THE UNIVERSITY OF WESTERN AUSTRALIA

SECOND SEMESTER EXAMINATIONS NOVEMBER 2001

DEPARTMENT OF COMPUTER SCIENCE & SOFTWARE ENGINEERING

Robotics (231.315)

This paper contains:
7 Pages
6 Questions

Time allowed: TWO HOURS
Reading time: TEN MINUTES

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SEE OVER

Instructions

There are six (6) Questions in this paper.
Each Question is worth different marks.
This exam paper is worth 60 marks in total.
Candidates must answer ALL Questions.

1.

(a) What is the *forward kinematics problem*?

(3)

(b) What is a *proper rigid transformation*?

(2)

(c) Given H is a homogeneous transformation, describe the structure of H, the properties of its components and those of the inverse of H.

(4)

(d) A point P is rotated about the z axis by θ and subsequently rotated about the base frame x axis by ϕ. Give the rotation matrix that accomplishes these rotations in the given order. Describe how this is accomplished using relative transformations.

(4)

(e) Given a 2R planar robot, with link lengths l_1 and l_2, what are the *reachable* and *dexterous* workspaces if $l_1 = l_2$?

What are the *reachable* and *dexterous* workspaces if $l_1 \neq l_2$?

(3)

(f) Describe a major weakness with generating trajectories using joint space schemes.

(2)

(g) Describe a major weakness with generating trajectories using Cartesian space schemes (Hint: this weakness is not evident when employing joint space schemes).

(2)

(h) What is a kinematically redundant manipulator? Use an illustration in your example. What is the form of the Jacobian Motion Rate Control equations? What is the form of its *minimum norm* solution?

(5)

2.

(a) Draw a diagram that clearly illustrates how the Denavit-Hartenburg parameters are used to describe the relative transformation from one link to the next at a **prismatic** joint of a serial manipulator.

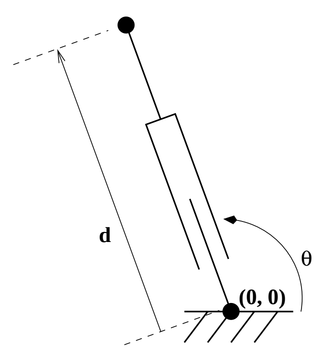
(5)

(b) Write the sequence of homogeneous transformations that make up the Denavit-Hartenburg transformation matrix. Define the variables that you use in your expression.

(2)

3.

Consider the 2 link planar arm shown below. The base of the robot is at $(0, 0)$. The first axis is a rotary joint with range $[0 - 2\pi]$. The second axis is a prismatic joint with a range of movement of [0.5–2].



(a) Write out the 2×2 Jacobian matrix relating the velocity of the end effector in x and y to the joint velocities $\dot{\theta}$ and $\dot{d}$. Each element of the Jacobian should be expressed in terms of the robot's current configuration (θ, d).

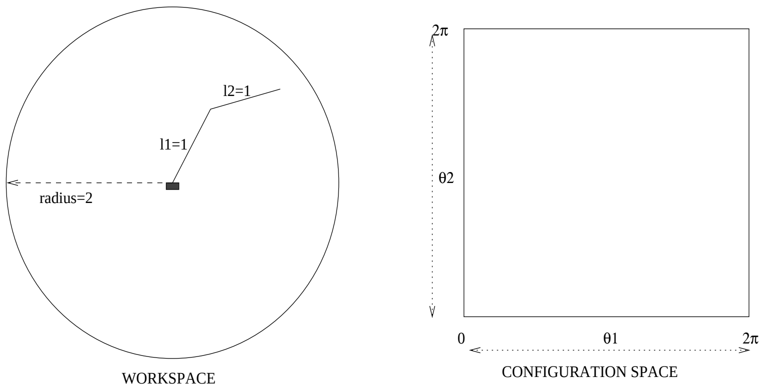
(5)

(b) What special property does the Jacobian matrix of this robot have?
What implications does this have for the kinematic solution of the arm?

(3)

4.

Consider a 2R planar robot with link lengths $l_1 = l_2 = 1$. With no actuator constraints, the reachable workspace of the tip of this robot is a disc of radius 2, and the configuration space of this robot is $[0, 2\pi] \times [0, 2\pi]$. Assume the zero configuration of this robot occurs when both links are aligned with the x-axis, and that movement of the second link is measured relative to the first.



(a) Assume that the robot's movements are restricted to allow only the following configurations: $\theta_1 \in [\pi, 2\pi]$ and $\theta_2 \in [0, 2\pi]$. Draw a diagram showing the robot's physical workspace.

(2)

(b) Assume now that the robot's movements are restricted as follows: $\theta_1 \in [0, 2\pi]$ and $\theta_2 \in [\pi, 2\pi]$. Again illustrate the robot's physical workspace. Explain in words what these configuration restrictions mean in this case.

(2)

5.

(a) Write the general expression for a Bezier polynomial curve with $n + 1$ control points. Explain each component of the equation and define each variable you use.

(3)

(b) What are the properties of a *cubic* Bezier curve with respect to position and velocity, at the first and last control points?

(2)

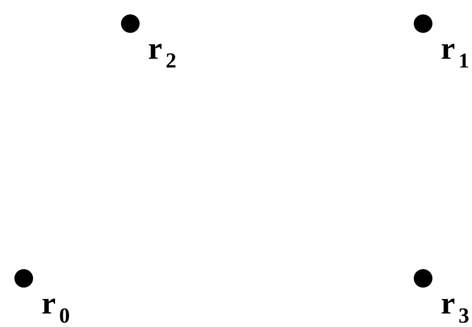
(c) How must your control points be chosen if you require the composition of two *cubic* Bezier curves to be continuous and smooth?

(2)

(d) Duplicate the control point arrangement shown below in your answer book.

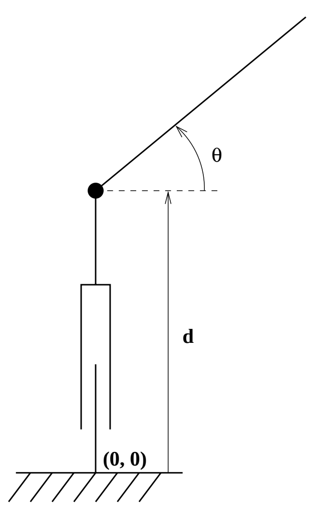
Sketch the characteristic polygon and the Bezier curve that would be produced by these control points.

(2)



6.

Consider the 2 link planar arm shown below. The base of the robot is at $(0,0)$. The first axis is a vertical prismatic joint with a range of movement of $[0-2]$, the second axis is a rotary joint with range $[0-2\pi]$. The length of the second link is 1 unit.



(a) In what configurations will the kinematic solution of the arm be unique?

(2)

(b) In what configurations will the kinematic solution of the arm have multiple solutions?

(3)

(c) In what configurations will the kinematic solution of the arm be singular?

(2)