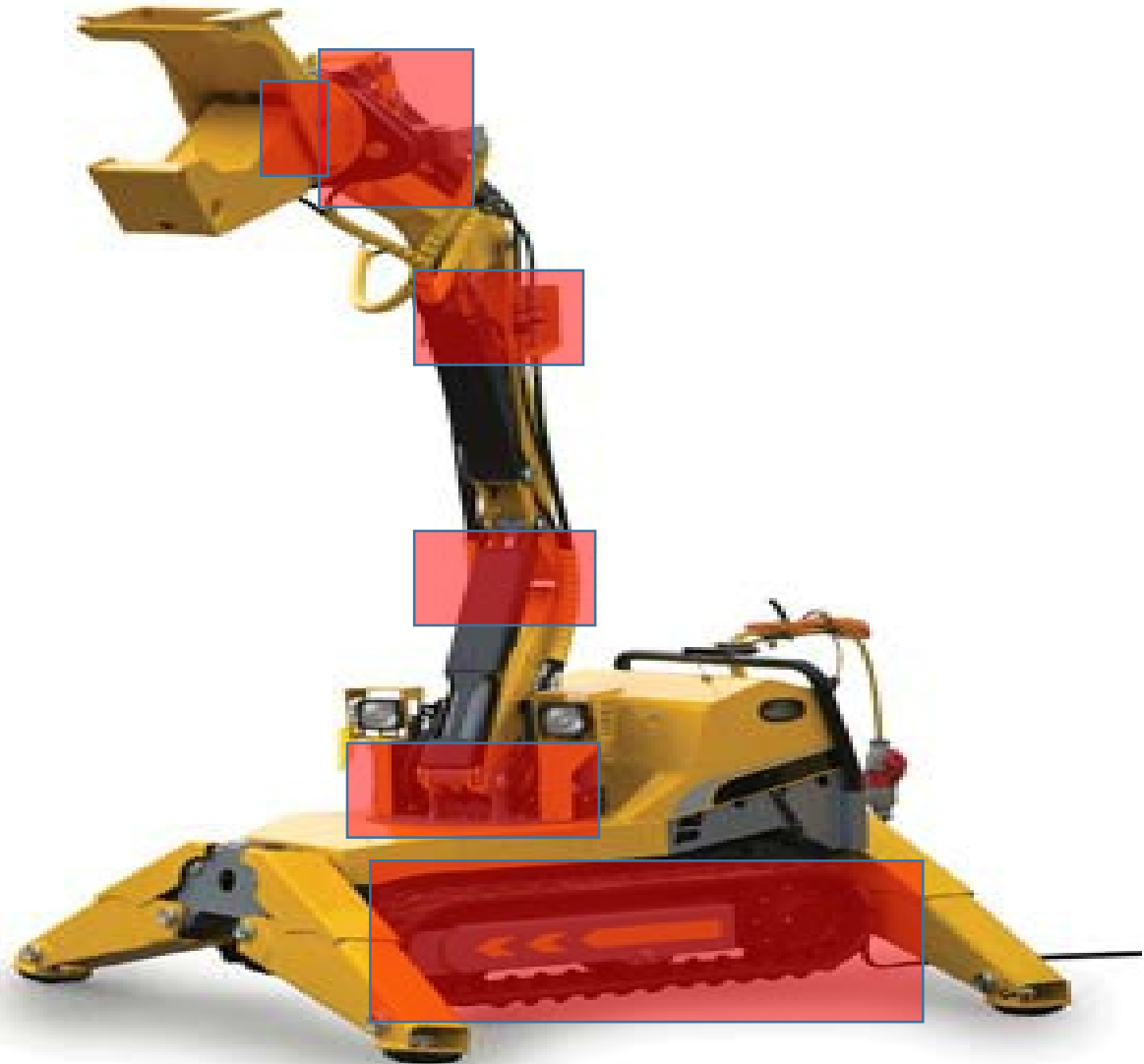
Pitch: wrist up and down

Yaw: wrist side to side

Roll: wrist rotation

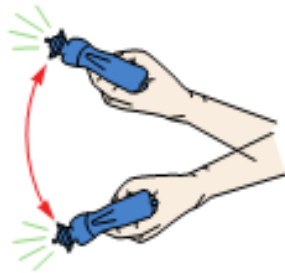
EOAT: open & close

Track: Move entire unit  
forward and backward

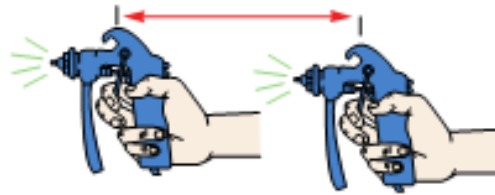


# Six Degrees of Freedom

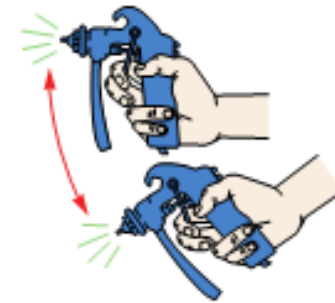
## Degrees of Freedom—Using a Spray Gun



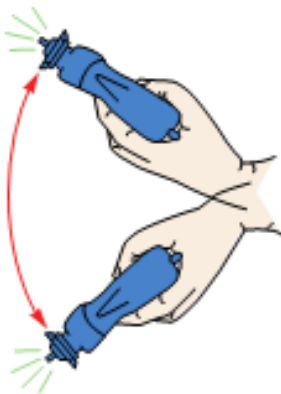
1. Rotational traverse



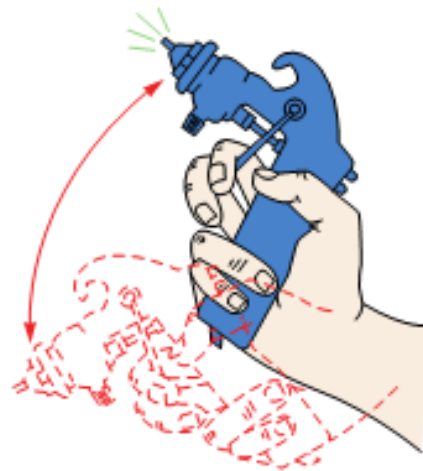
2. Radial traverse



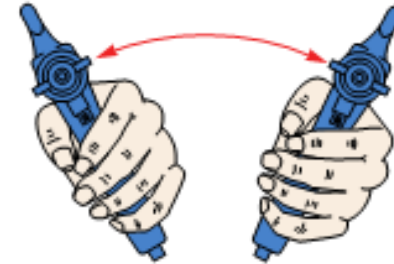
3. Vertical traverse



4. Yaw (top view)



5. Pitch (side view)



6. Roll (front view)

# Classifying a Robot

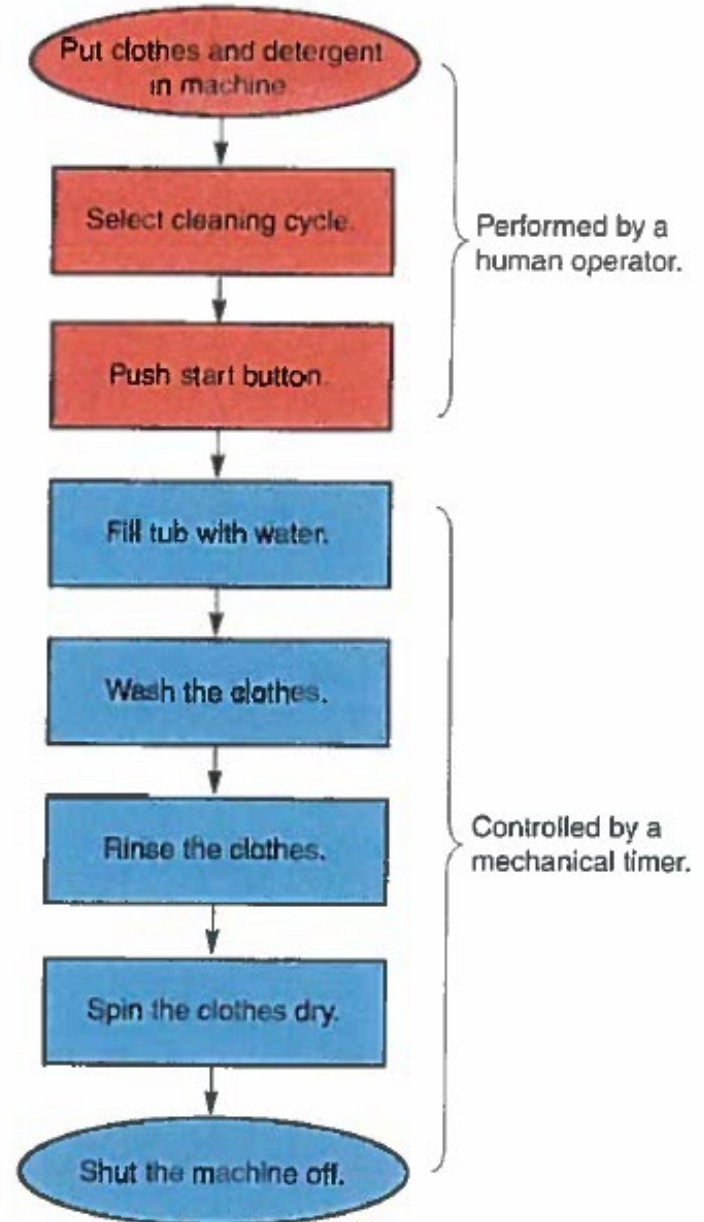
Three most common methods of classifying robots are:

- Type of control system
  - Servo
  - Non-servo
- Type of actuator drive used
  - Electric
  - Pneumatic
  - Hydraulic
- Shape of the work envelope
  - Revolute
  - Cartesian
  - Cylindrical
  - Spherical

# Classifying a Robot

## Type of control system

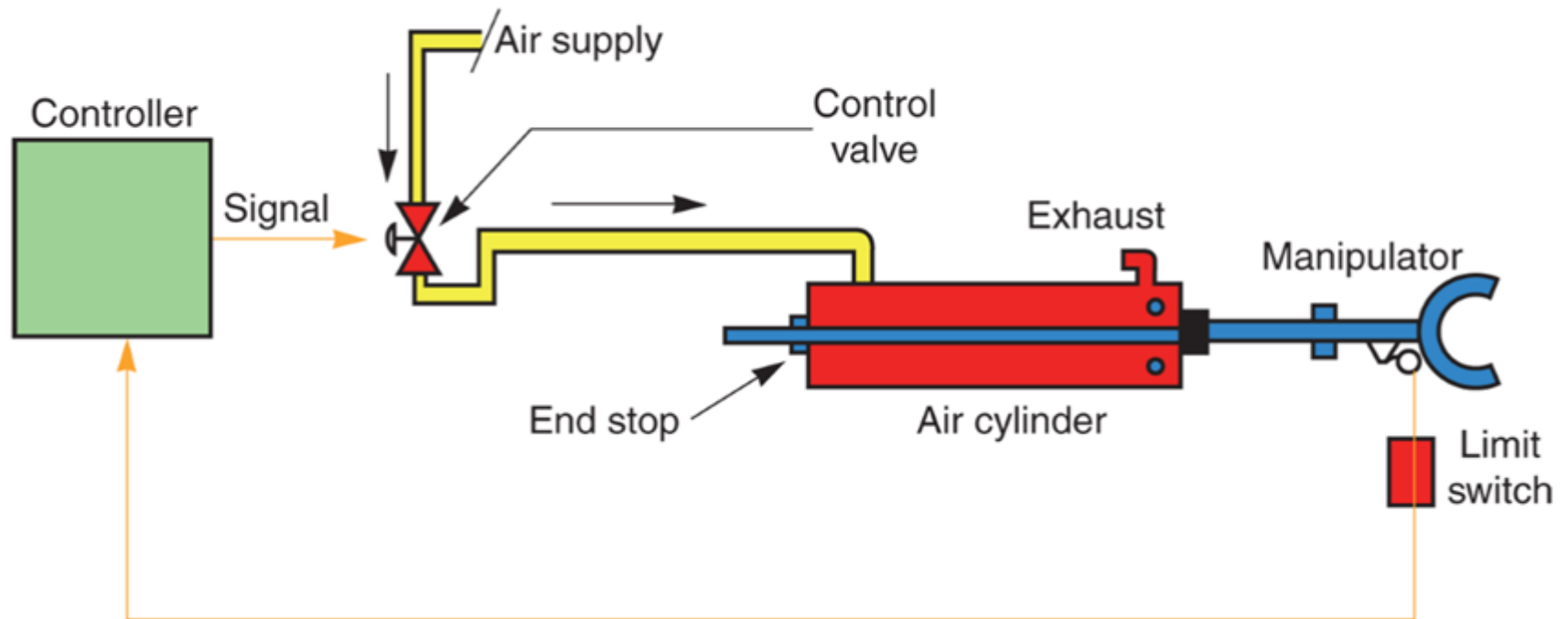
- ***Non-servo (open-loop)*** control – has no feedback signal
  - Limited sequence robot
  - Pick and place robot
  - Fixed stop robot
- Example: Wash Machine Cycle



# Classifying a Robot

## Type of control system

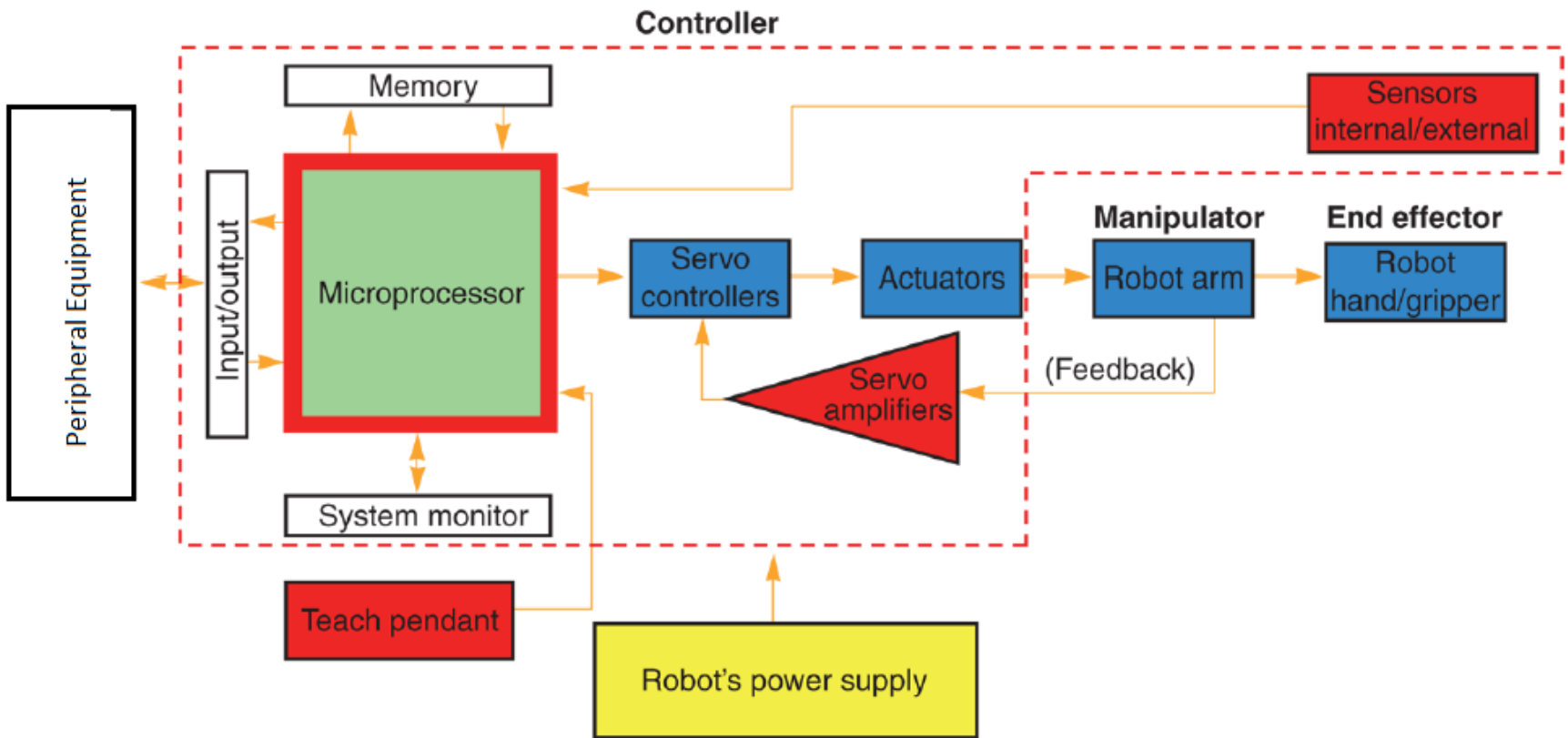
- Non-servo (open-loop) robot arm (manipulator)



# Classifying a Robot

## Type of control system

- Servo (closed-loop) – uses feedback to allow correction



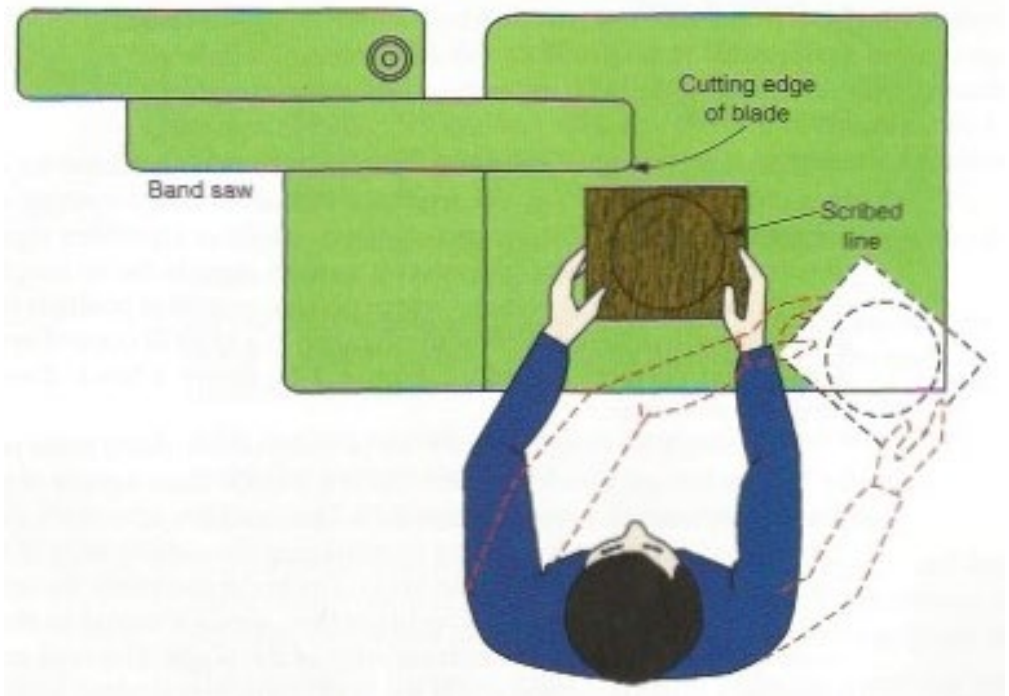


# Classifying a Robot

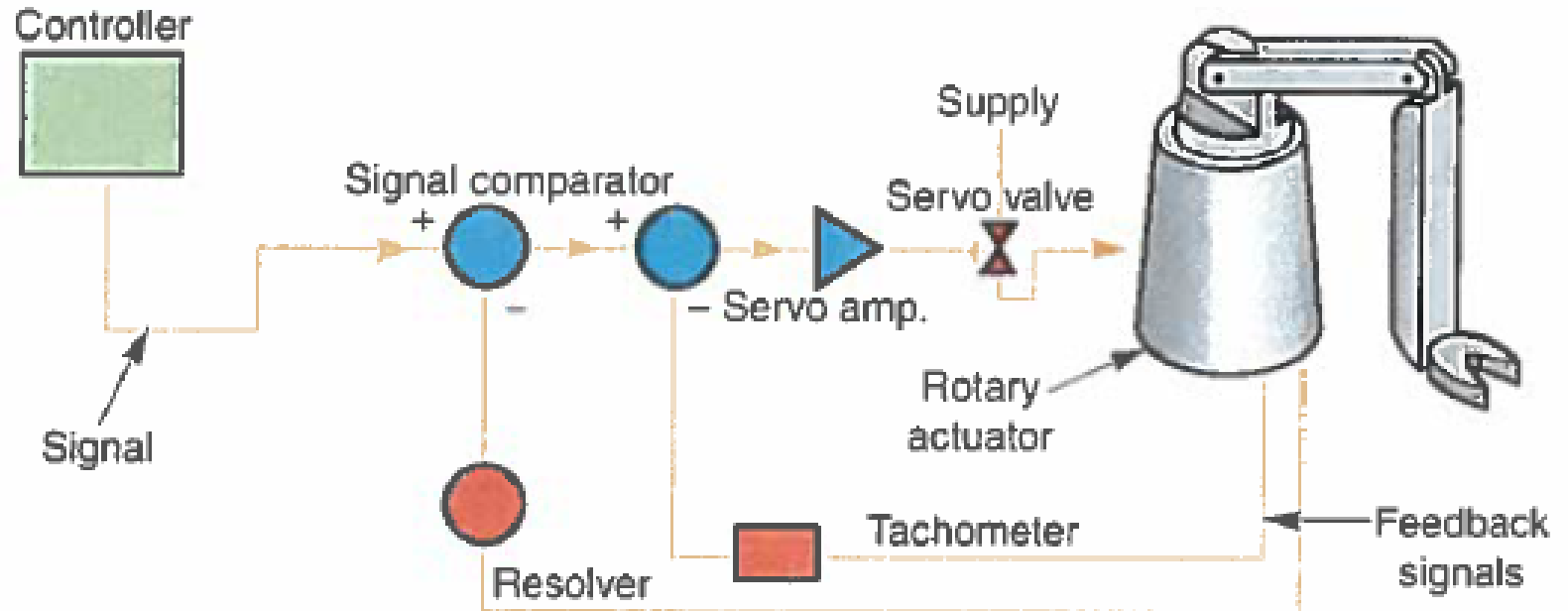
## Type of control system

- Servo (closed-loop) – uses feedback to allow correction
  - Allows precise control of position or velocity
  - Detects and corrects for errors

- Example: Band saw cut



# Classifying a Robot



# Classifying a Robot

## Type of actuator drive

- Electric
  - Alternating Current (AC) Servo Motors
  - Direct Current (DC) Servo Motors
  - Stepper Motors
- Hydraulic – Fluid system using oil
- Pneumatic – Fluid system using compressed air

# Classifying a Robot

## Type of actuator drive

- Electric
  - One of three common types of electric actuator drives:
    - AC Servo motors
    - DC Servo motors
    - Stepper motors

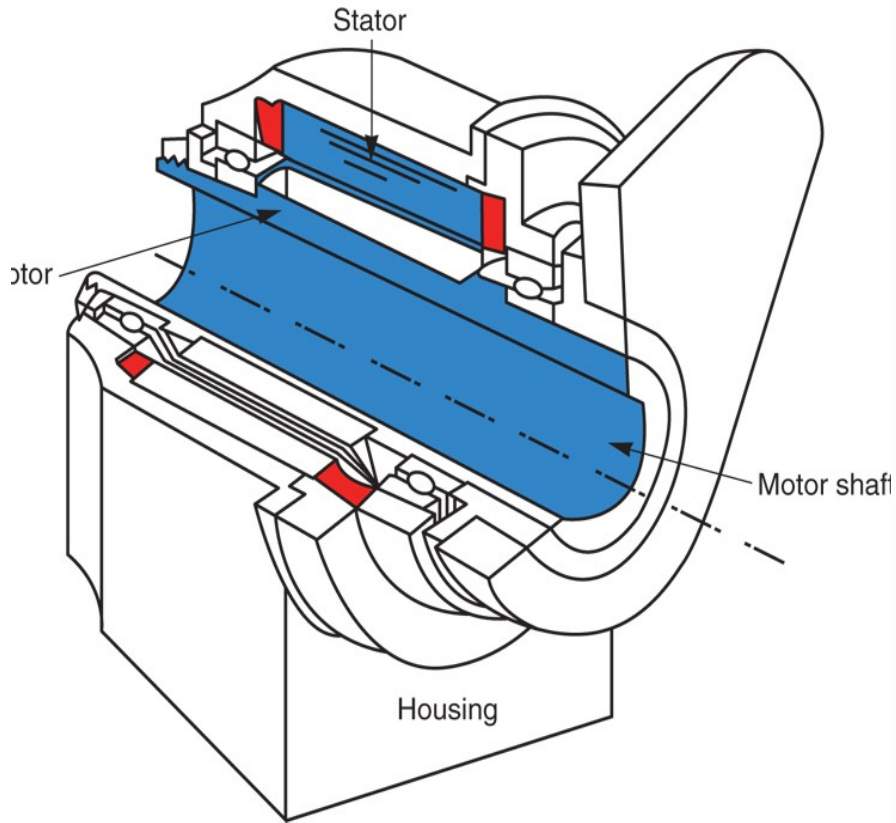


# Classifying a Robot



Stepper Motors

# Classifying a Robot

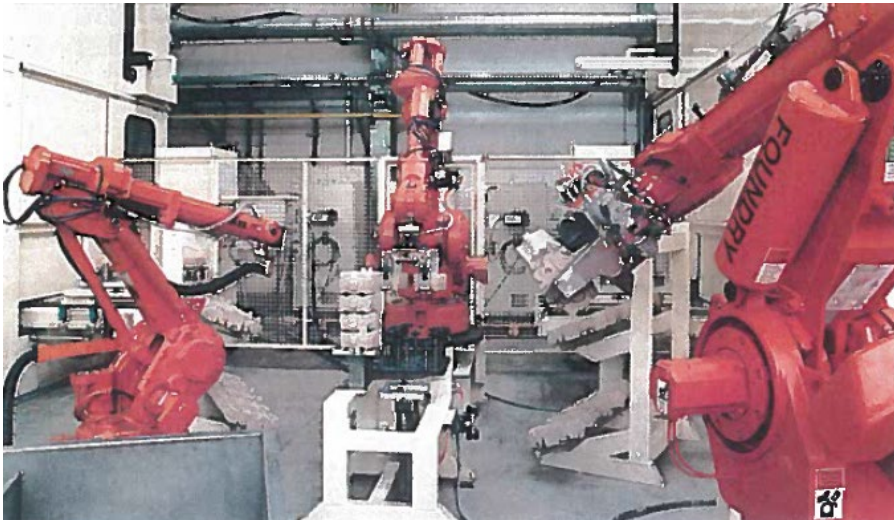


Direct-drive Motor

# Classifying a Robot

## Type of actuator drive

- Hydraulic – uses oil
- Pneumatic – uses compressed air
- Both considered to be “fluid power”



Hydraulic  
actuator

Hydraulic Actuator Drives

# Classifying a Robot

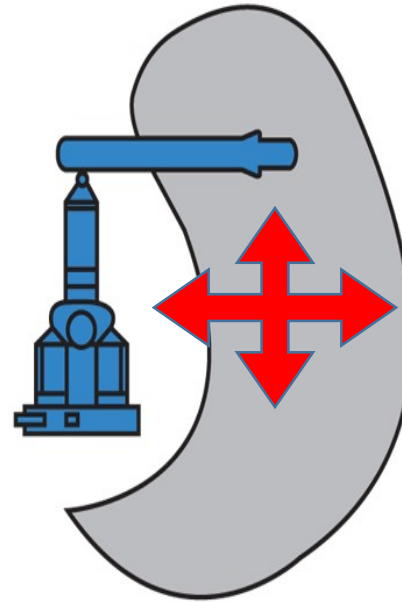
## Shape of the *work envelope*

- Determined by many factors:
  - *Coordinate system* used
  - Arrangement of the robot arm joints
  - Length of the manipulator segments
  - Reach of the *end effector* wrist
- *Work area* – determined by a point on the robot's wrist and **does not include the EOAT**
- *Work envelope* includes EOAT and is **slightly larger than the work area**

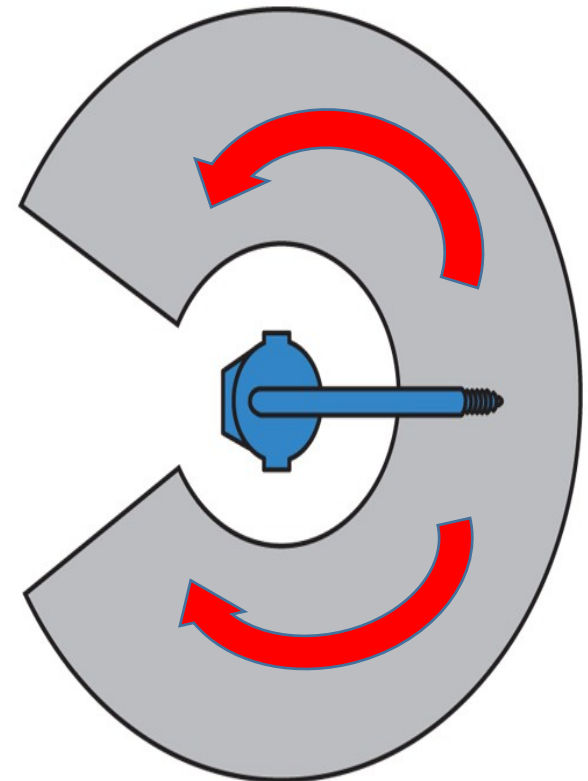


# Classifying a Robot

## Revolute Configuration—Vertically Articulated



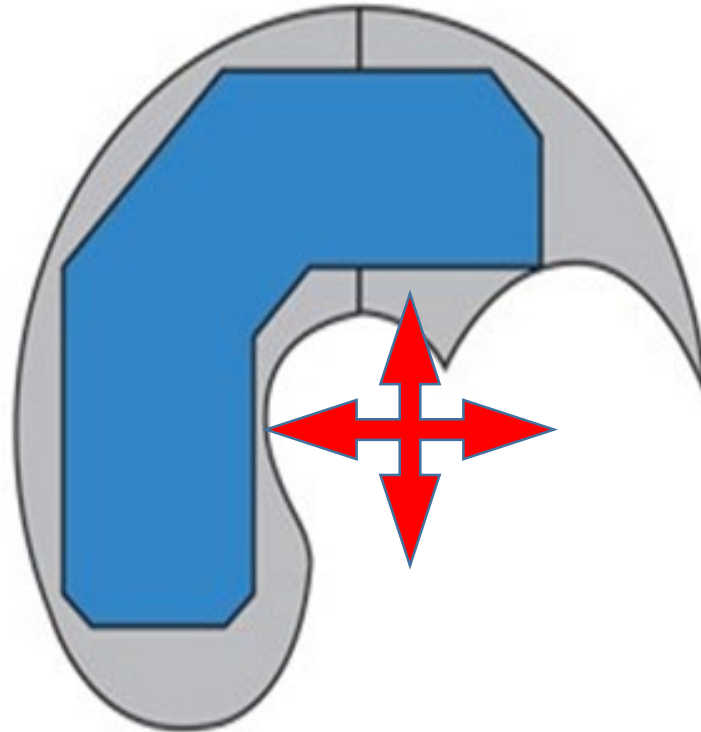
(Side view)



(Top view)

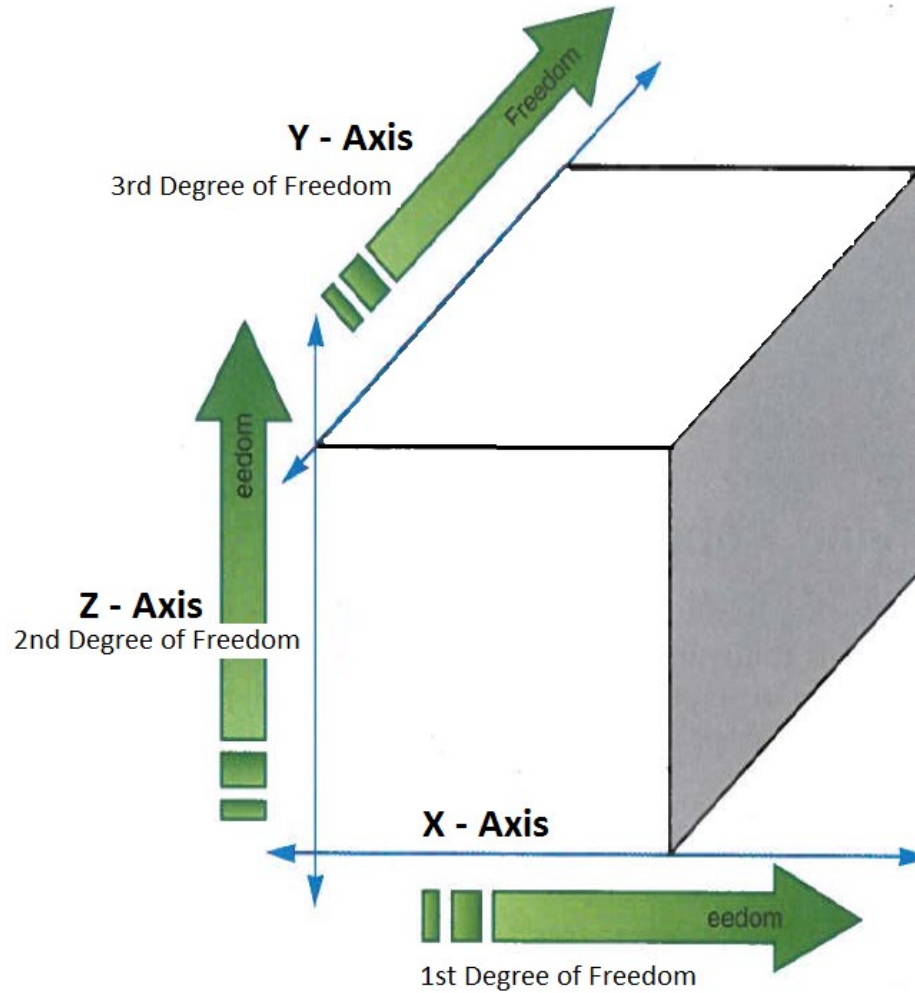
# Classifying a Robot

## SCARA Configuration

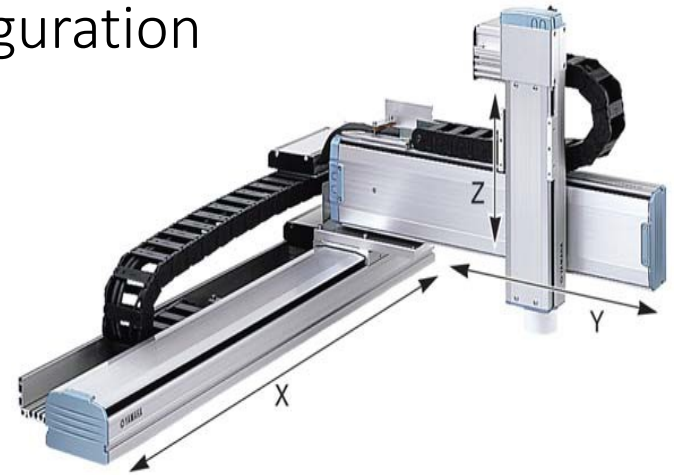


# Classifying a Robot

## Cartesian Coordinate Configuration

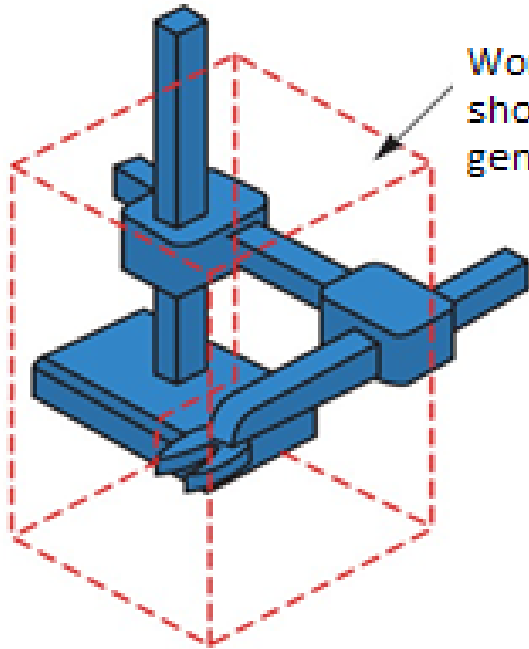


# Classifying a Robot Cartesian Configuration

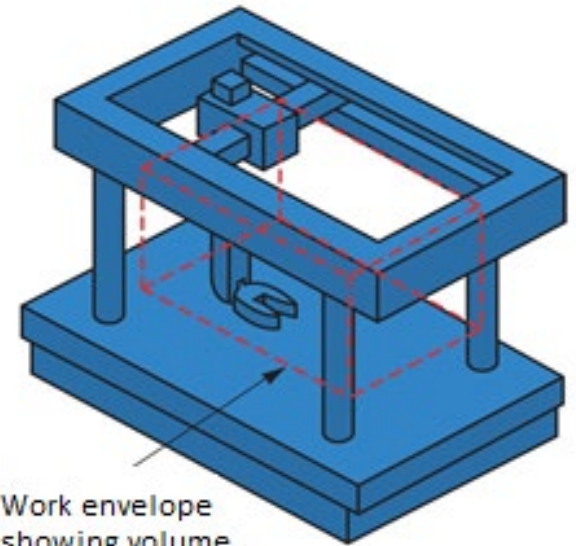


**Gantry Configuration**

**Standard Configuration**



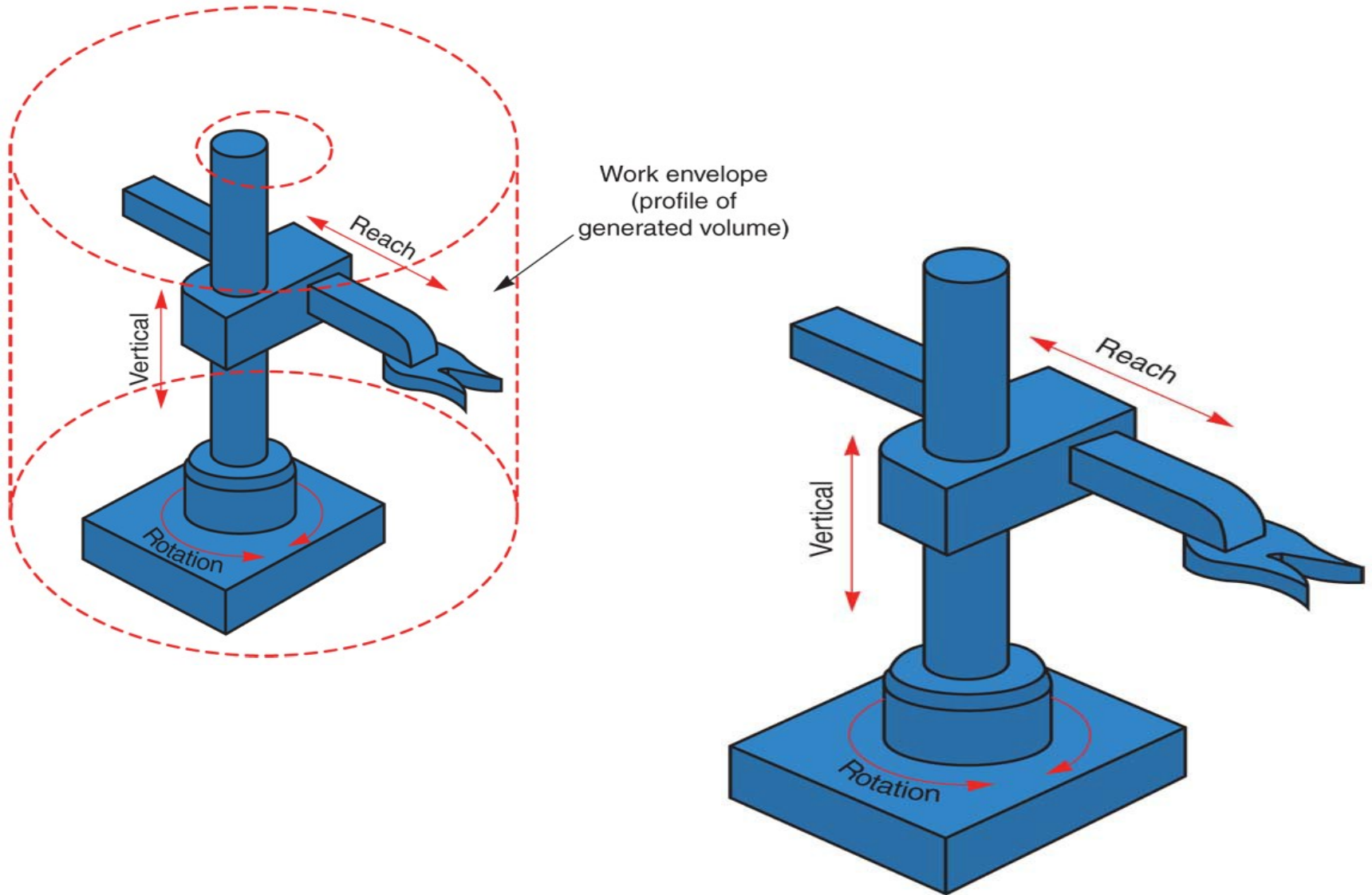
Work envelope  
showing volume  
generated



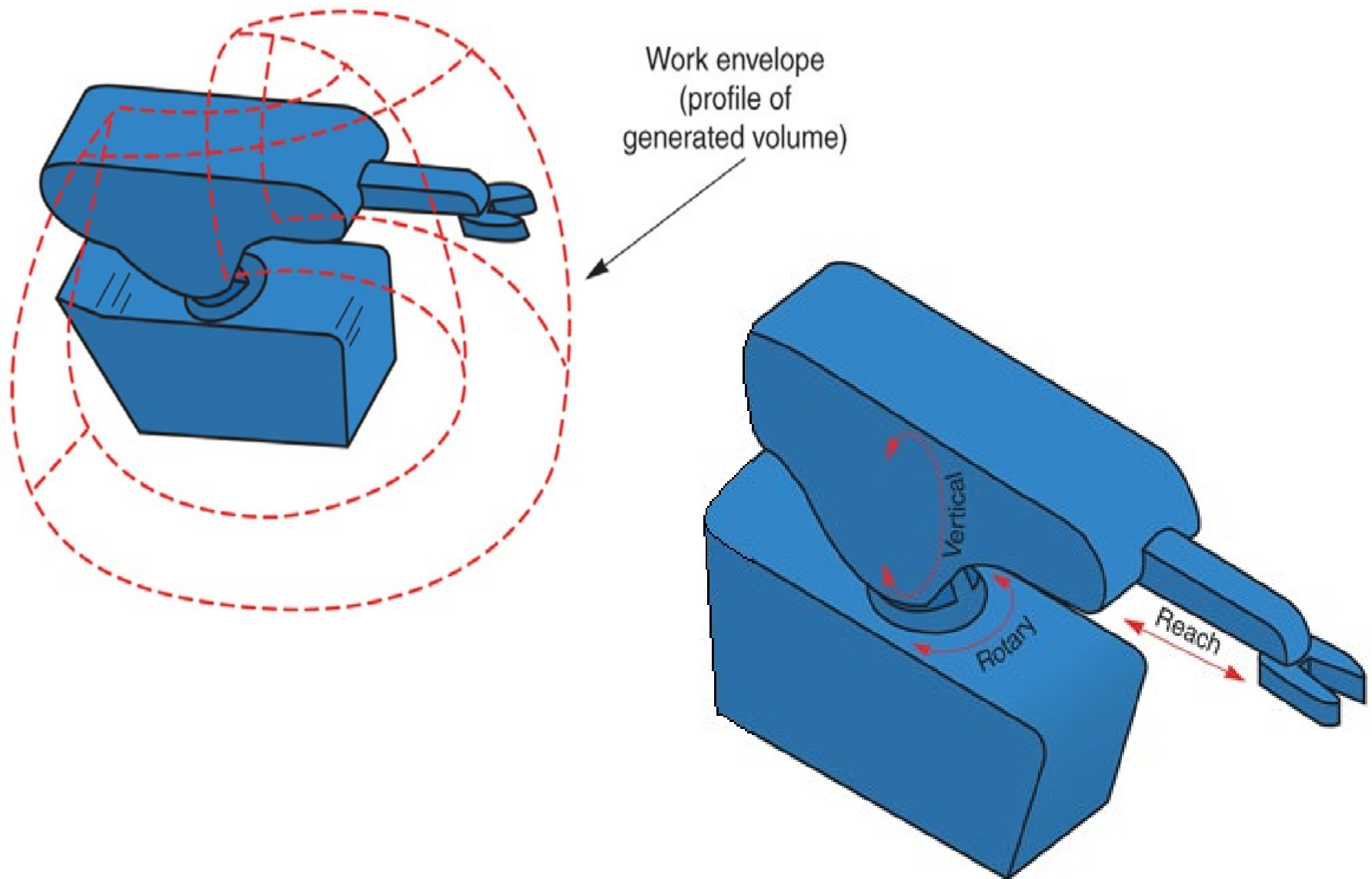
Work envelope  
showing volume  
generated

# Classifying a Robot

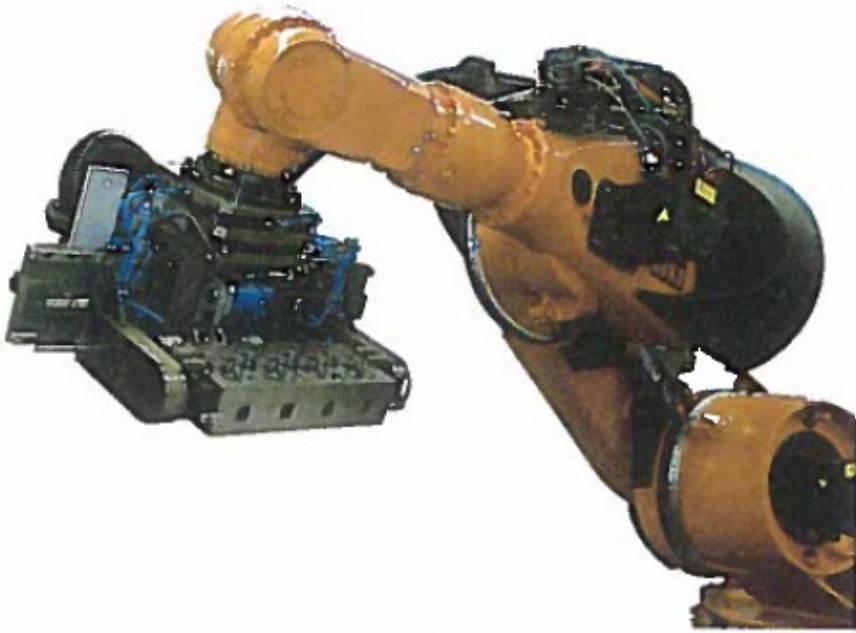
## Cylindrical Configuration



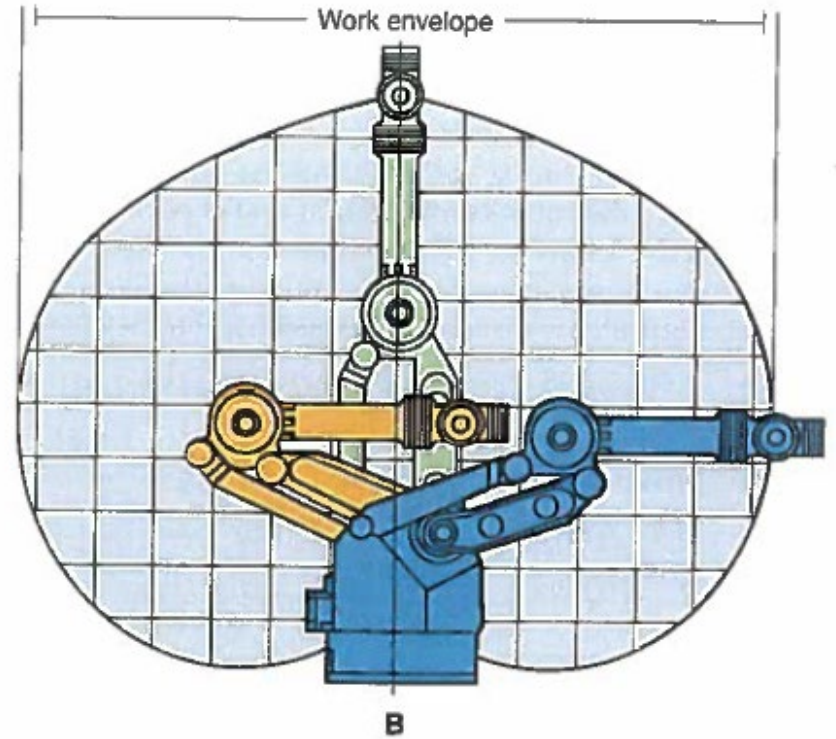
# Classifying a Robot Spherical Configuration



# Classifying a Robot



A



B