H. Choset Fall, 2000

ME 24-354: General Robotics
Final Exam

Date Handed Out: December 15, 2000
Time Allotted: 1 hour and 45 minutes

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

P1. [***D-H Notation, 20pts***] Consider the following four degree-of-freedom manipulator with one prismatic (linear translation) joint, followed by a prismatic (linear translation) joint that is perpendicular to the previous one, and then two revolute joints (Figure 1).

(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.

P2. [***Configuration Space, 10pts***]

(a) A mobile robot has a planar two-link manipulator, where link 1 is 3 units and link 2 is 2 units in length (Figure 2). What are the variables that describe the configuration space for this robot.

(b) The configuration space in Figure 3 is generated from the workspace in Figure 3 and which robot – A, B, C, or D. Write your answer in the test book in a full sentence. Robot X generated the configuration space.

P3. [***Inverse Kinematics, 30pts***] Consider again the mobile robot has a planar two-link manipulator, where link 1 is 3 units and link 2 is 2 units in length (Figure 2).

(a) Determine an (x, y) coordinate pair for the mobile base such that once it is placed at (x, y), the two-link manipulator can reach all three points $(0, 0), (6, 0)$, and $(6, 6)$ (the mobile base cannot move once it is placed).

(b) With the mobile base fixed at (x, y), perform the inverse kinematics for all three pairs of points for the two-link manipulator.

P4. [***Non-holonomic Planning, 20pts***] Consider the differentially driven cart in Figure 4 that has two independently driven wheels.

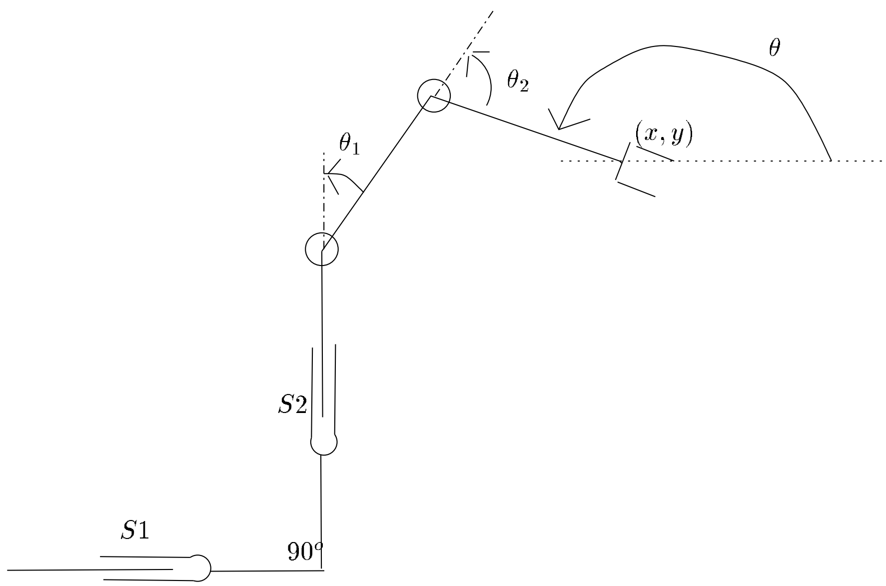

Figure 1. D-H Notation Question

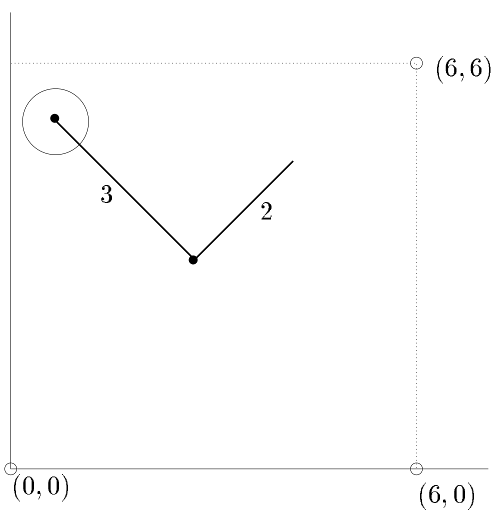

Figure 2.

(a) How many degrees of freedom does the cart have in the plane?

(b) What is the non-holonomic constraint for the cart (i.e., determine the w) and what does it mean.

(c) What are the initial allowable motions (i.e., determine the g's from

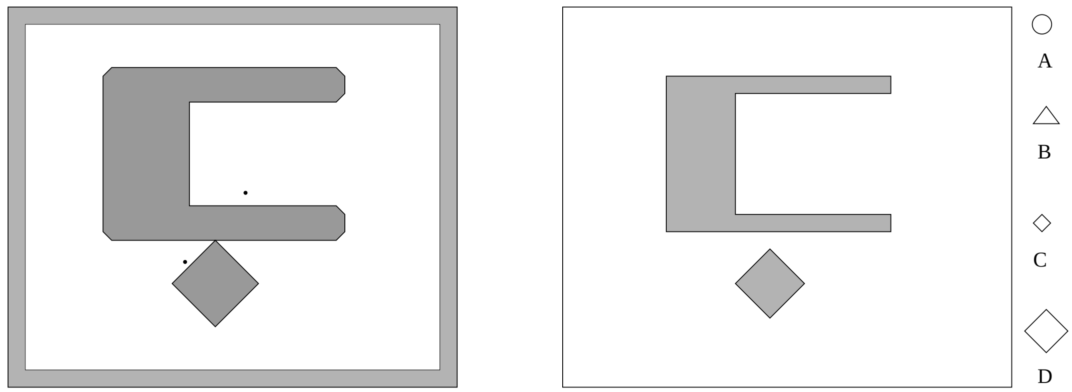

Figure 3. Configuration Space, Work Space and choice of robots that generated it.

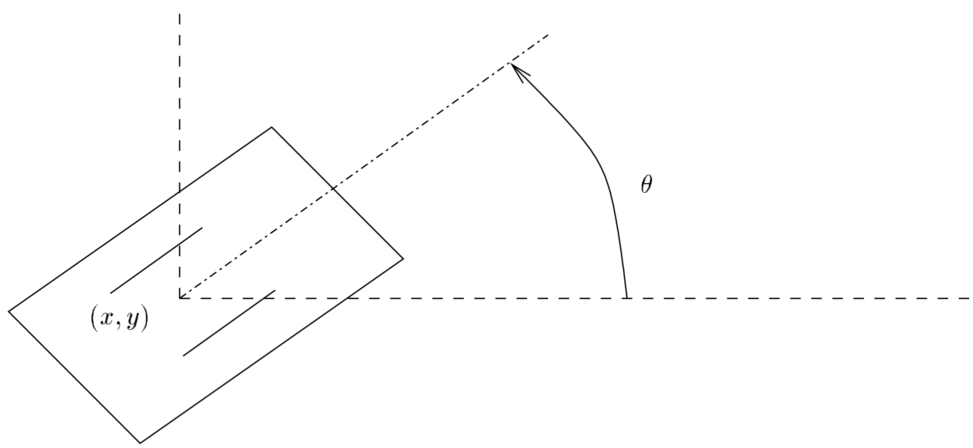

Figure 4. Cart.

the w) and what do they mean

(d) Can the cart arbitrarily position and orient itself in the plane? Use Lie Brackets to show this.

P5. [***Motion Planning, 10pts***] Pick a robot a robot in Figure 5 (assume robot cannot rotate) and then draw generalized Voronoi diagram of the *configuration space* of the given environment in Figure 5. Be clear as to which robot you chose. Draw on the image.

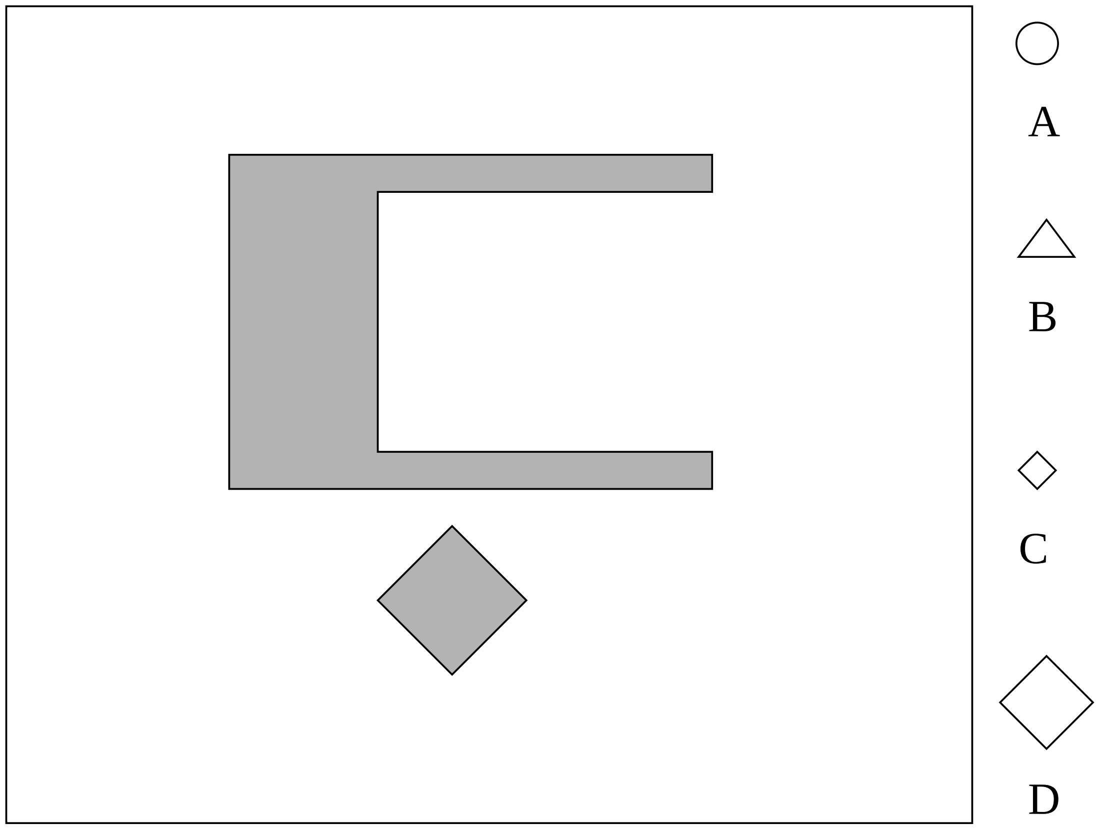

Figure 5. Workspace and choice of robots. Draw Voronoi diagram of the configuration space.

P6. [***Misc., 10 pts***]

(a) [***Design, 5pts***] The team that won the Mars rover competition had a key feature in their design. What was it and why did it enable them to win on the competition day?

(b) [***Overview, 5pts***] Robotics can be broken down into various classes of sub-categories. Pick three sub-categories that together encompass the robotics field and then define them.