16-311: Introduction to Robotics
Mid-term Examination
Spring 2007 Professor Howie Choset

February 28th, 2007

Instructions

1. You have 1 hour and 15 minutes to complete the exam.
2. Please write all answers either on the exam or in a blue book.
3. You must attempt all *six* problems.
4. Good Luck!!!

Name: ____________________________________

Score

1. __________
2. __________
3. __________
4. __________
5. __________
6. __________

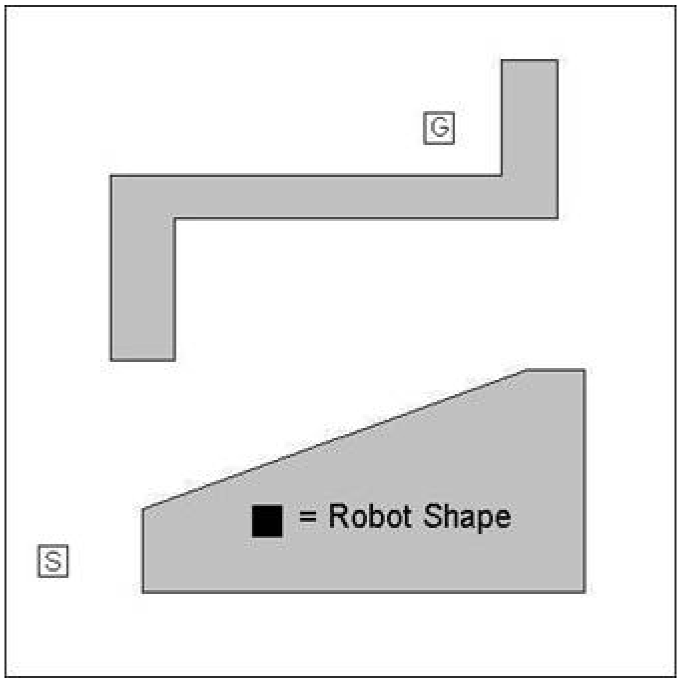
Total: ______________

Problem 1 **(25 points)**

(a) Draw the configuration space for the square-shaped robot shown and the trapezoidal decomposition of that configuration space. (15 points)

(b) Using the trapezoidal decomposition, draw a path from start to goal. (5 points)

(c) Is this the optimal path? (5 points)



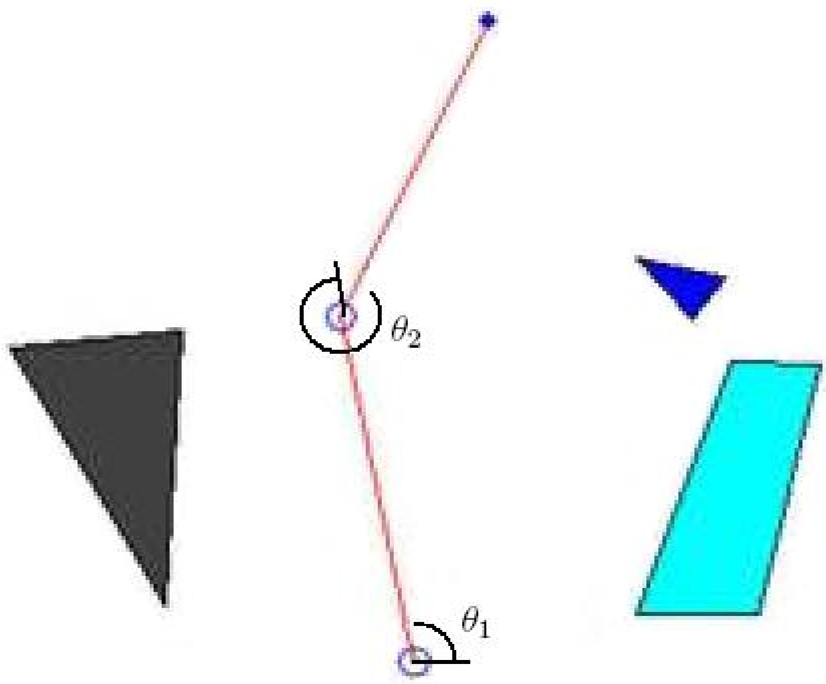
Problem 2 **(25 points)**

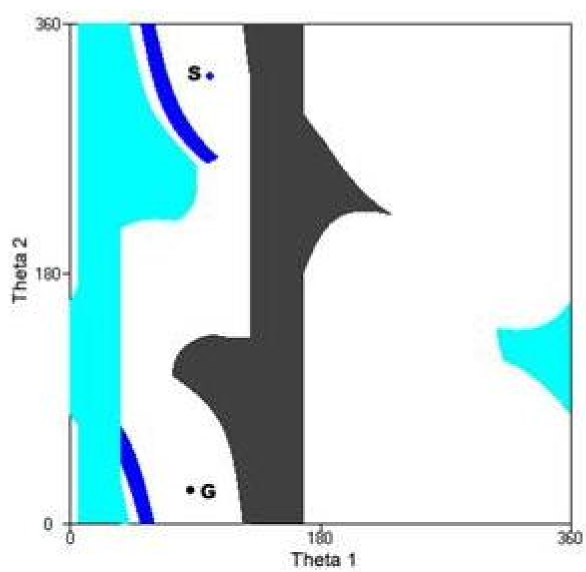
Use the following workspace (with robot shown at the start configuration), configuration space for a two link manipulator with no joint limits, and a distance between two configurations q_a and q_b given as:

$$d(q_a, q_b) = \alpha \left(|\mathtt{mod}(\theta_{1a} - \theta_{1b})| + |\mathtt{mod}(\theta_{2a} - \theta_{2b})| \right)$$

$$\alpha = \begin{cases} 1 & \text{for } 1 < \theta_2 < 359 \\ 4000 & \text{otherwise} \end{cases}$$

where $\mathtt{mod}(\cdot)$ is the shortest distance between two angles; e.g., $\mathtt{mod}(50 - 20) = 30$, and $\mathtt{mod}(5 - 355) = 10$. The $|\cdot|$ guarantees that this difference is always positive. Recall that the cost of a path is the integral of the point-wise distance.

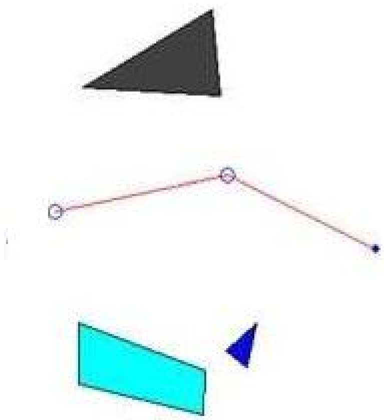


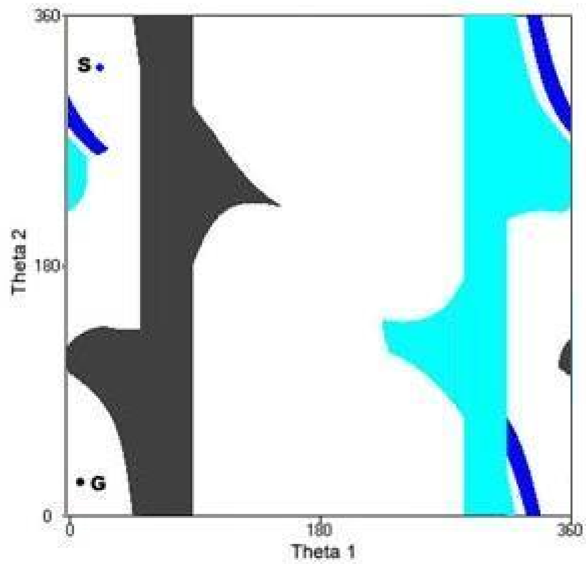


(a) Draw (on the figure) the shortest path in configuration space from the start configuration to the goal configuration. (15 points)

(b) Draw four additional configurations along this path (3 intermediate plus goal) on both the workspace and the configuration space. (5 points)

(c) In the configuration space shown below, indicate the path (if it exists) between start and goal (using the same angle conventions). (5 points)



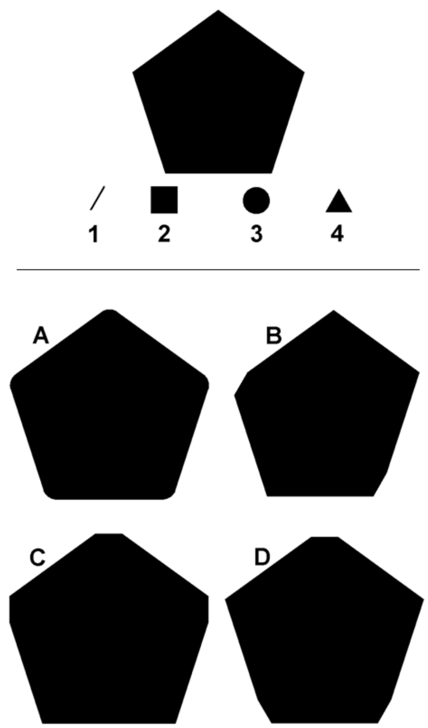


Problem 3

(20 points)

(a) A mobile robot traveling in a plane typically has a three-dimensional configuration space defined by $R^2 \times S^1$; however, when using the wavefront planner for lab 5, you planned in a two-dimensional array. Why was this permissible? (10 points)

(b) Given the pentagonal obstacle shown below and the four numbered robot shapes, match each robot shape with the lettered configuration space obstacle for the robot in the configurations shown. (10 points)



Problem 4 **(10 points)**

Answer *five* of the questions below. If you answer more, please mark with a star which five you want to be graded (no extra credit). (2 points each)

A	**B**	**C**	**D**
$\begin{pmatrix} 1 & 1 & 1 \\ 1 & 2 & 1 \\ 1 & 1 & 1 \end{pmatrix}$	$\begin{pmatrix} 1 & 1 & 0 \\ 0 & 0 & 0 \\ -1 & -1 & 0 \end{pmatrix}$	$\begin{pmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{pmatrix}$	$\begin{pmatrix} 0 & 1 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 0 \end{pmatrix}$

(a) Which of the above masks (**A** - **D**) would be best if you wanted to eliminate texture and/or white noise (i.e., small random deviations in pixel values)?

(b) Which would be best if you wanted to detect sharp (i.e., not gradual) horizontal edges, assuming the image had no noise?

(c) Which would be best if you wanted to eliminate noise *and* detect horizontal edges simultaneously?

(d) Which of these, if any, is a Gaussian mask?

(e) Below (**A2** - **D2**), we have doubled the height and width of each mask, while keeping the same pattern. What would be a benefit of using these doubled masks in the simultaneous edge-detection and noise-elimination scenario?

(f) What would be a detriment of using the doubled masks?

A2	**B2**	**C2**	**D2**
$\begin{pmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 2 & 2 & 1 & 1 \\ 1 & 1 & 2 & 2 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 \end{pmatrix}$	$\begin{pmatrix} 1 & 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & -1 & -1 & -1 & 0 & 0 \\ -1 & -1 & -1 & -1 & 0 & 0 \end{pmatrix}$	$\begin{pmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 \end{pmatrix}$	$\begin{pmatrix} 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & -1 & -1 & 0 & 0 \\ 0 & 0 & -1 & -1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$

Problem 5 **(10 points)**

Answer *five* of the questions below. If you answer more, please mark with a star which five you want to be graded (no extra credit). (2 points each)

(a) What was Dr. Efros' take-home message?

(b) Dr. Efros stated one main reason vision is easier for humans – what was it?

(c) List two of the difficulties associated with computer vision.

(d) For each difficulty you listed above, give a method that is used to overcome it.

(e) Where was Dr. Warwick's implant placed?

(f) With what external sensor did Dr. Warwick augment his own senses? He mentioned several in his later talk – just list one.

(g) What are the three D's of robotics?

(h) State Moore's Law and its implication (or lack thereof) to robotics.

(i) What was Hans Moravec's contribution to robotics?

Problem 6 **(10 points)**

Answer *all* of the questions below. (2 points each)

(a) Define transduction.

(b) Assuming sound can travel at 1000 inches/second on some planet, and the time it takes to transmit and receive a signal is 2 seconds, how far away is the obstacle?

(c) List one benefit of a laser range finder over an ultrasonic sensor.

(d) List one benefit of a switch or bump sensor over a laser range finder.

(e) How do you convert a resistance sensor to a voltage for an A/D input?