H. Choset Fall, 1999

ME 24-354: General Robotics
1 Exam

Date Handed Out: November 23, 1999
Time Allotted: 1 hour and 15 minutes

- Please show all work.
- You can use one crib sheet.
- You must attempt all *five* problems.
- GOOD LUCK!!!

P1. [***Transformations, 10pts***] Let

$$H = \begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

be a homogenous transformation. Demonstrate that H is either a translation followed by a rotation *or* a rotation followed by a translation.

P2. [***D-H Notation, 10pts***] Consider the following three degree-of-freedom manipulator with one revolute joint, followed by a prismatic (linear translation) joint, and then a revolute joint, which rotates the final link.

(a) Baring joint limits, can this robot arbitrarily position and orient an object in the plane?

(b) Write out the Dennavit-Hartenburg parameters and variables for this robot. Circle the variables.

P3. [***Inverse Kinematics, 40pts***]

The two-link manipulator shown above has three actuators which are used to specify θ_1, θ_2 and S. l_1 is the fixed length of the first link. The second link has a variable link length S.

(a) Write out the forward kinematics of the above manipulator, i.e., given l_1, θ_1, θ_2 and S, calculate x, y and θ.

(b) Write out the inverse kinematics of the manipulator, i.e., given x, y and θ, as well as l_1, calculate θ_1, θ_2 and S.

- If you prefer to use an algebraic method to calculate S, then you only need to specify A, B and C in the solution of an quadratic equation

$$S = \frac{-B \pm \sqrt{B^2 - 4AC}}{2B}$$

Hint:

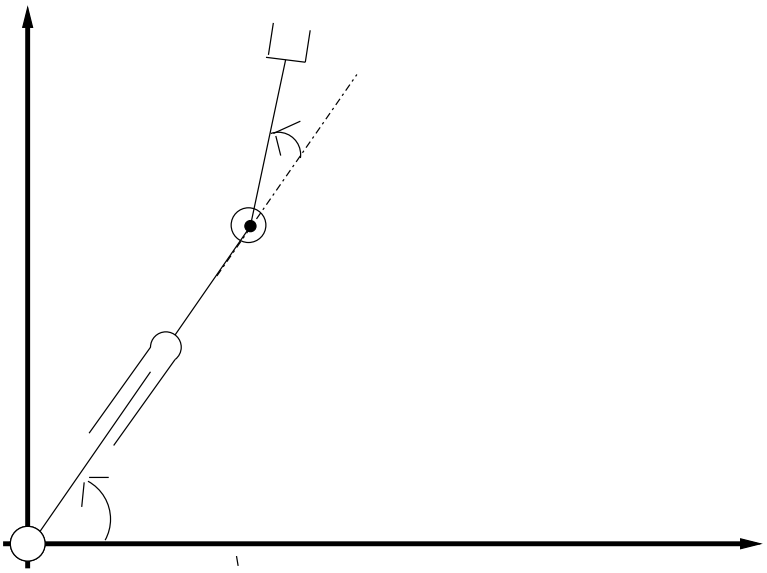


Figure 1. D-H Notation Question

- $(\cos\theta)^2 + (\sin\theta)^2 = 1$
- We found it easier to find S first.

- If you chose to solve for S with a geometric method, then feel free to define dummy variables, but you have to clearly label them on a clear diagram and define them. (Note, you cannot simply introduce a "convenient" variable and go from there.)

P4. [***Motion Planning, 30pts***] Draw the generalized Voronoi diagram of the *configuration space* of the given environment and robot in Figure 3. Draw diagram on page.

P5. [***Misc., 10 pts***] Professor Mason spoke of non-prehensile manipulation in class. Please describe two examples of non-prehensile manipulation.

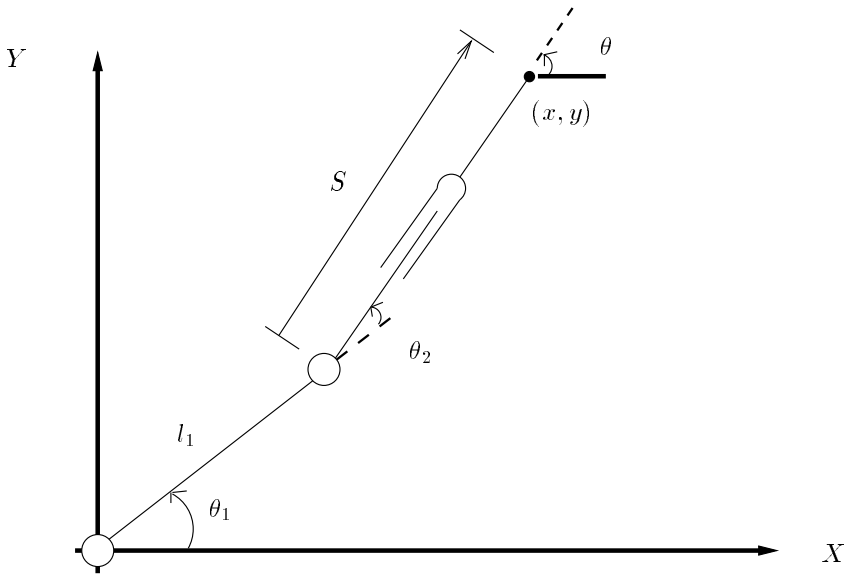
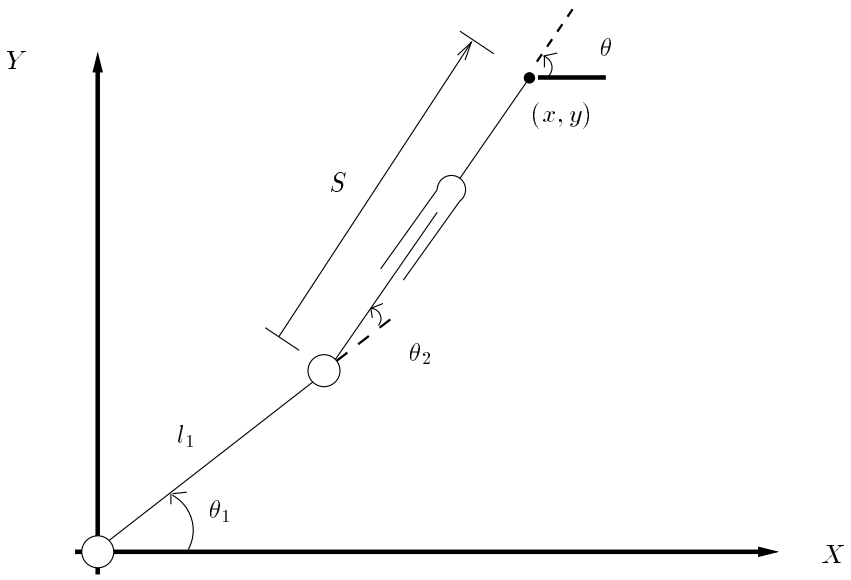


Figure 2. Inverse Kinematics.



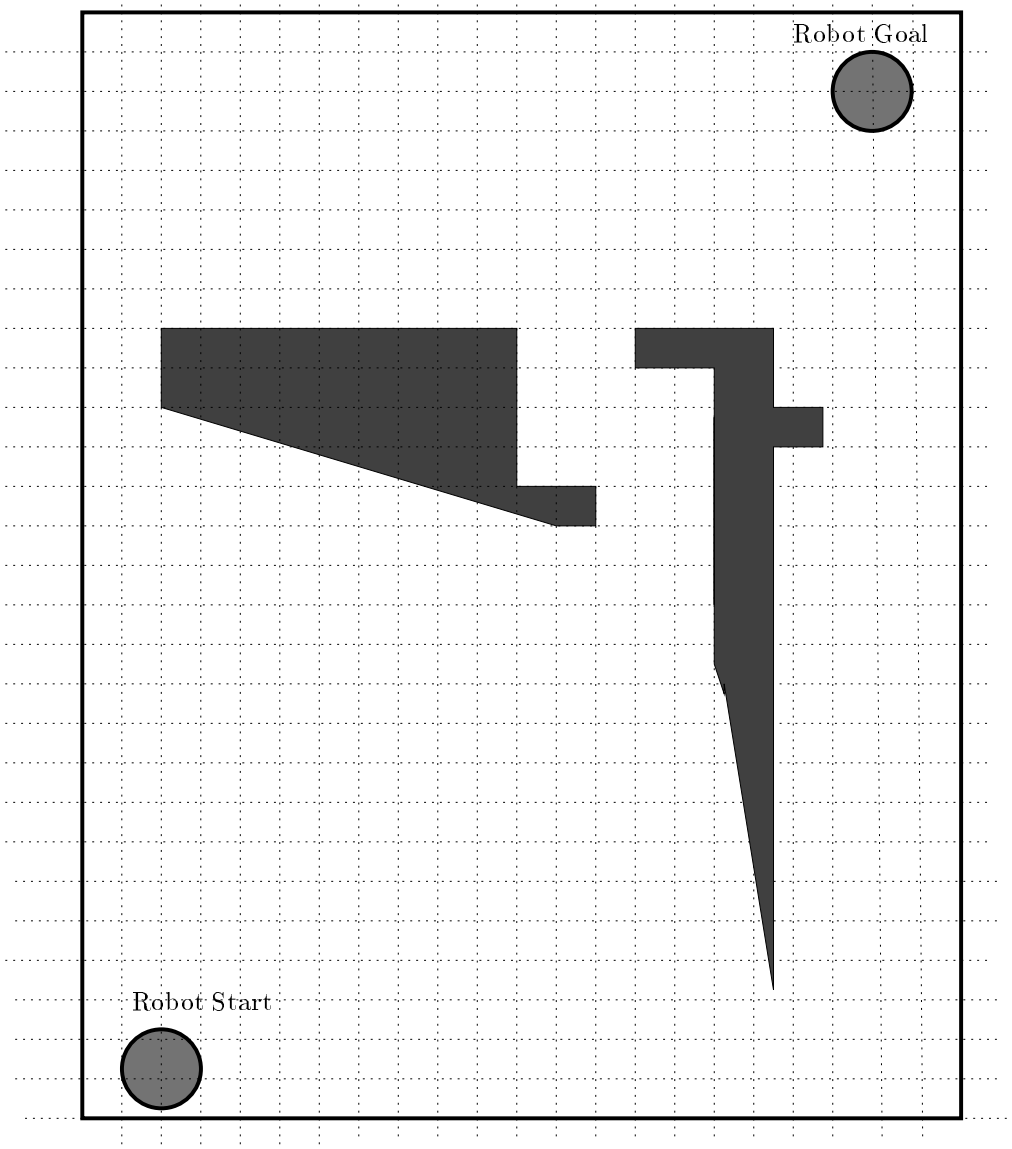


Figure 3. Voronoi Diagram: Draw on this page