**SMFG - 386**
**Manufacturing Automation**
**Week 1/ 2**
**H. Sinan Bank**

# Introduction

Kinematics is a way o describe motion. It is used to describe position and orientation with respect to time.

In terms of an industrial robot, it describes the calculations used to determine the Position of the operating end of the robot in relation to the current angles of the joints and the known dimensions of the robot's hardware.

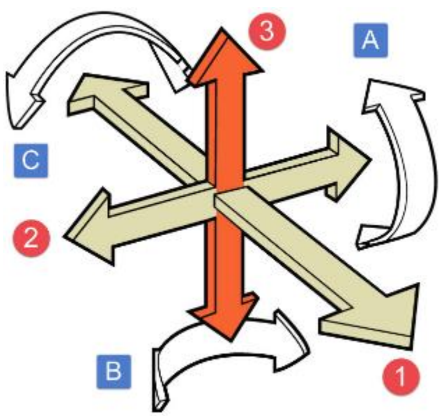
When working with industrial robots, the term inverse kinematics is also common. Inverse kinematics is the finding of required robot's joint angles to reach the target position and orientation.

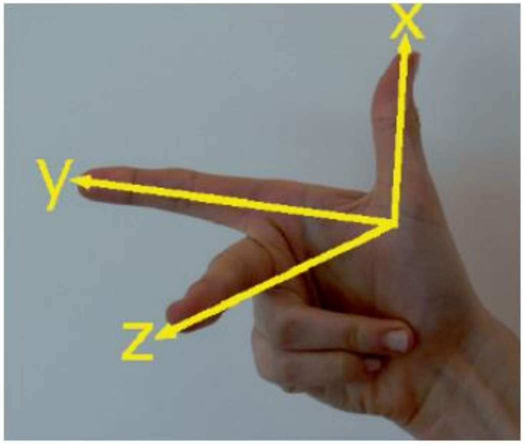
# Degrees of Freedom

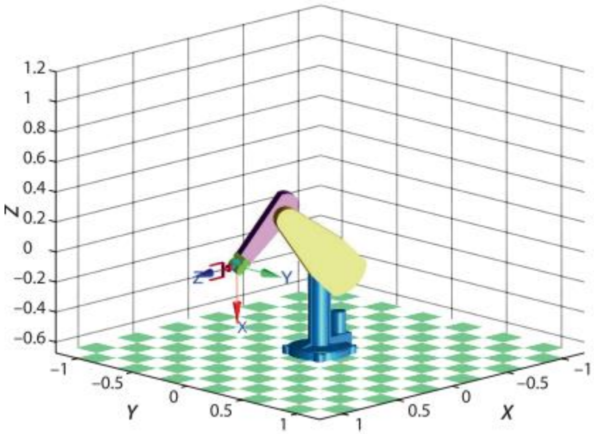
The term ‘degrees of freedom’ means the number of unique directions in which motion is possible. As an example, a hinge has one degree of freedom. It can rotate around the hinged axis.

In terms of an industrial robot, each joint may typically create one DoF. Some joints will allow the arm to move up or down, some will move left or right, and some will move forward or backward. Others will allow rotation in different planes.

This image demonstrates the six degrees of freedom.



# Degrees of Freedom

The image shown here depicts a typical SCARA robot, which offers 4 degrees of freedom.

- The first 2 joints offer position in X and Y axes
- The third axis gives the vertical (Z) motion
- The 4th axis provides rotation around Z (yaw)

The design of the SCARA robot does not allow for pitch or roll.

# Coordinate System

Commanded positions are given to a robot based on a coordinate system.

There are numerous coordinate systems which can be applied to any robot, and different commands may be issued in different coordinate systems on the same robot. The coordinate systems are:

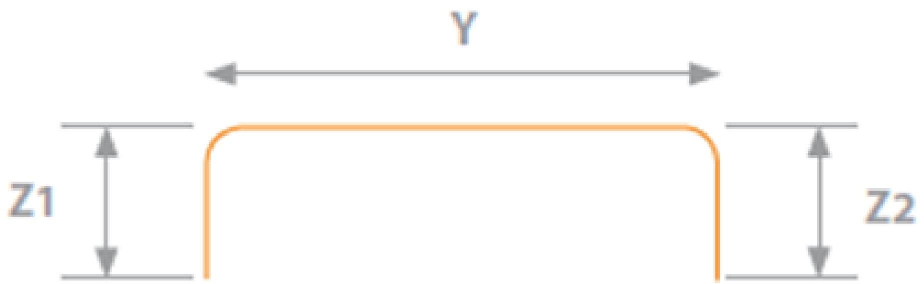
- Machine Coordinate System (MCS) position is based on the robot's mounting location
  - The MCS is fixed and cannot be changed by the user
  - Each robot will only offer 1 MCS
  - The term MCP (machine center point) is used to indicate the zero position
- User Coordinate System (UCS) represents a custom coordinate system designed by the user
  - Many UCS can be configured on the same robot
  - Can be used to account for conditions like rotated mounting, or offsetting the zero positon of the robot
- Tool Coordinate System (TCS) is typically used to give the commands to a robot in terms of the location of the tooling or end effector
  - Multiple TCS can typically be defined on the same robot
  - A tool center point (TCP) is used to identify the zero position of a TCS

# Parameters

## Cycle Time

For comparison, there has to be a way to measure the speed of different robots.  So a standard motion profile was conceived.  The standard cycle is described as 1 inch up (25mm), 12 inches across (305mm), 1 inch down (25mm), and then return via the same path to the origin point.

Robot manufacturers will typically indicate robot speed in cycles per minute.

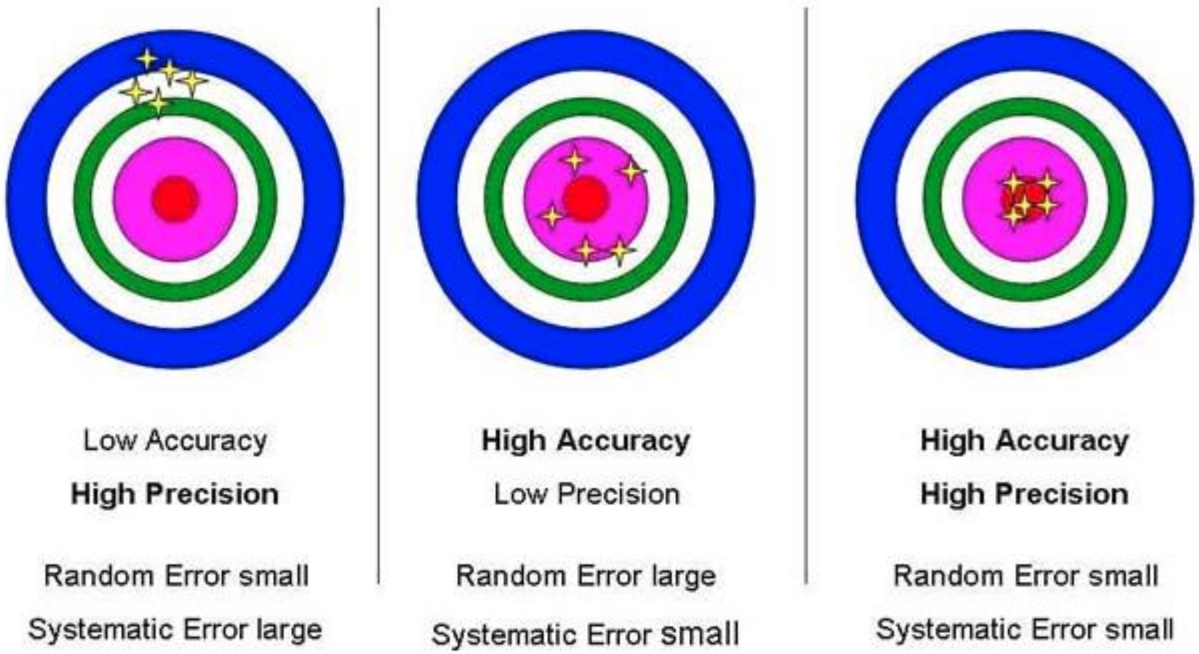



## Payload

Payload is the maximum amount of weight the robot can move.

It is very important to understand that the robot's payload rating must take into account not only the item the robot is moving, but any tooling or attachments made to the arm of the robot, as that weight is also being moved.

## Accuracy v.s. Repetability




- Accuracy is the difference between the commanded location of the robot and the actual position.
- Repeatability is the ability to achieve the same point multiple times when given the same commanded position multiple times. Repeatability is also sometimes referred to as precision.

# Direct Drive Motor

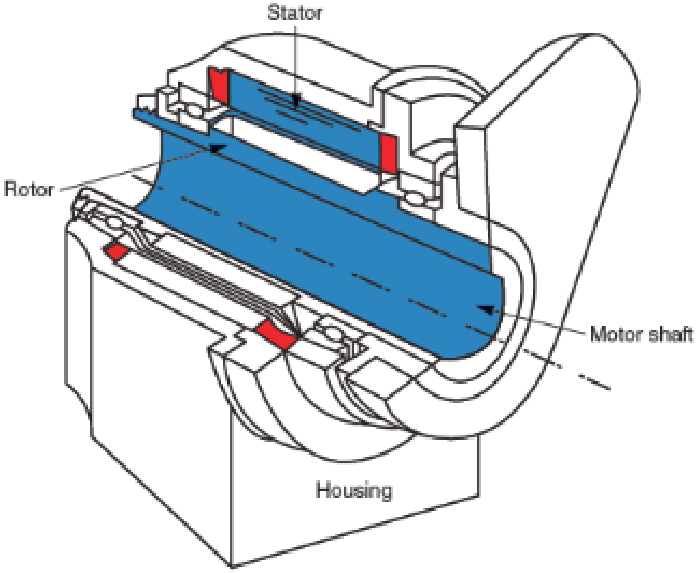
A direct drive motor couples the robot arm directly to the motor shaft, without requiring gear boxes.

Direct drive motors also typically offer hollow shafts, making wiring of tools or air lines inside the body of a robot easier.

By eliminating the gearboxes and having the motor effectively inside the robot's joint, space is saved on the outside of the robot. It also serves to reduce backlash and friction while increasing stiffness of the robot joints.

Direct drive motors are capable of very high torque.

This image shows a typical cutaway view of a direct drive motor.





# End effectors

The end effector (or end of arm tooling) is the device mounted at the end of the robot arm which is being controlled. Typically this is where any tooling, machining or gripping devices are attached to the robot arm.

Many vendors offer many solutions for end effectors. Some are grippers with fingers to grasp a product, while others are suction based. The end effector is typically very application-specific, so there are a wide variety of standard and custom solutions.

In cases where a robot may be used for inspection, the end effector may even be a camera.

There are a variety of factors to be considered when selecting an industrial robot.

Some of the important variables are:

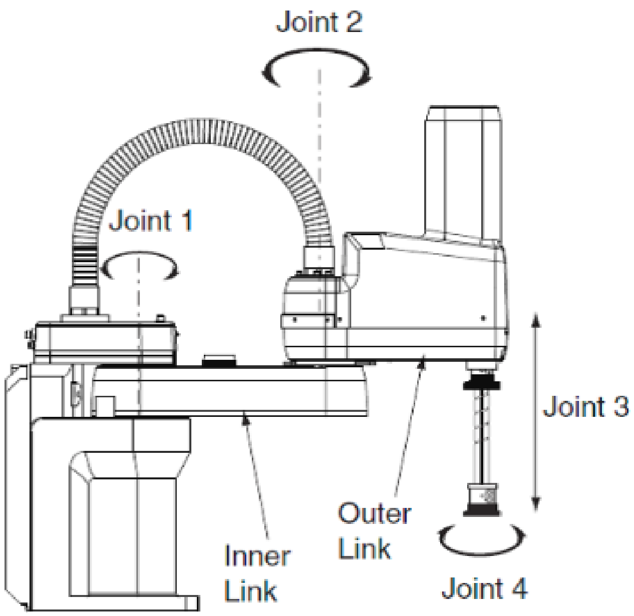
- Speed
- Repeatibility
- Operating Environment
- Payload
- Range of motion

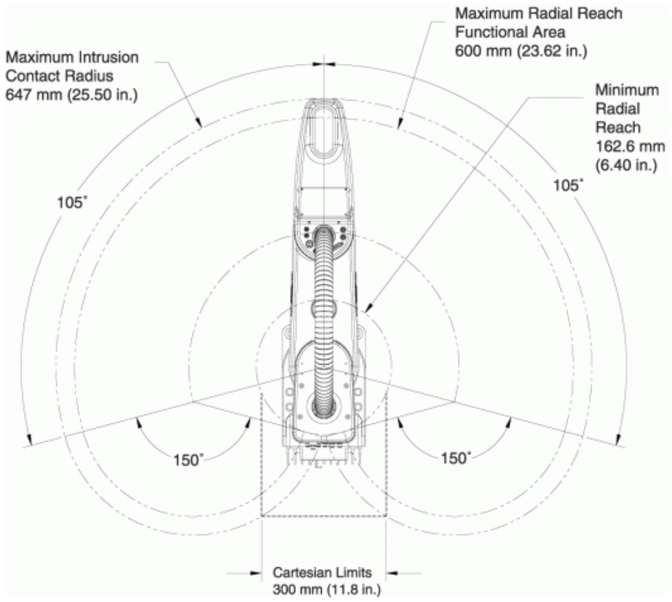
# SCARA – Selective Compliance Assembly Robot Arm

SCARA is short for Selective Compliant Articulated Robot Arm. A SCARA robot's arm typically consists of 2 links. The joints connecting these 2 links provide the robot with the ability to position its end effector (tooling) in both the X and Y directions.

A SCARA robot has a rigid Z axis, so the arm itself does not move up and down or rotate. The end effector can move vertically using a third motor. The end effector can also be rotated (yaw).

A SCARA robot is typically mounted on a flat surface or on a pedestal, though some models support ceiling or wall mounting. A ceiling mounted SCARA robot is sometimes referred to as an inverted SCARA robot.

# SCARA – Selective Compliance Assembly Robot Arm

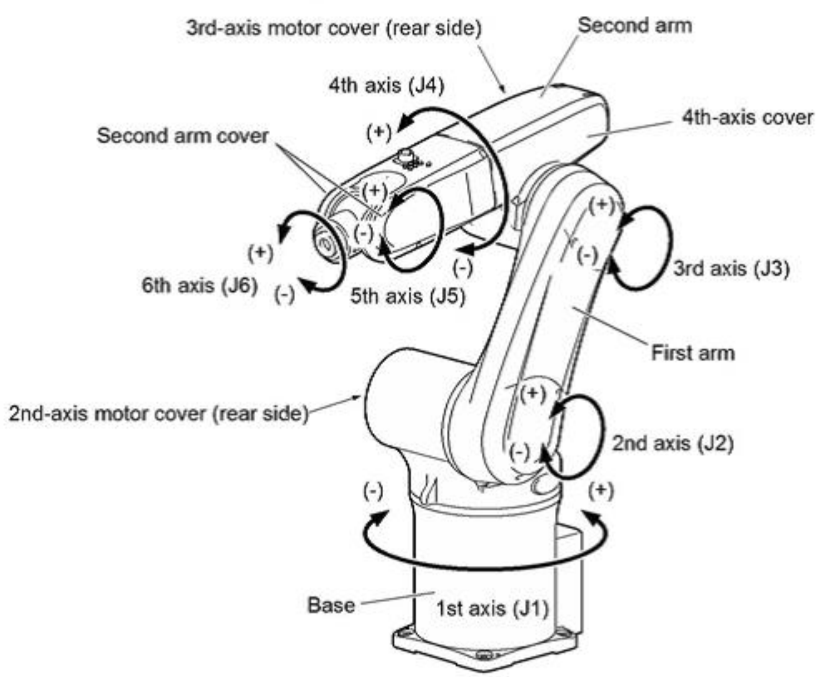
Reference: Adept eCobra

# Articulated Robot Arm

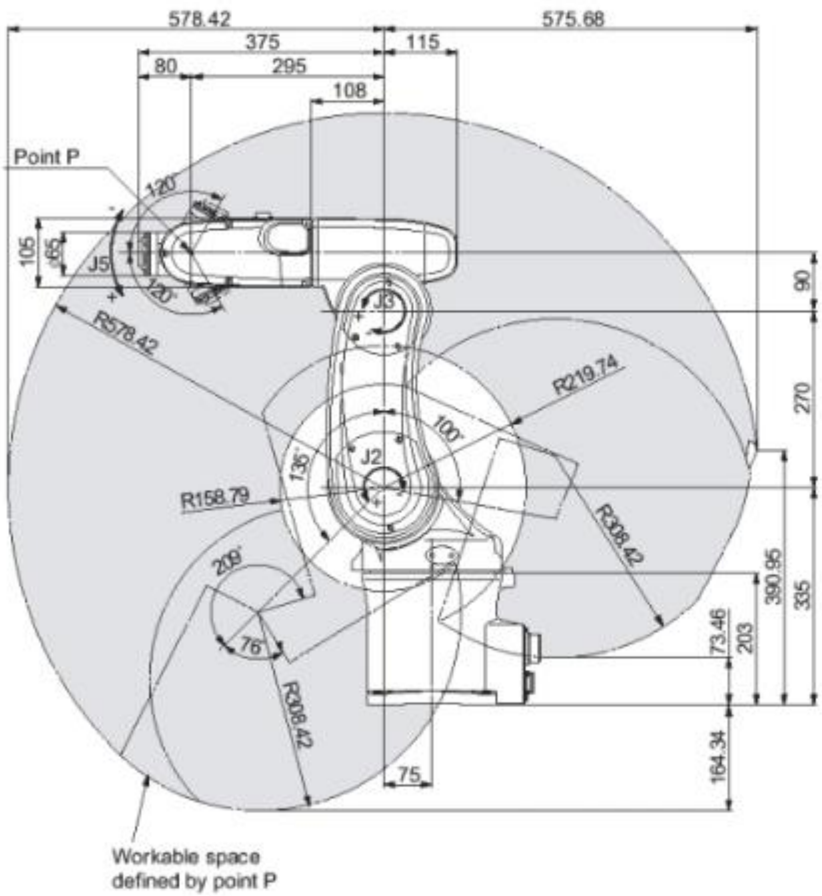
An articulated robot has many more joints than a SCARA robot, so parts can be picked up, rotated, and placed in almost any angle.

Typical configurations for articulated robots offer 5 or 6 degrees of freedom.

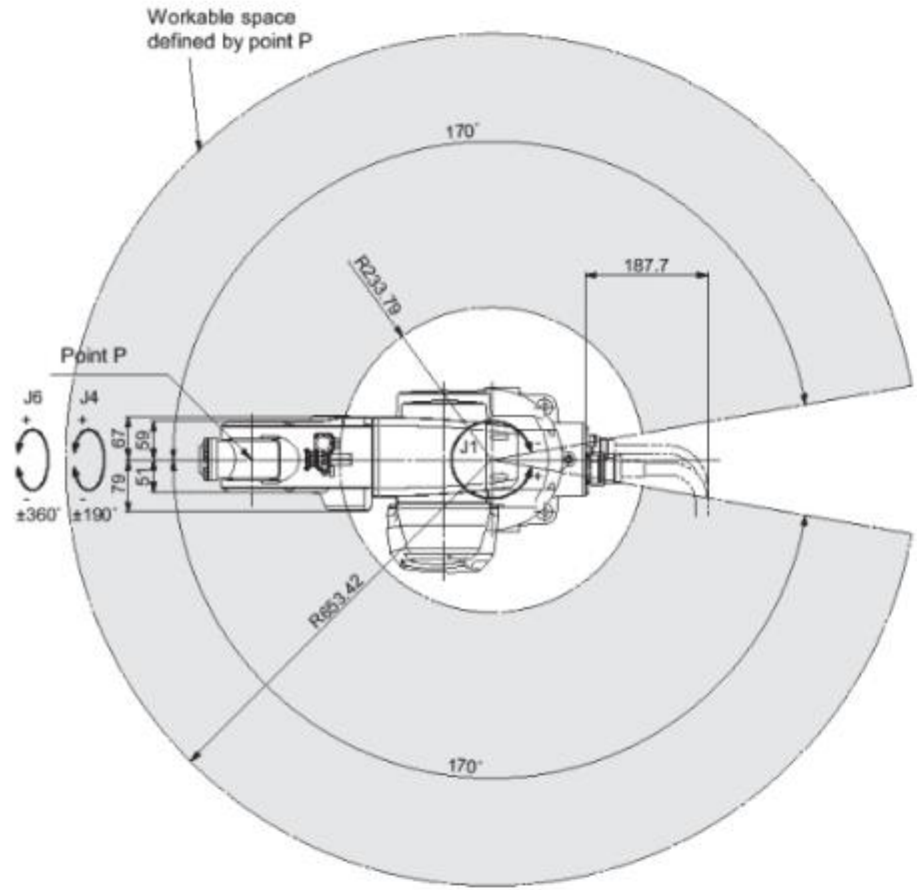
The image shows a 6-axis articulated robot from the Adept Viper series.




# Articulated Robot Arm (Open-chain or serial manipulator)

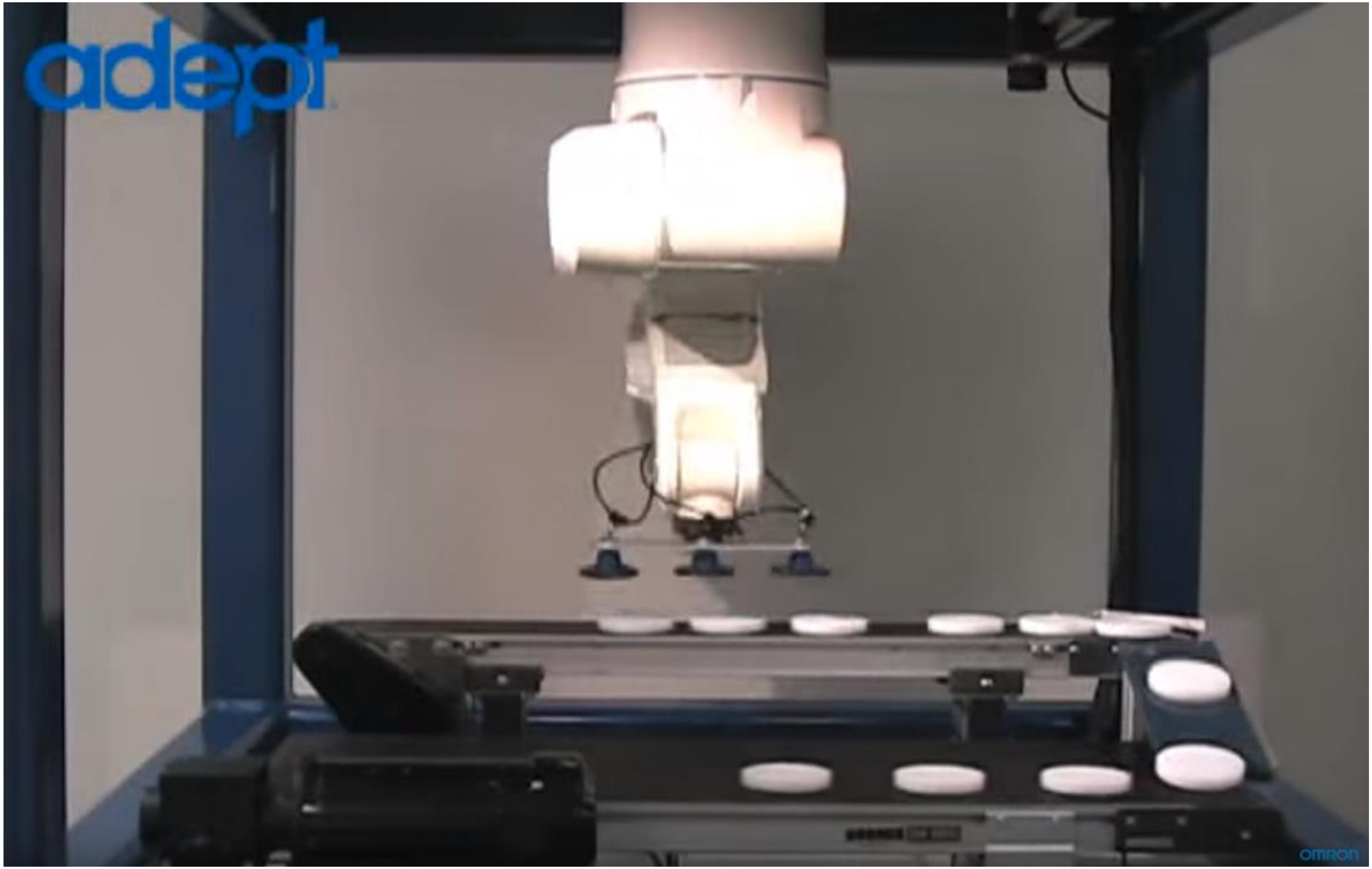



Side Dimensions and Work Envelope




Top Dimensions and Work Envelope

# Articulated Robot Arm

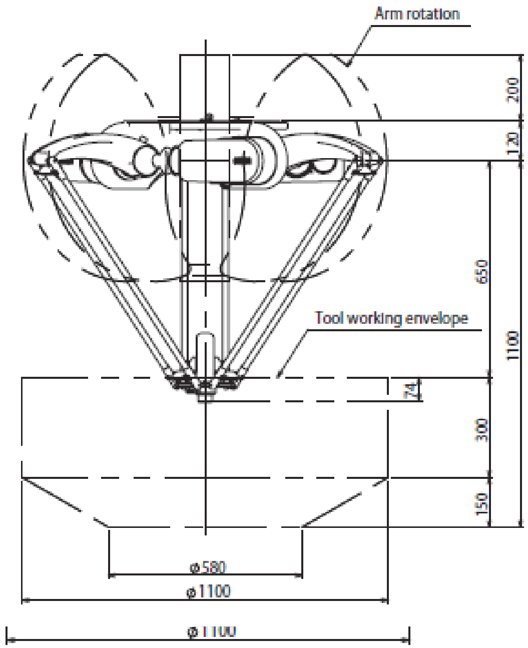



Reference: Adept Viper

# Delta Robot Arm (Parallel Kinematic Mechanism)

A delta robot typically consists of several lightweight links connected to motors and an end actuator. Each link is made up of two parallel bars. The end actuator typically remains parallel to the work surface at all times.

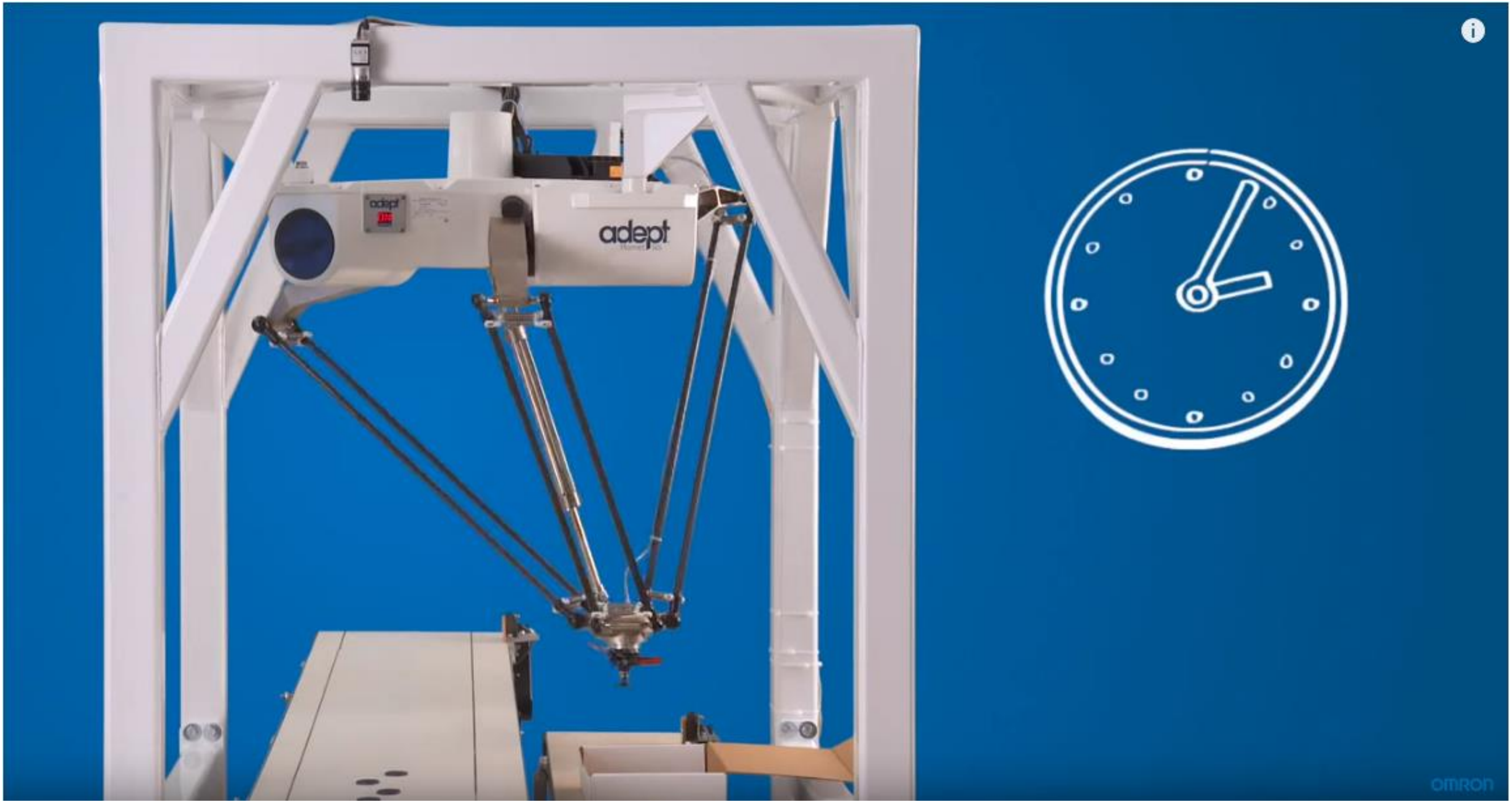

One major difference in the structure of a delta robot is that it does not have to carry the weight of its own motors. The motors that move the delta robot are mounted to a top plate and connected directly to the arms via a gearbox. The image to the right is an Omron delta robot.




Most delta robots use 3 motors and 3 sets of arms connected in a triangular pattern. By pushing or pulling the 2-part arm mechanisms using 3 motors, the end effector can be positioned within the X, Y, and Z axes.

Rotation can also be added to these models, giving a fourth degree of freedom.

# Delta Robot Arm (Parallel Kinematic Mechanism)




Reference: Adept Hornet

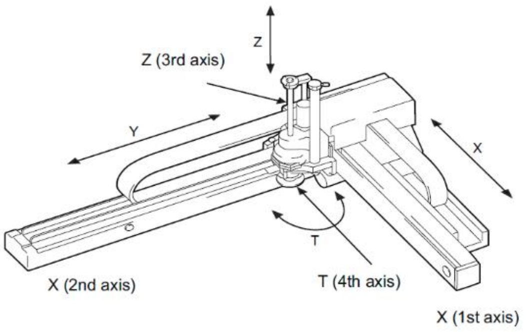
# Cartesian Robot

A Cartesian robot is not necessarily a dedicated piece of hardware in the same way as a delta robot or an articulated robot.

Cartesian robots are basically a series of multiple single axis modules connected together to perform coordinated motion. Typically a Cartesian robot will include from 1 to 4 axes.

Cartesian robots are sometimes called gantry robots if they ai mounted above the work area like a gantry crane.

This image shows a 3-axis Cartesian robot created using Adept Python linear modules.  This module can move a product or tool in the X, Y, and Z dimensions.

# Cartesian Robot


Reference: Adept

# Mobile Robot

Mobile robots are used in a variety of applications to replace large conveyor systems or humans pushing a cart.

A common type of mobile robot is called an AGV (autonomous guided vehicle). An AGV typically navigates a predefined course. Most AGVs require some form of signal to follow, such as navigational beacons or floor-mounted tracks or magnets. They cannot deviate from their track, which means they can be stopped by obstacles in their path.

Newer technology, such as Adept's Lynx, use a teaching system to 'learn' their way around a facility. By not using a dedicated track, magnetic stripe, or navigational beacons, these vehicles are far more capable. They are able to move around an object in their path, and can even determine a different route when their main path is blocked. These robots are typically referred to as AIV (autonomous intelligent vehicle).


I will share with you a link and a document to return the extra credit. For you to think a click deeper this week’s question is

What is the difference between production and manufacturing?

What do you think about the current problems of robotics for production or manufacturing?

# Thank you

**SMFG - 386**
**Manufacturing Automation**
**Week 1**
**H. Sinan Bank**