Robotics – May 2005

Time : 3 Hrs.] **[Marks : 100**

N.B.: (1) Question No. **1** is **compulsory.**
(2) Attempt any **four** questions out of remaining **six** questions.
(3) Assume **suitable** data wherever **required.**

1. (a) Compare the five basic Robot configurations according to the work envelope, typical applications, and power sources. **[10]**
(b) (i) How does the SCARA arm geometry differ from the vertical articulated arm ? **[6]**
(ii) Why is the SCARA arm more ideal for assembly applications ? **[4]**

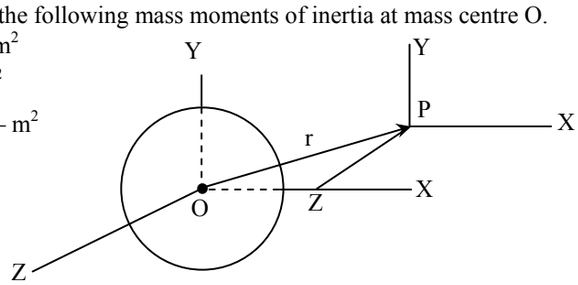
2. (a) Explain Trajectory planning with examples. What are the classical methods of trajectory planning? **[10]**
(b) Explain a 4 d.o.f. SCARA Robot and its work envelope with diagrams. **[10]**

3. (a) Explain compliance. How is this classified? **[10]**
(b) What are the considerations for applying DH algorithm? Explain the direct kinematic solution for a three link planar Robot. **[10]**

4. (a) Explain noise in images. How are these classified? **[10]**
(b) Explain shrink and swell operators with examples. How are these applied? **[10]**

5. (a) A thin plate weighing 100 N has the following mass moments of inertia at mass centre O. **[10]**

$I_{xx} = 15 \text{ kg} - \text{m}^2$
$I_{yy} = 13 \text{ kg-m}^2$
$I_{xy} = -10 \text{ kg} - \text{m}^2$



hat are the moments of inertia I_{xx}, I_{yy} and $I_{z'z'}$ at point P having position vector.

$\bar{r} = 5\,\bar{i} + .2\bar{j} + .6\,\bar{k}$ km . Also determine $I_{x'z'}$ at P.

(b) Name and explain with diagrams all the lower kinematic pairs. Indicate those that cannot be used in an actuated Robot joint and the reason for it. **[10]**

6. (a) Give your best definition of a Robot, along with an example of a Robot and one example of a device that is not a Robot but which can be mistaken for one. Explain why it can be so mistaken. **[10]**
(b) If a serial Robot has one helical joint, one cylindric joint, and one planar joint, how many degrees of freedom can it be said to possess? Is it possible to practically build a Robot with such joints actuated in all their degrees of freedom. **[10]**

7. Write notes on the following : **[20]**
(a) Robot specification
(b) Template matching in Robot vision
(c) Principles of NC and CNC machines
(d) Task planner simulation
(e) Link co-ordination arm equation

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Robotics – December 2005

Time : 3 Hrs.] **[Marks : 100**

N.B.: (1) Question No. **1** is **compulsory.**
(2) Attempt any **four** questions out of remaining **six** questions.
(3) Assume **suitable** data wherever **required.**

1. (a) Explain a 4 d.o.f SCARA robot and its work envelope with diagrams. **[10]**
(b) Name and explain all the lower kinematic pairs. Indicate those that cannot be used in an actuated Robot joint and the reason for it. Draw neat sketches wherever necessary. **[10]**

2. (a) Describe the classification and characteristics of mechanical gripper. **[8]**
(b) (i) Describe active and passive compliance. **[6]**
(ii) Describe vacuum, magnetic and adhesive grippers. **[6]**

3. (a) Explain a 4 d.o.f SCARA robot and its work envelope with diagrams. **[10]**
(b) Name and explain all the lower kinematic pairs. Indicate those that cannot be used in an actuated Robot joint and the reason for it. Draw neat sketches wherever necessary. **[10]**

4. (a) Explain template matching with an example. Give two examples where this can be used. **[10]**
(b) What is shape analysis and role of area descriptors ? **[10]**

5. Suppose that $[q]^m = [0, 0, 10, 1]^T$ represents the homogenous co-ordinates of a point located 5 units along the third vector of a mobile co-ordinate frame M. Assume that initially M is coincident with a fixed co-ordinate frame F. If we rotate the mobile frame M by $\pi/6$ radian about the first unit vector of F, then determine the resulting homogenous co-ordinate transformation matrix. Also determine the physical co-ordinates of the point of in the fixed co-ordinate frame F. **[20]**

6. (a) Explain compliance. How is this estimated ? **[10]**
(b) What are the considerations for applying DH algorithm ? Explain the direct kinematic solution for a three link planar Robot. **[10]**

7. Write notes on the following : **[20]**
(a) Robot programming
(b) Robots and industrial safety
(c) Robot dynamics
(d) Robot vision

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Robotics – May 2006

Time : 3 Hrs.] **[Marks : 100**

N.B.: (1) Question No. **1** is **compulsory.**
(2) Attempt any **four** questions out of remaining **six** questions.

1. (a) Define the following terms w.r.t. Robots : **[14]**
(i) Repeatability (ii) Precision (iii) Accuracy
(iv) Degree of freedom (v) Co–ordinate transformation (vi) Tool orientation
(vii) Workspace envelope
(b) How are robot classified? **[6]**

2. (a) Write a short note on Hard and Soft automation. **[5]**
(b) If F and M are two orthonormal co–ordinate frames, translated M along axis f^2 by three units, rotate M about f^3 axis by π radians and hence find $[m^1]^F$ after composite transformation. **[10]**
$[m^1]^m = [1, 0, 0, 1]^T$.
(c) Define Yaw, Pitch, roll motions of the tool/grippers. **[5]**

3. (a) Define kinematic parameters. **[4]**
(b) If F and M are two frames coincident initially, after performing a screw transformation along f^2axes of F by a distance of $\lambda = 3$ and rotation by an angle of 90° about f^2 axes. Find $[m^3]^F$ after screw transformation. Also find pitch of the screw $[m^3]^m = [0, 0, 1, 1]^T$. **[6]**
(c) Find the position of the tool tip P of a SCARA robot when the kinematic parameters given are : **[10]**
$q = [\pi/4, -\pi/3, 120, \pi/2]^T$ rads
$d = [877, 0, d_3, 200]^T$ mm
$a = [425, 375, 0, 0]^T$ mm

4. (a) Why solution of Inverse kinematics is not unique for generic robots? **[4]**
(b) What is TCV? Explain its role in the solution of IKP. **[4]**
(c) What is the difference between path and trajectory? **[4]**
(d) Determine the tool configuration vector of SCARA robot when – **[8]**
$q = \{\pi/6, \pi/3, 150, \pi/2\}^T$

5. (a) Explain the work space analysis of five axis articulated Rhino XR–3 Robot arm. **[10]**
(b) What is linear interpolation with parabolic blends and what is its advantages. **[5]**
(c) Explain the bounded deviation algorithm method for achieving straight line path in tool configuration space. **[5]**

6. (a) What are the template matching techniques at a gray level image and there applications to robot vision. **[5]**
(b) What are Shrink and Swell operations? Define them. How are they applied in the processing of digital images. **[8]**
(c) Write a short note on perspective transformation. **[7]**

7. Write a short notes on : **[20]**
(a) Effect of moment of Inertia on the dynamic performance of robot.
(b) NC and CNC machines.

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Robotics – December 2006

Time : 3 Hrs.] **[Marks : 100**

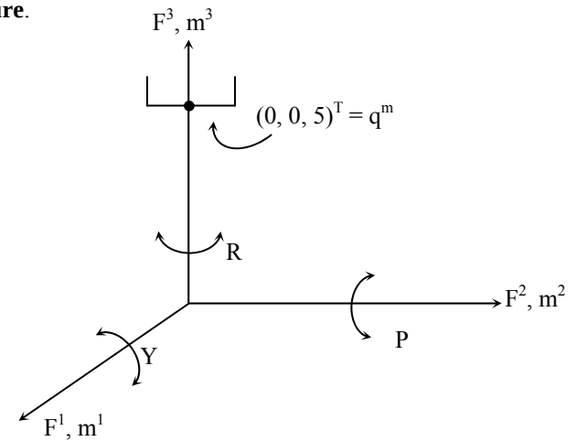
N.B. : (1) Question No. **1** is **compulsory** and answer any **four** questions out of remaining **six** questions.
(2) Assume **suitable** data if **necessary** with proper **justification**.
(3) **Figures** to **right** indicate **full** marks.

1. (a) Define the following terms related to robotic manipulators and give brief comments : **[10]**
(i) Repeatability, precision and accuracy
(ii) Kinematic parameters
(iii) Tool path and trajectory
(b) (i) Explain the Euler number and its use in Image Processing. **[5]**
(ii) Explain the Degree of Freedom for a mini drafter with neat sketch. **[5]**

2. (a) Compare and contrast : **[10]**
(i) Direct kinematics and Inverse kinematics.
(ii) Analytical method of 1K and numerical method of 1K.
(b) Consider an adept 1 SCARA robot 4 axes having axes B, E, VE, TR. Write a note on its physical construction. Explain its kinematic configuration (LCD and KPT using pass 1 and pass 2 of DH Algorithm) with a neat sketch. Obtain the arm matrix and verify it by substituting the last column of the KP table. **[10]**

3. (a) Obtain the inverse kinematics solution of three axis planer articulated robot arm. **[10]**
(b) Define total work envelope, joint space work envelope, dexterous work envelope with their relevant formulas and explain the terms involved in them. Illustrate these total work_envelope, joint space work envelope, and dexterous work envelope for a dimensional rotary–rotary manipulator with a neat sketch. **[10]**

4. (a) (i) Explain the advantages/disadvantages of using pneumatics vis a vis hydraulics as power source for drives in Robotics. **[5]**
(ii) Determine the tool configuration vector of a SCARA Robot when the vector of joint variables is $q = \{30°, -60°, 150 \text{ mm}, 90°\}^T$ and GLP's are given as $q = \{425, 375, 0, 0,)^T$ mm and $d = \{877, 0, d_3, 200\}^T$ mm. **[5]**
(b) Consider the robotic tool shown in **figure**. **[10]**



Sketch the tool positions after each intermediate position of the following YPR operation. Yaw 90° pitch – 90°. Rotations are performed about the fixed axes of F frame. Find co–ordinate of q w.r.t. to fixed axis.

5. (a) Explain the bounded deviation algorithm for obtaining a straight line motion in TCs, R^6 using an articulated robot by considering an example. Draw neat sketch. Where do you use bounded deviation algorithm. **[10]**
(b) Consider the image I(k, j) and template T(k, j). Using the performance index, compute P(x,y) for $0 < x < 2$ and $0 < y < 1$. What transition of the template produce the best match with the image? Also find normalized cross correlation function at P1best match position: **[10]**

1	0	0	2
0	1	2	0
2	0	2	1
0	1	0	0

I(k, j)

0	2	0
1	2	3

T(k, j)

6. (a) Explain task planning subproblems. **[10]**
(b) Consider the binary image I(k, j) of size 4 × 6 as shown below. **[10]**

0	0	0	0	0	0
0	0	1	1	1	0
0	1	1	1	0	0
1	1	1	0	0	0

I(k, j) of size (4 × 6)

Find area, centroid, m_{20}, m_{02}, m_{11}, μ_{11}, μ_{01}, μ_{10}, μ_{20}, μ_{02}, also find normalized central moments V_{20}, V_{022}, V_{11} and find the principal angle ϕ. Also find the storage requirement for the given binary image using run length encoding. Is it advantageous ?

7. (a) Write short notes on : **[10]**
(i) Inverse Perpective Transformation
(ii) Robot Programming
(b) (i) Compile a list of sensors that might be used in robotic systems. For each sensor, give an application. **[5]**
(ii) Describe active and passive compliance. **[5]**

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Robotics – May 2007

Time : 3 Hrs.] **[Marks : 100**

N.B.: (1) Question No. **1** is **compulsory.**
(2) Attempt any **four** questions out of remaining **six** questions.

1. (a) What is the essential feature that distinguishes soft automation from hard automation ? For what type of robot the precision uniform throughout the work envelope ? For which robots is the vertical precision uniform ? **[5]**
(b) Define Repeatability, Precision and Accuracy of Robot ? Why repeatability is important is important design characteristics ? **[4]**
(c) Draw Joint and Link diagram and define : (i) Joint angle, (ii) Joint distance, (iii) Link length, (iv) Link twist angle. Which is the variable parameter for revolute Joint and Prismatic joint. **[6]**
(d) Explain the conditions for existence of the Inverse kinematics solution ? Why the inverse kinematics solutions are not unique ? **[5]**

2. (a) Let F = $\{f^1, f^2, f^3\}$ and M = $\{m^1, m^2, m^3\}$ be Initially coincident fixed and mobile orthonormal co-ordinate frames, respectively. Perform screw transformation along f^2 axis for $\lambda = 3$ and $\phi = \pi/2$ and find $[m^3]^F$ and Determine the pitch of the screw. **[6]**
(b) Apply D-H algorithm for SCARA robot and construct a link-coordinate diagram. Compute the arm matrix T_{base}^{tool}, (q) for the SCARA Robot. **[10]**
(c) Find the position of the tool tip of the Adept one robot when the joint variables are **[4]**
$q = \{\pi/4, -\pi/3, 120, \pi/2\}^T$.

3. (a) Define Tool-Configuration vector ? Show how to obtained tool roll angle q_n ? What are the advantages/disadvantages of Numerical approach and Analytical approach to solve the Inverse kinematics problems. **[6]**
(b) Explain the role of the tool configuration vector in Inverse kinematics of robot. **[4]**
(c) Find the inverse kinematics solution of rive axis articulated robot (Rhino XR–3). **[10]**

4. (a) Define : **[4]**
(i) Joint-Space work envelope (ii) Dexterous work envelope
(iii) Tool Trajectory (iv) Path
(b) Compute the maximum horizontal reach and minimum vertical reach of Rhino XR-3 robot. **[6]**
(c) Explain the problem of threading a hex nut on a bolt ? Plan a nut fastening trajectory for the tool ? **[10]**

5. (a) Explain Chain Coding process for shape analysis ? State its advantages and disadvantages ? **[10]**
(b) What are the template matching techniques of gray level Image and their application to Robot vision. **[10]**

6. (a) Consider the Image l(k, j) and template T(k, i) show in figure. Using performance Index compute $\rho(x, y)$ and Normalized cross co-relation performance index $\sigma(x, y)$ for $0 \le x \le 1$ and $0 \le y \le 2$. What translation at template produces the best match with the Image ? **[10]**

k ↓ \ j →					
	2	1	0	0	3
	0	0	5	0	0
	0	4	0	6	0
	1	0	5	0	0

k ↓ \ j →			
	0	4	0
	3	0	5
	0	4	0

(b) Explain the bounded deviation algorithm for achieving straight line motion. **[10]**

7. Write a note on : **[20]**
(a) NC and CNC machines
(b) Perspective Transformation
(c) Moment of Inertia

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Robotics – December 2007

Time : 3 Hrs.] **[Marks : 100**

N.B.: (1) Question No. **1** is **compulsory.**
(2) Attempt any **four** questions out of remaining **six** questions.
(3) Assume **suitable** data if **necessary**.

1. (a) Define the following terms : **[10]**
DOF, Precision, accuracy, tool orientation, reach and stroke.
(b) Explain the direct kinematics of a 2–axis planar robot. **[10]**

2. (a) What is an inverse Kinematics Problem ? What are the different methods of solving it ? Compare numerical approaches over analytical approaches. **[10]**
(b) Explain the Bounded Deviation Algorithm (BDA) for straight line motion of the tool path. **[10]**

3. Describe DH algorithm for a 5 axis Rhino XR3. Show all the steps with reference to figures. **[20]**

4. (a) Compare Hard Automation and Soft Automation. State advantages and drawbacks of each. **[10]**
(b) Explain the principle and application of edge detection techniques using a gray scale image. **[10]**

5. (a) Explain guarded and considered motion. **[10]**
(b) Explain the PNP motion trajectory in detail. **[10]**

6. (a) Explain the effect of moment of inertia on the dynamic performance of a robot. **[10]**
(b) Explain how GVD is constructed. **[10]**

7. Write a note on : **[20]**
(a) Direct Numerical Control (DNC) Machines
(b) Perspective transformation
(c) Robot classification
(d) Workspace fixtures

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Robotics – May 2008

Time : 3 Hrs.] **[Marks : 100**

N.B.: (1) Question No. **1** is **compulsory.**
(2) Attempt any **four** questions out of remaining **six** questions.
(3) Assume **suitable** data if **necessary** with proper justification.

1. (a) How are robot classified? **[5]**
(b) Define Precision, Accuracy, repeatability DOF and work space envelope for Robot. **[5]**
(c) Explain the properties of inverse kinematics solution. **[5]**
(d) Define kinematic parameters. What is soft home configuration? **[5]**

2. (a) Find the composite rotation matrix by rotating the tool about fixed axis of Frame with a yaw of $\pi/3$ followed by a pitch of $-\pi/2$ and finally roll of $\pi/2$ radiance, if $[P]^M = [0, 0, 0.5]^T$. Find $[P]^F$. Draw the frame rotations. **[10]**
(b) Explain the four fundamental operations to transferring frame K–1 to frame k, obtain T^k_{k-1} transformation matrix. **[10]**

3. (a) Construct the link coordinate diagram using D–H algorithm for the SCARA robot and compute the arm matrix T^{Tool}_{Base} (9) and Kinematic parametes. **[10]**
(b) What is TCV? Explain its role in the solution of Inverse kinematic problem. **[10]**

4. (a) Find the inverse kinematic solution of Microbot Alpha–II robot. **[10]**
(b) Determine the tool configuration vector of SCARA robot, when – **[10]**

$$9 = \left\{\frac{\pi}{6}, \frac{\pi}{3}, 120, \frac{\pi}{2}\right\}^T$$

$a = \{425, 375, 0, 0\}^T$ mm
$d = \{877, 0, 9_3, 200\}^T$ mm.

5. (a) What is difference between path and trajectory? **[2]**
(b) Define joint space work envelope, Dexterous work envelope. **[2]**
(c) Compute the maximum horizontal and vertical reach and vertical stroke of four axis Adept one SCARA robot. **[6]**
(d) Explain robot task planner in brief with the help of block diagram. **[10]**

6. (a) Explain the bounded deviation algorithm method for achiving straight line path in tool configuration space. **[10]**
(b) What are the template matching techniques explain one in detail? **[10]**

7. (a) Consider the 8 × 10 binary image shown in figure. Compute the zeroth, first and second order moments of the foreground region R, also compute second order normalized central moment: **[10]**

	1		V ⟶							10
1	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
x	0	1	1	1	0	0	0	0	0	0
↓	0	0	0	1	1	1	0	0	0	0
	0	0	0	0	0	1	1	1	0	0
	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0

(b) Write a short notes on : **[10]**
(i) Perspective transformation
(ii) NC, CNC Machines.

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Robotics – December 2008

Time : 3 Hrs.] **[Marks : 100**

N.B.: (1) Question No. **1** is **compulsory.**
(2) Attempt any **four** questions out of remaining **six** questions.
(3) Assume **suitable** data if **necessary** with proper justification.

1. (a) State whether the following statement is true or false and justify your answer :
(i) Robots are better suited to 'Flexible Automation' compared to CNC machines. **[4]**
(ii) Gross motion planning is robot independent and Fine motion planning is robot dependent. **[4]**
(b) Compile a list of sensors that might be used in robotic systems. For each sensor give an application. **[4]**
(c) Define total work envelope, joint space work envelope. Dexterous work envelope with their relevant formulae and explain the term involved in them. **[8]**

2. (a) Consider an Adept 1 SCARA robot 4 axes having axes B, E, VE, TR. Write a note on its physical construction. Explain its kinematic configuration (LCD, KPT using pass 1 and pass 2 of DH algorithm) with neat sketch and obtain the arm matrix and verify it by substituting the last column of the KP table. **[12]**
(b) Compute, sketch and label the minimum and maximum horizontal and vertical reach of a five axis Rhino XR–3 Robot. **[8]**

3. (a) Explain the conditions for existence of inverse kinematics solution. Obtain inverse kinematics solution for two axis planar articulated robot arm. **[10]**
(b) (i) Explain how do you simulate a planar motion of a robot between the two points (x_1, y_1) and (x_2, y_2). **[6]**
(ii) How will you determine the direction of intensity gradient while detecting the edges ? **[4]**

4. (a) An (8 × 8) grey level image with 16 grey levels as shown in figure below : **[15]**

7	3	0	4	3	4	3	5
3	14	14	13	14	11	13	3
3	7	10	13	13	10	11	4
3	4	8	12	13	5	3	3
5	5	3	13	12	5	0	6
5	10	13	15	14	14	12	3
5	12	13	14	10	13	10	4
1	5	3	3	5	4	7	4

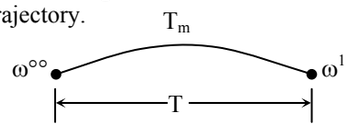
Construct the histogram of the image. Convert the image not a binary image using suitable threshold value. Compute m_{00}, m_{01}, m_{10}, μ_{02}, μ_{11}, μ_{20}, v_{00}, v_{01}, v_{10}, v_{02}, v_{20}, principal angle, centroid, run length code.
(b) Explain position uncertainty and velocity uncertainty. **[5]**

5. (a) Derive the three fundamental rotation matrices $R_1(\theta)$, $R_2(\theta)$ and $R_3(\theta)$ with the help of neat sketch and prove that – **[10]**

R_{YPR} = Y_{RPY}
about fixed axis about mobile axis.

(b) (i) Explain Shrink and Swell operators. **[5]**
(ii) Write an algorithm that finds the corner points in a m × n binary image l(k, j) using the eight corner point template. **[5]**

6. (a) Find the cubic interpolating polynomial w(t) which will smoothly move the robot between the following two points in TCS as shown in figure below over the time interval (0, T) = (0, 2). Assume zero velocity at each end of the trajectory. **[10]**



$w^\circ = [12, 12, 10, 0.372, 0.389, -0.575]^T$
$w^1 = [14, 12, 15, 2, 2, -2]^T$

Also calculate w(t) over the interval (0, T) for any five points.

(b) (i) Write short note on 'Image Segmentation'. **[6]**

(ii) Explain the significance of $\left[\exp\left(\frac{qn}{\Pi}\right)r^3\right]$ in root configuration vector. **[4]**

7. (a) (i) Analyse a conceptual robot for teaching in a classroom. **[6]**

(ii) Describe how do you use motion heuristics in gross motion planning. **[4]**

(b) Write short notes on : **[10]**

(i) Inverse Perspective Transformation

(ii) Computer Integrated Manufacturing.

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Robotics – May 2009

Time : 3 Hrs.] **[Marks : 100**

N.B.: (1) Question **No. 1** is **compulsory.**
(2) Attempt any **four** questions out of remaining **six** questions.

1. (a) Discuss the difference between fixed and flexible automation. **[5]**

(b) What is linear interpolation with parabolic blends ? What are the advantages ? **[5]**

(c) Define the following terms : Tool Path, Tool Trajectory, DOF, Precision, Accuracy. **[5]**

(d) Define Kinematic Parameters. **[5]**

2. (a) Explain the edge detection algorithm. **[10]**

(b) Explain Bounded Deviation Algorithm. **[10]**

3. (a) What is image smoothening ? Explain how it is done on a binary image. **[10]**

(b) Construct the arm matrix using homogeneous transformation matrices for a 2–DOF articulated robot. Draw neat diagram. **[10]**

4. (a) Determine the tool configuration vector of SCARA robot, when – **[10]**

$q = \left\{\frac{\pi}{6}, \frac{\pi}{3}, 120, \frac{\pi}{4}\right\}^T$

$a = \{425, 375, 0, 0\}^T$ mm

$d = \{877, 0, q_3, 200\}^T$ mm

(b) Explain guarded and constrained motion. **[10]**

5. (a) Explain the effect of moment of inertia on the dynamic performance of a robot. **[10]**

(b) What is an Inverse Kinematics problem ? What are the methods of solving it ? Compare numerical approaches over analytical approaches. **[10]**

6. (a) Explain the PNP motion trajectory in details. **[10]**

(b) Explain position uncertainty and velocity uncertainty. **[5]**

(c) Define total work envelope, Joint space work envelope and Dexterous work envelope with their relevant formulae and explain each term in them. **[5]**

7. Write short notes on : **[20]**

(a) NC and CNC machines

(b) Perspective transformation

(c) Robot programming

(d) Linear interpolation with parabolic blends.

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Robotics – December 2009

Time : 3 Hrs.] **[Marks : 100**

N.B.: (1) Question **No. 1** is **compulsory.**
(2) Attempt any **four** questions out of remaining **six** questions.
(3) Assume **suitable** data wherever **required**.

1. (a) Compare the five basic robot configuration according to the work envelope and applications. **[5]**

(b) Explain Reach and Stroke of a robot. **[5]**

(c) Discuss Total Work Envelope (TWE) and Dexterous Work Envelope (DWE) of two axis articulated planar robot. **[5]**

(d) Compare area descriptor and line descriptor. **[5]**

2. (a) Explain the significance of TCV vector in the solution of Inverse Kinematic. **[5]**
(b) Discuss the general properties of the solutions of the Inverse Kinematic. **[5]**
(c) Develope IK analysis of 2-axis planar articulated robot. **[10]**

3. (a) Explain D-H algorithm. Develope the D.K. analysis of 4 axis SCARA robot. **[15]**
(b) Explain screw Transformations. **[5]**

4. (a) Define Joint space work envelope (JSWE) and Tool Trajectory. **[5]**
(b) Explain work space fixtures required in the robotic work cell. **[5]**
(c) Discuss work envelope of a four axis SCARA robot. **[10]**

5. (a) Explain how straight line motion can be obtained using an articulated robot. **[10]**
(b) Explain linear interpolation with parabolic blends. Discuss its advantages over piecewise linear interpolation. **[10]**

6. (a) Discuss edge detection technique. Explain the significance of edge threshold $\in$. **[10]**

(b) **[10]**

0	0	1	1	0	0
1	1	1	1	1	1
0	0	1	1	0	0

For the above image shown calculate area, centroid, first order moments, second order moments, central moments and principal ange.

7. Write short notes on the following : **[20]**
(a) Region growing and region labeling
(b) Shrink and swell operator
(c) Task planning problem
(d) NC and CNC machines

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