Spring 2011 Final

Introduction To Robotics (16-311)
5/9/2011

Name: _____

Group Number: _____

Read all of the following information before starting the exam:

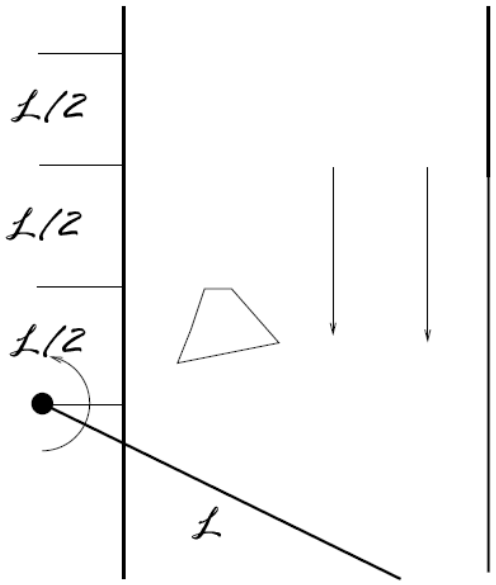
- You have 1hr and 30 minutes to complete this exam.
- When drawing paths, be sure to clearly indicate rounded edges vs sharp edges.
- When in doubt, explain your answer as you might get partial credit.
- Justify your answers algebraically whenever possible to ensure full credit. When you do use your calculator, and explain all relevant mathematics.
- Circle or otherwise indicate your final answers.
- Please keep your written answers brief; be clear and to the point.
- This test has 5 problems and is worth 100 points. It is your responsibility to make sure that you have all of the pages!
- Good luck!

1. (*20 points*)

a. (*15 pts***)** Consider a conveyor belt system on which arbitrarily shaped objects are placed. Naturally, these objects move with the conveyor. Down- stream along the conveyor, there is a one-degree-of-freedom fence which can only rotate about a pivot point.

The allowable movements for the conveyor belt and fence system are $g_1(x, y, \theta) = (0, 1, 0)^T$ for the best and $g_2(x, y, \theta) = (-y, x, 1)^T$ for the fence.

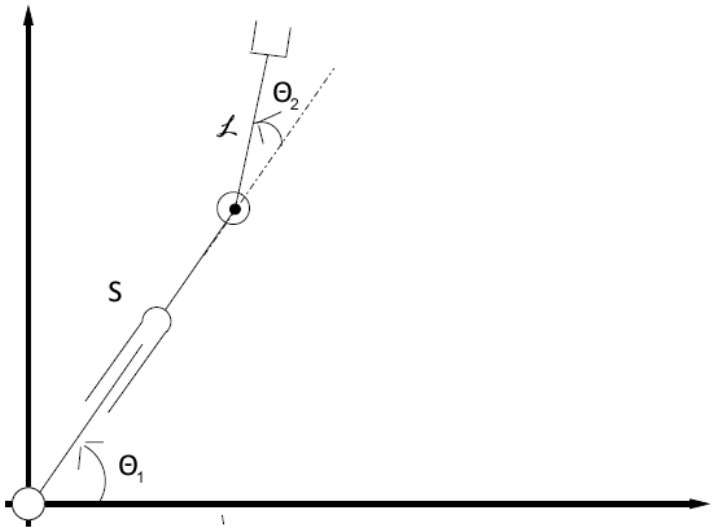
Can the fence-conveyor arbitrarily position and orient a planar part? Show all work (hint: use Lie Brackets) and explain your result.



b. (*5 pts***)** Now bins are placed next to the conveyor (that do not interfere with the fence movement) to catch the objects. Assuming the objects are small enough to fit into the bins, how many of the bins can the object be put in and why? Refer to the figure for relevant length information (figure not drawn to scale).

2. (*20 points*)

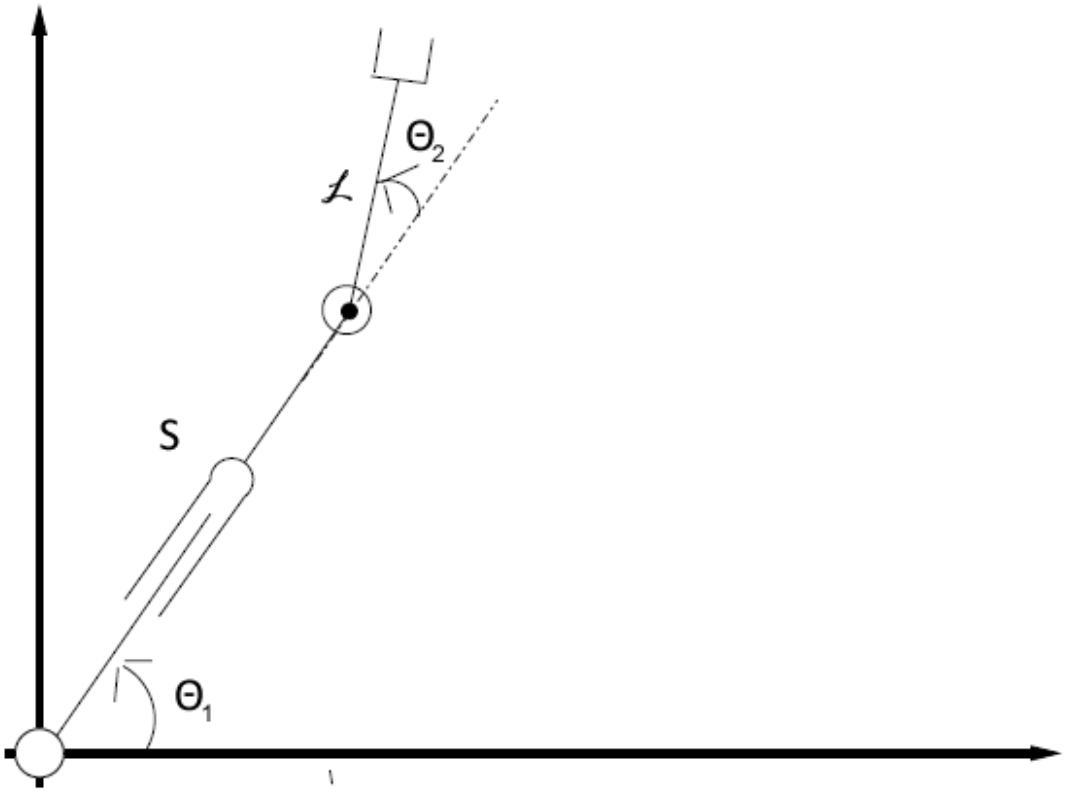
a. (*10 pts*) For the following RPR arm, the target (x, y, θ) is specified. Derive the inverse kinematic equations. Be sure to include in your answer how many solutions there are in each region (and if relevant, what equations are relevant where).



b. (*10 pts*) Given (x, y). Please give the new inverse kinematics model. Feel free to number equations from previous part and refer to them. Also be sure to state how many solutions are in each region and where the equations are valid.

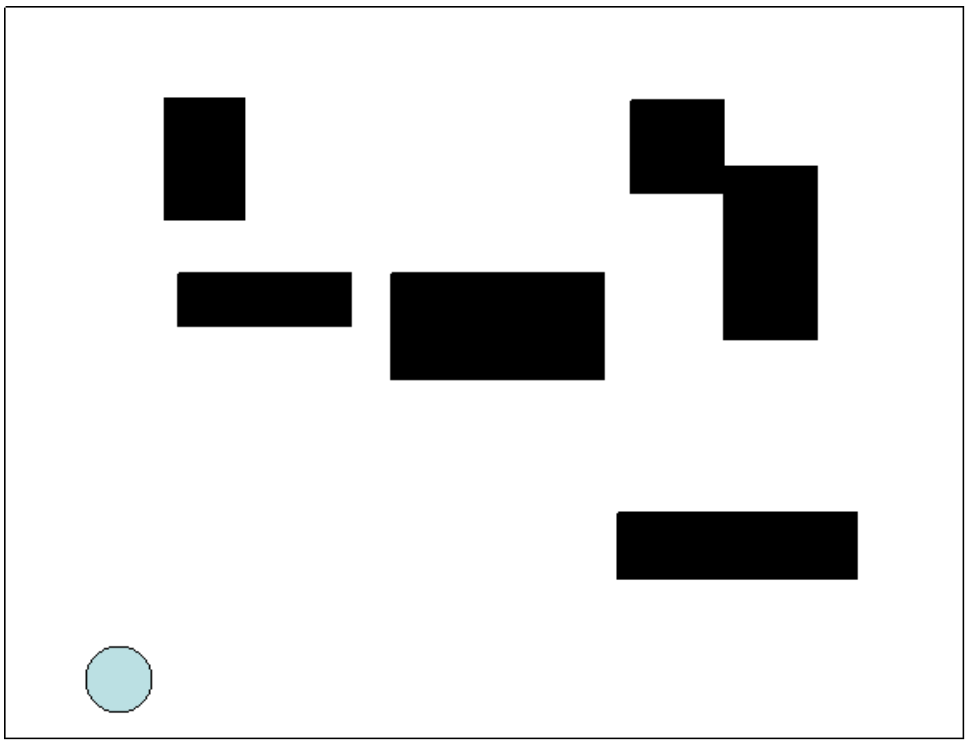
3. (*20 points*)

For the same RPR arm as in the last question, please assign frames and fill out the DH table according to the convention presented in class. You must have a clear z and x axis for each frame. If your solution is not readable, the no points will be given. Assume the reference position has the arm completely horizontal.

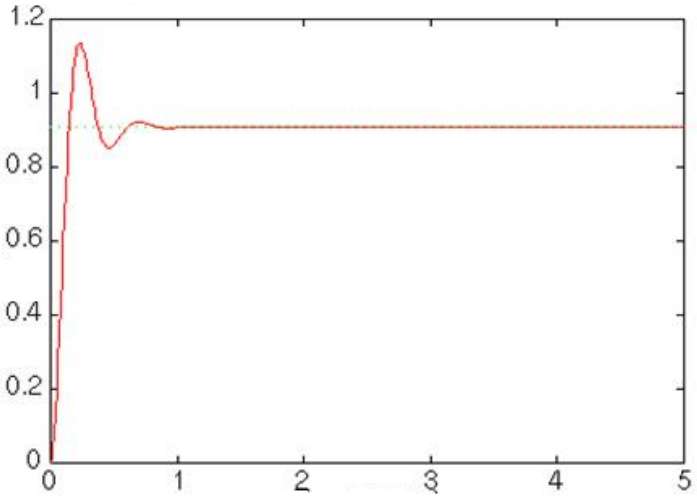


4. (*20 points*)

a. (*10 pts*) Draw the Voronoi diagram for the C-space of the environment and robot depicted in the following figure.



b. (*10 pts*) This is the response to commanding a system to $y = 1$. Assume this system already has positive values for P, I, and D. Describe and draw what happens when I is eliminated, and D is decreased.



5. (*20 points*) There are 6 short answer questions below. Please choose 4 and clearly answer them. CLEARLY indicate which questions you select.

a. (*5 pts*) State the rigid body assumption.

b. (*5 pts*) What type of graph search is A-Star? Why?

c. (*5 pts*) Draw and label the variable of a RP robot in a singular configuration.

d. (*5 pts*) As you increase the baseline of a stereo camera pair, what abilities of the system change?

e. (*5 pts*)
In class we stated that the DH matrix is:

$H_1 = Rot(x, \alpha)Trans(x, a)Rot(z, \theta)Trans(z, d)$

Suppose we consider:

$H_2 = Trans(x, a)Rot(x, \alpha)Trans(z, d)Rot(z, \theta)$

What would the difference be? Why?

f. (*5 pts*) Which path is longer according to the L1 metric?