THE UNIVERSITY OF WESTERN AUSTRALIA

SECOND SEMESTER EXAMINATIONS NOVEMBER 2002

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 a kinematically redundant manipulator? What difficulties to solving the Joint Motion Rate Control equations does the form of the *Jacobian* introduce in kinematically redundant manipulators?

(2)

(b) What is the *inverse kinematics problem*?

(2)

(c) What is the *joint common normal*? What does its length represent?

(2)

(d) "A kinematically non-redundant arm (or *minimum dexterity arm*) has a single unique configuration that satisfies the Cartesian contraints". Discuss the validity or otherwise of this statement using an example.

(2)

(e) A transformation T is composed of the following rotation and translation

T = Rot(z, $\pi/4$) Trans(x, 0.5)

Using a series of illustrations show how the same final transformation frame results, whether these operations are performed with respect to a fixed frame or using relative frames

(3)

(f) Describe an algorithm for trajectory generation in *Joint Space* for a 3R (3 rotary link) manipulator, from cartesian coordinates $\mathbf{x}_i$ to $\mathbf{x}_f$.

(4)

2.

The following table gives the Denavit-Hartenberg parameters for a 3 rotary joint (joints 2, 3 and 4) robot on a fixed base (joint 1).

Joint	Variable	Angle	Length	Offset	Twist
1	fixed	0	0	2	$\pi/2$
2	angle	θ_2	0	0	$\pi/2$
3	angle	θ_3	0	0	$\pi/2$
4	angle	θ_4	0	1	0

(a) Draw the coordinate frames for each joint and the end-effector for the robot when the angle of joint 3 is $-\pi/2$, and all other joint angles are 0. Since several of the coordinate frames share a common origin you should slightly shift each frame to ensure your diagram is clear.

(8)

(b) Would you consider this a useful manipulator design? Why?

(1)

(c) Consider a 6 DOF robot consisting of 1 prismatic joint followed by 5 rotary joints, Given you have the following data for this robot:

z_0, z_1, z_2, z_3, z_4 and z_5 — the axes of the six joints,
O_0, O_1, O_2, O_3, O_4 and O_5 — the origins of the axis frames, and
P — the end effector location.

Write the expression for the 6x6 Jacobian matrix for this robot.

(4)

3.

Consider the 2 link planar arm shown below in its **zero** position. The first axis is a prismatic joint with range of movement [0 – D]. The second link is of length l and has a rotary joint with a range of $[0 - \pi]$.

(a) Draw the locations and orientations of the coordinate frames for the second joint and for the end-effector.

(2)

(b) What is the *forward kinematic mapping* for the end-effector position in base frame coordinates when the manipulator has the joint values $[d, \theta]$.

(3)

(c) What is the Jacobian matrix for this manipulator when it has the joint values $[d, \theta]$?

(3)

(d) For what joint values is the manipulator in a *singularity*?

(2)

(e) Draw a diagram of this manipulator's Cartesian workspace in the case where $l > d$.

(3)

(f) Give a real work place use for a manipulator of this design.

(1)

4.

In pseudo-code write and explain the kinematic control algorithm that guides a robot along a trajectory using motion rate control. Assume you have a forward kinematics function that calculates the configuration of the robot and its Jacobian matrix, from the current set of joint positions. Note: Only consider control over the position of the end effector, not its orientation.

(5)

5.

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

(2)

(b) "Generally, Bezier curves are used for *designing* trajectories, rather than fitting them". Explain how Bezier curves are used in this way.

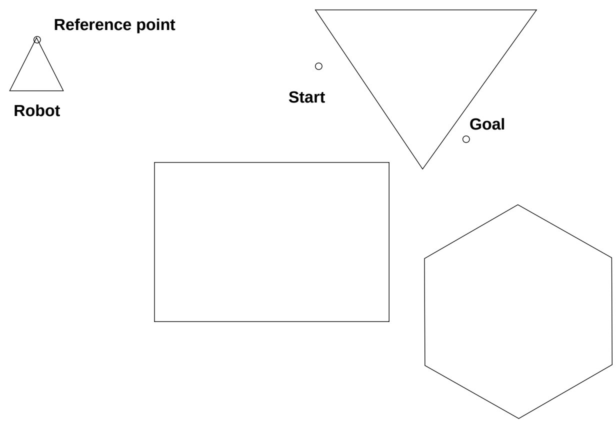
(2)

(c) Not withstanding the previous statement, given the position and desired velocity of $n+1$ points it is possible to generate the trajectory that interpolates through these points, using cubic Bezier splines. Explain how this could be done.

(4)

6.

Copy in to your answer booklet the following diagram of a field of obstacles and the start and goal points for a mobile robot.



(a) Assuming a **point** robot, draw the visibility graph of the paths between the robot start state to its goal state. Highlight the optimal (shortest) path.

(2)

(b) Assuming the robot has a shape and a *reference* point as shown in the figure, expand the obstacles to reduce the path planning problem. Draw the new visibility graph and highlight the optimal (shortest) path.

(3)