Midterm Exam 1, Version C

March 31, 2016, Intro to Robotics

|  |  |  |
| --- | --- | --- |
| Problem | Score | Possible |
| 1 |  | 15 |
| 2 |  | 25 |
| 3 |  | 15 |
| 4 |  | 25 |
| 5 |  | 25 |
| 6 |  | 25 |
| EC |  | 25 |
| Totals |  | 130 |

You may have on your desk:

* Your student ID card
* 1 handwritten 8.5”x11” double-sided crib sheet
* This exam (provided by Professor)

Grading: (problem difficulty)

Concepts: Covers chapters 1-4, 11.1--11.2

*Rotations & transformations*

* Composition of rotations about world or current frame
* Construct a homogenous transform

*Kinematics*

* Assign DH parameters
* Given DH parameters, construct A matrix
* Given two A matrices, construct T matrix

*Inverse Kinematics*

* Two-argument arc tangent function
* Solve inverse position kinematics for a 3-link arm

*Jacobian*

* Construct Jacobian given sketch and T matrices

*Computer Vision*

* Move from camera frame to world frame

Problem 1: \_\_\_\_\_\_/15

1. (5 pt) Write the matrix product that will give the resulting rotation matrix

(*do not perform the matrix multiplications*):

* 1. Rotate by γ about the world *z*-axis
  2. Rotate by *ψ* about the current *y*-axis
  3. Rotate by *Φ* about the current *x*-axis
  4. Rotate by *β* about the world *y*-axis
  5. Rotate by *α* about the world *x*-axis

1. (5 pt) Suppose the three coordinate frames

, , and are given, and suppose

, .

 Find the matrix

1. (5 pt) Consider the diagram at right. Robot is 1 meter from a table. The tabletop is 1 m high and 1 m square. A frame is fixed to the side of the table as shown. A cube measuring 20 cm on a side is placed in the center of the table with frame established at the center of the cube as shown. A camera is situated directly above the center of the block 2 meters above the table top with frame attached as shown. Find the **homogenous transform** relating the frame to the camera frame, that is, .

Problem 2: \_\_\_\_\_\_/25 Rotation matrices

Let =

If and are not both zero, then , , and .

If >0, , and

* 1. (5 pt)
  2. (5pt)
  3. (15 pts) Matrix Identification, state **Yes** or **No**. +1 for each correctly listed

|  |  |  |  |
| --- | --- | --- | --- |
|  | valid so(*k*) | valid SE(3) | valid SO(3) |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

Problem 3: \_\_\_\_\_\_/15, Forward Kinematics

a.) (5 pt) For the 3-link robot below, draw the *z* and *x*-axis according to the DH convention

Parallel-jaw

gripper

 origin

b.) (5pt) Give the DH parameters for this RPR robot.

4

­

3

­

\* indicates variable

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Link |  |  |  |  |
| 1 |  |  |  |  |
| 2 |  |  |  |  |
| 3 |  |  |  |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Link |  |  |  |  |
| 1 | 3 |  |  |  |
| 2 | 0 |  |  |  |
| 3 | 5 |  |  |  |
| 4 | 3 |  |  |  |

c.) (5pt) Compute the transformation matrix *A2* using the DH parameters:

\* indicates variable

*A2* =,

Problem 4: \_\_\_\_\_\_/25 Inverse kinematics

RPR robot for inverse kinematics.

1

1. (5pt) draw cross section of the manipulator’s *workspace* at

*x*0

*z*0

1

2

2

-2

1

-1

*x*0

*y*0

1

1

2

2

-3

-1

-2

1. (5pt) draw cross section of the manipulator’s *workspace* at

What joint variables place the end-effector at the point [*xc,yc,zc*] specified in the frame ? Assume the point is reachable.

Hint for d&e: **law of cosines**

1. (5pt) =
2. (5pt) =
3. (5pt) =

Problem 5: \_\_\_\_\_\_/25

Calculate the manipulator Jacobian of the 2-link RP arm at the position o2 = oc.

* 1. (10 pts) Write out the *J* matrix in terms of *zi* and *oi*.
  2. (5 pt) Write out the *zi* and *oi* values needed for part a. Don’t forget *o0*.
  3. (10 pts) Write out the *J* values. Calculate the cross products.

Problem 6: \_\_\_\_\_\_/25 Computer Vision

1. **(5 pt) Two frames**  and are related by the homogenous transformation

A particle has position relative to frame .

What is the position of the particle in frame ?

1. (5 pt) For a camera with focal length , find the image plane coordinates for the 3D points in the camera frame

(14,21,28)c 🡪 (*u,v*) =

1. Our underwater robot has two parallel laser beams located at [-1,0,0], [1,0,0], and pointing in the direction [0,0,1]. They are used to measure the distance to objects and walls. The camera has focal length , and the images of the laser beams are located at [-1/10,0,], and [1/6,0,].

(5 pt) How far is the wall from the laser at [1,0,0]?

(5 pt) How far is the wall from the laser at [-1,0,0]?

(5 pt) What angle is the wall with regard to the *x*-axis of the camera frame?

For Fun \_\_\_\_\_\_/25 Extra Credit

At *Frontier Fiesta* Li Huang got on a carnival ride that can be modeled as an RRR planar robot. The links are 4,2,1 units long.

Joint rotation speeds are limited to , and .

(5 pt) What are the DH parameters? (10 pts) What is the Jacobian?

(5 pt) What is the maximum angular velocity (give values and values)?

(5 pt) What is the maximum linear velocity (give values and values)?

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Link |  |  |  |  |
| 1 |  |  |  |  |
| 2 |  |  |  |  |
| 3 |  |  |  |  |

*x*1

*y*1

­

­

a­

Li Huang will be sick if the maximum linear velocity > 15. If Li is sick, draw this on the image