Solution

Department of Mechanical Engineering

Course: B. Tech. Semester: VII

Session: 2017-2018 Section: ME 1, 2, 3

Subject: Automation & Robotics Sub. Code: NME-044

Max Marks: 50 Time: 2hr

Section-A

Q-1(a) Define an Industrial Robot.

Ans:- An industrial Robot is a manipulator designed to move materials, parts and tools and perform a variety of programmed tasks in manufacturing industry. They are often used to perform duties that are dangerous or unsuitable for human workers.

Characteristics of industrial robots:

- Freely programmable
- Flexible application
- Programming via teach pendant
- Complex spatial motion sequences possible, e.g. linear and Circular paths.

Q-1(b) What is meant by robot anatomy?

Solution- The manipulator of an industrial robot consists of a series of joints and links. Robot anatomy deals with the study of joints and links. Robot anatomy deals with

the study of different joints and links and other aspects of the manipulator's physical construction. A robotic joint provides relative motion between two links of the robot. Each joint, or axis, provides a certain degree-of-freedom (dof) of motion. In most of the cases, only one degree-of-freedom is associated with each ~~other~~ joint. Robot complexity can be classified according to no. of joints.

Q 1-(c) What are the basic elements of an Industrial Automation System?

Solution An industrial automated system consists of three basic elements:

(1) power to accomplish the process and operate the system.

(2) a program of instructions to direct the process, and

(3) a control system to actuate the instructions.

The relationship amongst these elements is illustrated in Figure below.

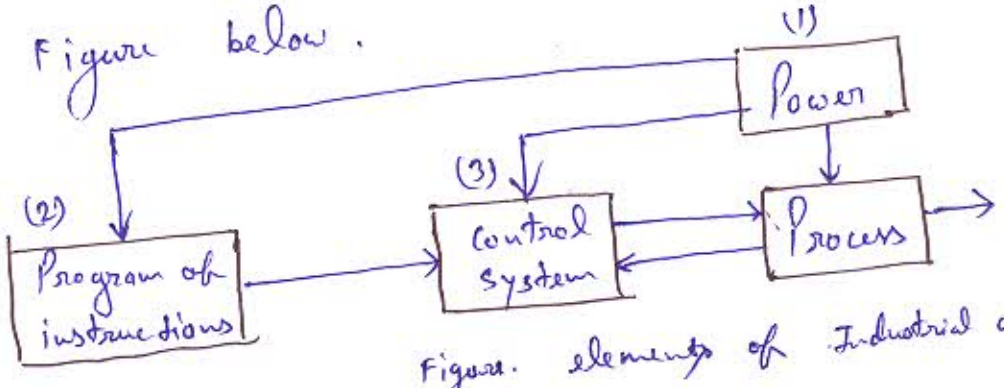


Figure. elements of Industrial automation System

Q-4(d) Explain programmable manufacturing automations as a CNC machine tools.

Solution- CNC machine tool consists of a machine control Unit (MCU) and machine tool itself. MCU, a computer is the brain of a CNC machine tool. It reads the part Programs & controls the machine tool operations. Then it decodes the part program to provide commands and instructions to the

Q1(e) What is homogeneous Transformations?

Solution The transformation is called "homogeneous" because we use homogeneous co-ordinate frames. In fundamental rotation with Yaw, pitch and roll, the origin of the frame is always the same (0,0,0). But when is comes to translate 3X3 matrix can not work, then we have to take 4th dimension of homogeneous co-ordinates (Projective geometry)

Representation of Transformations-

1- A pure translation
2- A pure rotation about an axis
3- A combination of translations and rotation

Section-B

Q-2(a) What do you understand by robot Kinematics? How Forward Kinematics is different from reverse Kinematics.

Solution: Robot Kinamatic is the study of the motion of the robot manipulator and the study of position, velocity & acceleration without considering the force and the mass of the robot.

Forward (direct) Kinematics :— Given the joints trajectories find the link's or end-effector's position and orientation.

Inverse Kinematics :— Given a path calculate the motion of joints. Because Kinematics equations are non-linear their solution is not always easy or even possible in closed form. The existence of multiple solution is there for point or trajectory.

Q-(2)(b) :— Write Asimov's laws of robotics?

Solution Issac Asimov's "Three laws of Robotics"

1. A robot may not injure a human being or, through inaction, allow a human being to came to harm.
2. A robot must obey orders given it by human beings except where such orders would conflict with the First law.
3. A robot must protect its own existance as long as such protection does not conflict with First & Second law.

Q-2 (c) Explain the importance of co-ordinate system for industrial robot and explain its explain its classifications with sketch.

Solution:- Co-ordinate system is a system that uniquely specifies each point in plane by a pair of numerical co-ordinates. By using this co-ordinate system, we can exactly calculate the position of tool & object w.r.t. the base or world co-ordinate system.

The industrial robot coordinate system widely follows the the cartesian co-ordinate system. Most industrial robot comparies of 6 degree of freedom. Co-ordinate system for the robot are given below.

1) World Co-ordinate System —
World co-ordinate is freely definable and uses the origin of Robroot & Base. It uses the cartesian co-ordinate system ie. X, Y, Z plane to define the translational motion of robot axis. In most cases it is located in the robot base.

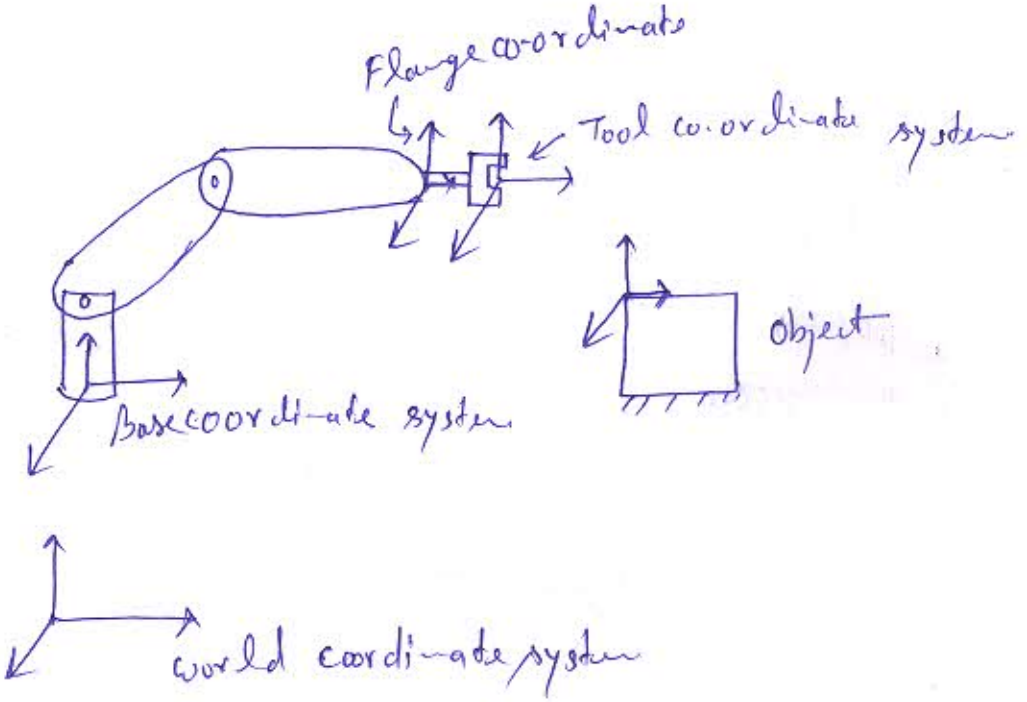
2) Flange Co-ordinate system —
Flange co-ordinate system is fixed at the ~~the~~ robot flange & the origin is the center of the robot flange. It is used as the origin for the tool.

3. Tool co-ordinate system :— Tool coordinate system is freely definable. The origin of the tool co-ordinate system is called the tool center point (TCP) and it is used for tools.

4. Base Co-ordinate System :—

Base co-ordinate system defines the position of the base relative to the World Coordinate System. Base Co-ordinate system is freely definable and is used for tools & fixtures.

Q-2



Q (2). (d):- What are the factors to be considered for selecting a Robot ? Explain in details.

Solution - Factors consideration for selecting of robots.-

1) Industrial Robot Applications -
According to the application, robots are selected for the specific purpose of applications like. material handling, welding and material removal.

2) Robot Payload -
The payload is the maximum load that the robot can carry in its working space.

3) Number of Axis :-
The quantity of axis on a robot is directly related with its degree of freedom.

4) Industrial Robot Reach :-
When looking at your target application, you should know what maximum distance the robot needs to reach. Every company gives the work envelope of the robot, according you can determine the specific application.

5) Repeatability :- The repeatability can be described as the capacity of the robot to reach the exact same position each and every time it completes a routine.

6) Speed :- Speed depends on the rate in which the job needs to be done. This motion unit is often in degree/second.

7) Robot Mass :- Robot mass is an important factor when designing a robot cell. If the industrial robot needs to be ~~se~~ sitting on a custom bench or even on a rail, to design the support, you must know the weight of robot.

8). Brake & Inertial- Some of the robot have brakes on all the axis and other don't. To have a precise and repeatable position in the workspace, must have sufficient no. of brakes.

9) I P Rating :- Depending on where you want your robot to work you may need to achieve a certain Ingress Protection rating or I P rating. In fact, if robot works with nutrition related products, laboratory tools, medical tools or in highly flammable environments, the I P rating will be different.

2 (c) What are the different classifications of industrial manipulators based on geometric configuration? Also given the work envelope of each configuration.

Solution:- There are different types of Industrial manipulator which are given below with the details of their envelope –

1) Cartesian Co-ordinate – In this industrial robot, its 3-principle axis have prismatic joints or they move linearly through each other. The primary advantage of cartesians is that they are capable of moving in multiple linear directions.

The working envelope of Cartesian configuration is a rectangular prism.

2) SCARA Robot :– The SCARA acronym stands for Selective Compliance Assembly Robot Arm or Selective Compliance Articulated Robot Arm. SCARA robots have motions similar to that of a human arm. These machines comprises both a 'shoulder' and 'elbow' joint along with a 'wrist' axis and vertical motion. SCARA robots have 2 revolute joints and 1 prismatic joint. It has limited movements but can move faster than 6-axis robot.

Its working envelope as a heart or kidney-shaped prism. having a circular hole

passing through the middle.

3) Cylindrical robot :- It is basically a robot arm that moves around a cylinder-shaped pole. A cylindrical system has three axis of motion - the circular motion axis and the two linear axes in the horizontal and vertical movement of the arm. So it has 1 revolute joint, 1 cylindrical joint & 1 prismatic joint.

The working envelope of cylindrical configuration is a hollow ~~cylindrical~~ cylinder since there is a limit to how far the arm can retract, this creates a cylindrical dead zone around the robot structure.

4) Polar Robot :-

It is sometimes regarded as spherical robots. These are stationary robot arm with spherical or near spherical work envelopes that can be positioned in a polar co-ordinate system. It has 2 revolute joints and 1 prismatic joint to make near spherical ~~envelope~~ workspace.

The working ~~en~~ envelope of polar configuration sweeps out a volume between two partial spheres. There are physical limits imposed by the design on the amount of angular movement in both the vertical and horizontal planes. These restricted zones above & below creates dead zones.

Section - C

3) (a) what is automatic transfer machines and its types? Explain the various design model used for production lines.

Solution: The aim of production engineer is to increase the output particularly in mass production. This technique of transfer divice / machines has been introducing to achieve same motive.

The transfer devices/machines are often the most suitable method for continous flow of identical or view similar component in the mass production of consumer goods.

Automatic transfer machines are system of machinery, a set of basic and auxiliary equipment which carries out in entire manufacturing processes or reprocesses of a product or part of it automatically within a specific technological sequence and at a specified pase.

The transfer machines are classified according to the arrangment of work stations.

→ In line transfer machine

→ Rotary indexing table transfer machine

→ Drum type transfer machine

In-line transfer machine:—

→ It consists of a central bed and the ~~machine~~ machining heads are arranged on the sides at a convenient pitch.

→ The components are transferred along guide rails on the central bed.

→ Cylinder blocks, gear box casting and axle box casting are ~~transferred~~ machined by this method.

Rotary indexing table transfer machines—

→ A rotary indexing table is used for transferring components from fixed stations or machining heads, which are spaced at equal intervals around the periphery of the table.

→ These machines are smaller in size.

→ It saves ~~the~~ floor space and presents more compact arrangement.

→ It can ~~be~~ also be installed for complete automatic assembly of a product.

Drum type transfer Machines:—

Like rotary table type, this machine also transfers the components in a circular path to workstations positioned around at equal distances.

This machine instead of having a table ~~gets~~ has got a drum which rotates about a horizontal axis.

The work fixtures are fixed around the periphery of the drum.

→ Design model used for production line are given below-

1) Single model:- Single model production is the practice of assembling same type of product in assembly line which result is mass production of specific product.

A special type of machine is prepared to manufacturing that product which is one time investment and we can not get other other product.

Cycle time of product to manufacturing is minimum.

2) Multi Model :- In multi model production system a bunch of product is produced for a particular time & after it according to demand other product (having similar configuration are produce in other batch.

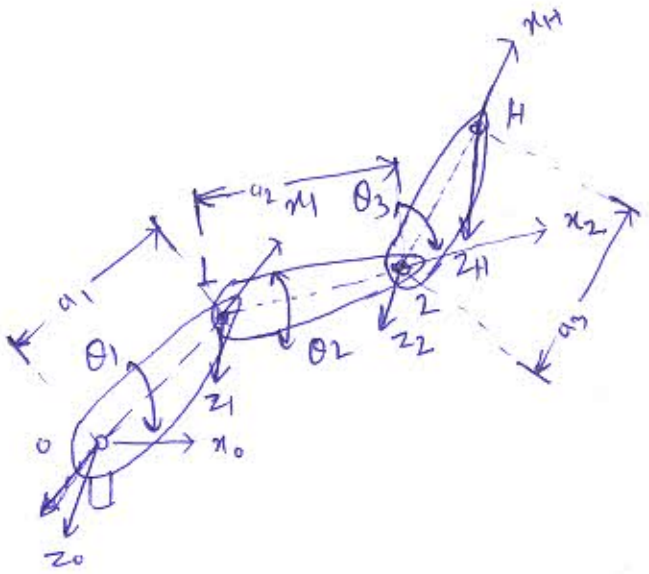
3) Mixed Model :- Mixed model production is the practice of assembling several distinct models of a product on the same assembly line without changeovers and then sequence those models in a way that smoothest the demand upstream components. The objective is to smooth demand on upstream work centre, manufacturing cells or supplies and thereby reduce inventory, eliminate changeovers, improve Kanban operations.

3) (b) Define Jacobian in the field of Robotics. Obtain the forward and reverse kinematics of a 3R Planner Manipulator.

Solution:- Jacobian of Manipulator —

Jacobian specifies a mapping from velocities $\dot{\theta}$ in joint space to velocities in Cartesian space. Also given a desired contact force and moments what set of joint torques are required to generate them here also Jacobian appears.

3R- Planner Manipulator :—



D-H Parameters Table for 3-R Planner manipulator.

#	θ	d	a	α
0-1	θ_1	0	a_1	0
1-2	θ_2	0	a_2	0
2-H	θ_3	0	a_3	0

Substituting these parameters into the corresponding A matrixes as follows.

$$A_1 = \begin{bmatrix} C_1 & -S_1 & 0 & a_1 C_1 \\ S_1 & C_1 & 0 & a S_1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_2 = \begin{bmatrix} C_2 & -S_2 & 0 & a_2 C_2 \\ S_2 & C_2 & 0 & a_2 S_2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_3 = \begin{bmatrix} C_3 & -S_3 & 0 & a_3 C_3 \\ S_3 & C_3 & 0 & a_3 S_3 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$^0T_H = A_1 \times A_2 \times A_3$$

The forward kinamatic solution allows us to find the location (and orientation) of the robot's end effector if values for θ_1, θ_2, θ_3, a_1, a_2 & a_3 are specified.

Inverse Kinamatics :-

$$\theta_1 = \tan^{-1}\left(\frac{P_y}{P_x}\right) \text{ and } \theta_1 + = \theta_1 + 180$$

$$\theta_{234} = \tan^{-1}\left(\frac{a_2}{C_1 a_x + S_1 a_y}\right) \text{ and } \theta_{234} = \theta_{234} + 180^\circ$$

$$C_3 = \frac{(P_x C_1 + P_y S_1 - C_{234} a_4)^2 + (P_z - S_{234} a_4)^2 - a_2^2 - a_3^2}{2 a_2 a_3}$$

$$S_3 = \pm\sqrt{1 - C_3^2}$$

$$\theta_3 = \tan^{-1}\frac{S_3}{C_3}$$

$$\theta_2 = \tan^{-1}\frac{(C_3 a_3 + a_2)(P_z - S_{234} a_4) - S_3 a_3 (P_x C_1 + P_y S_1 - C_{234} a_4)}{(C_3 a_3 + a_2)(P_x C_1 + P_y S_1 - C_{234} a_4) + S_3 a_3 (P_z - S_{234} a_4)}$$

From the above eqn the value of the angle found for the robot's arm which defines multiple solution.