16-311: Introduction to Robotics
Mid-term Examination
Spring 2008 Professor Howie Choset

February 27th, 2008

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: _SOLUTIONS_

Problem 1 (25 points)

a) Draw the configuration space for the hexagon-shaped robot shown and the Vornoi diagram of that configuration space. (15 points)
b) Using the Vornoi diagram, draw a path from start to goal. (5 points)
c) Is this the optimal path? (5 points)

= Robot Shape

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

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

$$\alpha = \begin{cases} 1 & for & \theta_2 < 160 \\ 4000 & for & 160 \le \theta_2 < 190 \\ 1 & for & \theta_2 \ge 190 \end{cases}$$

Where mod(.) is the shortest distance between two angles; e.g., mod(50-20) = 30, and mod(5-355)=10. The |.| guarantees that this difference is always positive. Recall that the cost of the path is the integral of the point-wise distance.
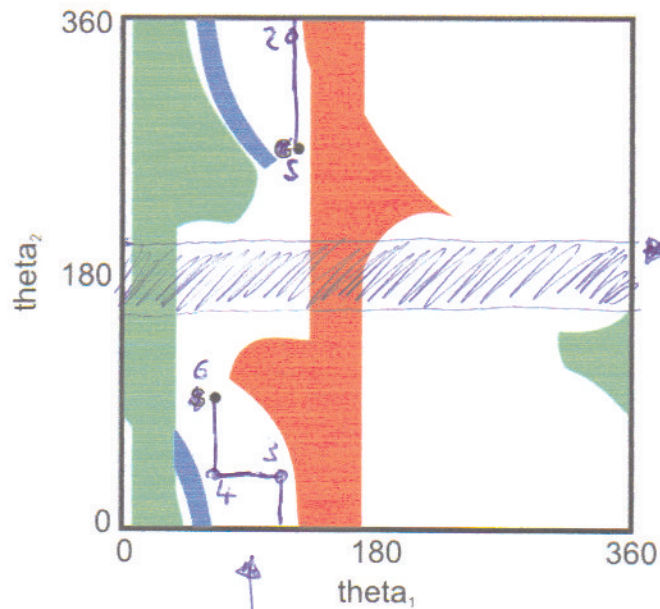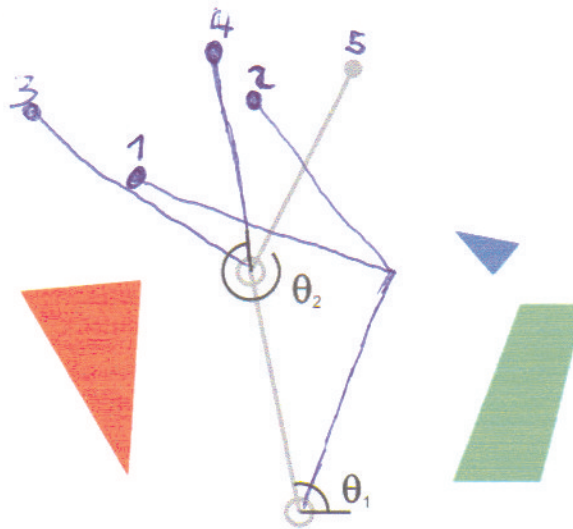
a) Draw (on the figure) the shortest path in configuration space from the start configuration to the goal configuration. (18 points)

b) Draw four additional configurations along this path (3 intermediate plus goal) on both the workspace and the configuration space. (7 points).

For the following sub problems, assume that you have a fill function, as outlined below, as well as all of the other vision functions we described in class or implemented in homework, such as threshold, edge detection, etc. If you introduce a new function, be sure to write out a function prototype for it.

```
void fill(char* image, int x, int y, int replace_value, int color)
```

The function 'fill' takes the pointer to an *image*, an *x-y* location, and a *replace_value* which we would like to replace in the image. The function then replaces all of the pixels of *replace_value* which are contained in the same connected blob as the location *x,y* with the value *color*.

Consider the following images of the letters A, B, C and D.
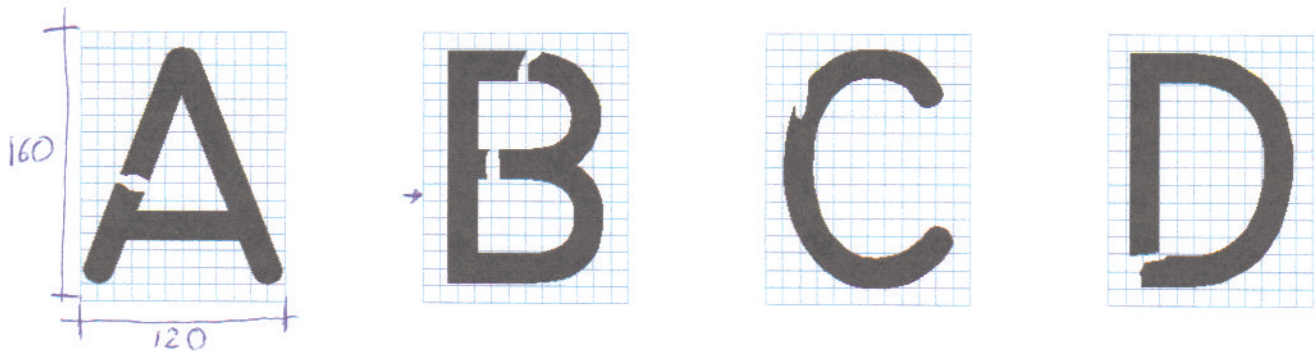
a) Write pseudo code which distinguishes between the letters A, B and C. Notice that the images are not perfect, but somewhat broken. (15 points)
   (!) Again, when writing out this code be sure to clearly define which "subroutines" you are using. You don't have to explicitly write out the subroutine but you should write the function prototype, such as the one given above for fill. State that you are using it and what it does.

b) Write pseudo code which distinguishes between the letters A, B, C and D. (10 points)

Note: You can't assume to have a library of infinitely many combinations of A, B, C and D's you can compare to determine the letters.

Ⓐ I assume the function blurImage(...) which closes the gaps in the characters: First step is to blur the image, then:

ⓐ ① • fill(img, 0,0, 1, ...)
   • fill(img, 60, 70, 2, ...)
   • fill(img, 60, 95, 3, ...)

② switch (countregions(img, [1,2,3])
   case 1: output("C"),
   case 2: output("A");
   case 3: output("B");

ⓑ Same as in ⓐ, but:

   case 2:
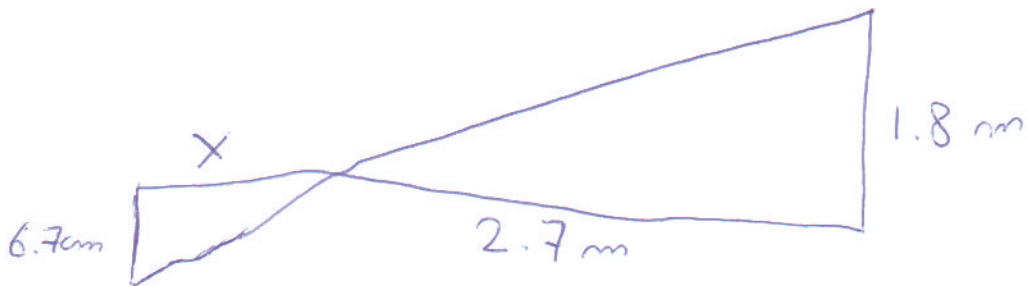   if regions aprox. same size: "D"
      else "A"
   end

Problem 4 (10 points)

A camera is used to take a photograph of a student who is 1.8 m tall. The student stands 2.7 m in front of the camera. The image height on the film is 6.7cm. What is the focal length of the camera? Show your work. (10 points)

$$\frac{2.7\,m}{1.8\,m} = \frac{X}{0.067\,m}$$

$$X = \frac{2.7}{1.8} \cdot 0.067\,m$$

$$X = 10.05\,cm \quad //$$

Problem 5 (10 points)

Answer ONLY 2:

   (a) People drive faster or slower in fog? Why (One sentence) *Faster, objects dist. look different in fog.*
   (b) What is novel about how Srinivas determines depth?
   (c) To remove fog, does simple contrasting work? Why or why not? *No, further objects look different than close ones*
   (d) What capability did Srinvas add to graphic cards? *Realistic, real time fog etc.*
   (e) What properties of different fluids did Srinivas measure? List three fluids.

Beer, milk, wine. He measures light refraction.

Answer ONLY 3:

   (a) Who won urban challenge? *CMU Tartan Racing*
   (b) How many miles plus or minus 5 did the first grand challenge robot go? *7 miles*
   (c) Why is the urban challenge more difficult than the original grand challenge? *Multiple vehicles etc.*
   (d) What does the vision system do for urban challenge? *Nothing, novision used*
   (e) Which device did the jumbo tron screw up on Boss, the CMU entry? *GPS*

Problem 6 (5 points)

Draw the gradient vector of $d_i(x)$, i.e. draw the gradient of the distance function at x.