Intro To Robotics
Spring 2016
Exam 1: Robots of the Lab
2/29/2016
Time Limit: 75 Minutes

Name: ______________________
Group: ______________________
On Wait List: ______________________

This exam contains 16 pages (including this cover page) and 5 questions.
Total of points is 100.

* You are allowed one sheet of standard printer paper with your own hand written notes on both sides. Calculators are not allowed for this exam.

* To receive credit for a question you must show your work.

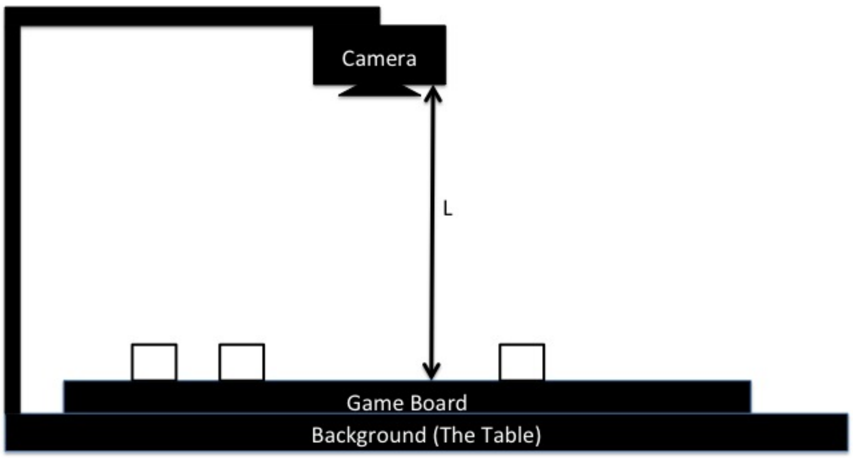
* Put all answers inside the given boxes

* Unless you specify otherwise and we see two different answers to a question we will give you 0 points for that question

Grade Table (for ta use only)

Question	Points	Score
1	29	
2	10	
3	25	
4	20	
5	16	
Total:	100	

1. (29 points) **Computer Vision**
Given a downward facing camera that is looking at a board game, develop an algorithm to detect game objects on the board. The distance between the camera and board is L and the camera is above the center of the board



Question 1.1 (10 points):
Design an algorithm in pseudo code to detect the location of any red [255,0,0], green [0,255,0], blue[0,0,255], and white[255,255,255] 100 pixel by 100 pixel squares in an RGB image. RGB values go from 0 to 255 inclusive. The input image is 16 megapixels in size (4,000 by 4,000 pixels)

Question 1.2 (2 points): How could you make your program run faster?

Now we will do image segmentation with the double raster scan algorithm on a small 5 pixel by 4 pixel portion of an image. Remember double raster operates on a binary image, so first we will have to make each channel of the image into a binary image.To do this threshold each of the color channels with a threshold of 213.

red:

$$\begin{bmatrix} 18 & 25 & 255 & 247 \\ 27 & 19 & 255 & 251 \\ 0 & 12 & 3 & 253 \\ 250 & 251 & 248 & 250 \\ 253 & 249 & 1 & 4 \end{bmatrix}$$

green:

$$\begin{bmatrix} 3 & 4 & 254 & 236 \\ 2 & 6 & 251 & 255 \\ 14 & 11 & 2 & 255 \\ 18 & 8 & 3 & 4 \\ 15 & 7 & 5 & 18 \end{bmatrix}$$

blue:

$$\begin{bmatrix} 15 & 0 & 255 & 251 \\ 19 & 4 & 253 & 250 \\ 1 & 9 & 18 & 255 \\ 2 & 7 & 0 & 1 \\ 4 & 6 & 5 & 3 \end{bmatrix}$$

Question 1.3 (3 points): Write down the three binary images for each red, green and blue?

Question 1.4 (5 points): Run double raster on the red image, what is the final resulting pixel labels?

Assume that for the green and blue images you get the following:

green:

$$\begin{bmatrix} 0 & 0 & 2 & 2 \\ 0 & 0 & 2 & 2 \\ 0 & 0 & 0 & 2 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

blue:

$$\begin{bmatrix} 0 & 0 & 2 & 2 \\ 0 & 0 & 2 & 2 \\ 0 & 0 & 0 & 2 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

Question 1.5 (4 points): Mark each pixel in the 5 by 4 grid below as red,green, blue, white or none. Do this labeling from the results of the double raster scan in problem 1.4 and the segmentation presented directly above. The labeling will reflect the colors given in the red, green, and blue channels presented in section 1.2.

Question 1.6 (5 points): If the distance L were to be set to 20 inches how many pixels would a one inch cube lying on the table be in the image? Assume the cameras focal length is 1 inch and Each image sensor on the image plane is .01 inches by .01 inches.

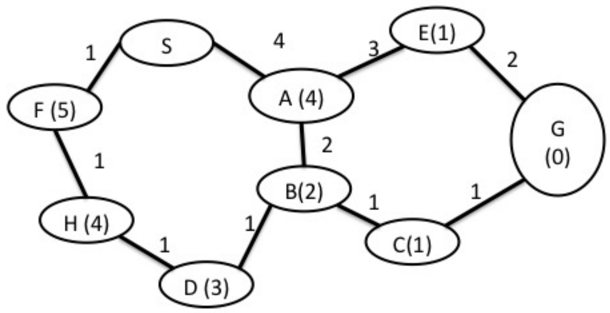
2. (10 points) **Data Structures**

Assume that you took a picture of a board game and after running a region classification algorithm found that the board contains N different game objects. The board takes up the entire input image and is of width W pixels and height H pixels. You remember from class that two common data structure options would be to store the board as a mesh (a graph of triangles) or as a grid.

Question 2.1 (5 points): Describe a data structure that could be used to store a grid in a computer. List one advantage and disadvantage of this data structure in terms of space needed to store the data structure and time needed to access a specific element in the data structure.

Question 2.2 (5 points): Describe a data structure that could be used to store a mesh in a computer. List one advantage and disadvantage of this data structure in terms of space needed to store the data structure and time needed to access a specific element in the data structure.

3. (25 points) **Graph Search?**
Question 3.1 (15 points):
From the following graph run the A* algorithm. The entry point in the graph is S and the desired end location is G. Node heuristics are in parentheses inside each node and edge costs are on written over each edge. For this problem optimality is with respect to edge weights.



3.1.1 [3 points] List the vertices in the optimal path from S to G

3.1.2 [10 points] Write down the order in which nodes are expanded, and for each node, write out the nodes on the priority queue with their f values

3.1.3 [2 points] Does the path you found by inspection match the path found by A*

Question 3.2 (5 points):
How does changing E's heuristic to (2) affect the optimality of the path you found in the previous part? Explain.

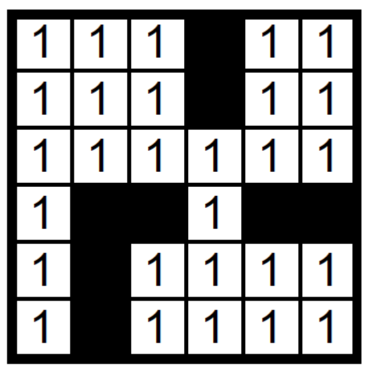
Question 3.3 (5 points):
If the cost for edges A to E and E to G were changed to one, but the heuristic values were not changed in the original graph, would the requirements for calculating an optimal path still hold? why or why not? Based on that information would A* calculate the same path? Would this path be optimal for that graph?

4. (20 points) **Where is the robot?**

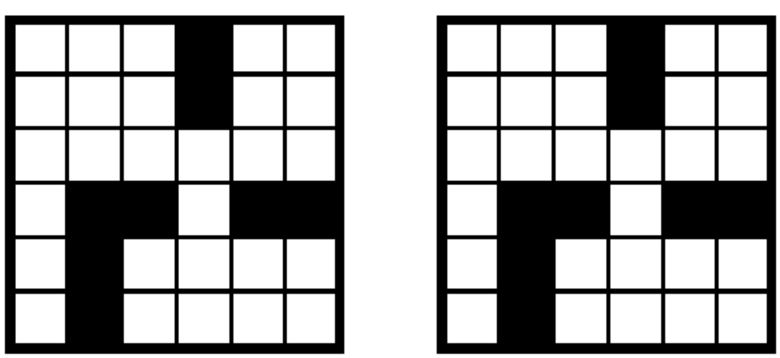
We have previously studied localization using transition and observation models. Now we will explore a situation where a robot has lost its sensors and cannot observe, but can still localize.

The robot in consideration has an omnidirectional base that allows it to move in any direction and begins knowing its orientation, but not position. The known map of the world is shown below, with black cells indicating obstacles and white cells indicating free space.

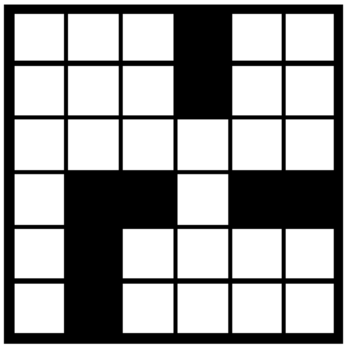
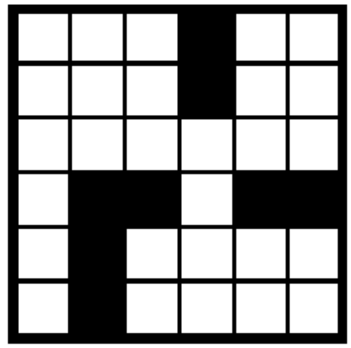
The robot begins with a uniform initial belief state shown below. A 1 in a cell indicates that the robot may exist in that cell, and a 0 means it cannot be there. On each time step, the robot executes a left-up movement at every step (1 unit left, 1 unit up) in the world coordinates. Assume that there is no transition noise. If there is an obstacle in the way of the robot, the robot will stay in place.



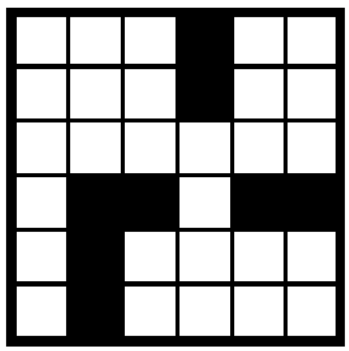
Question 4.1 (4 points):
Assuming the robot cannot pass through obstacles, draw the robot's belief state after the first left step (left) followed by the first up step (right)



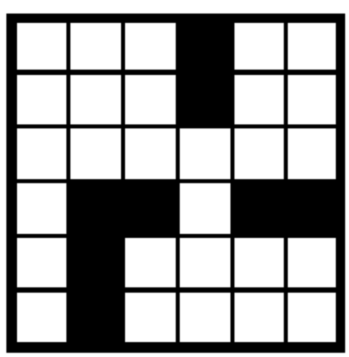
Question 4.2 (4 points):
Draw the robot's belief state after another left and up step.

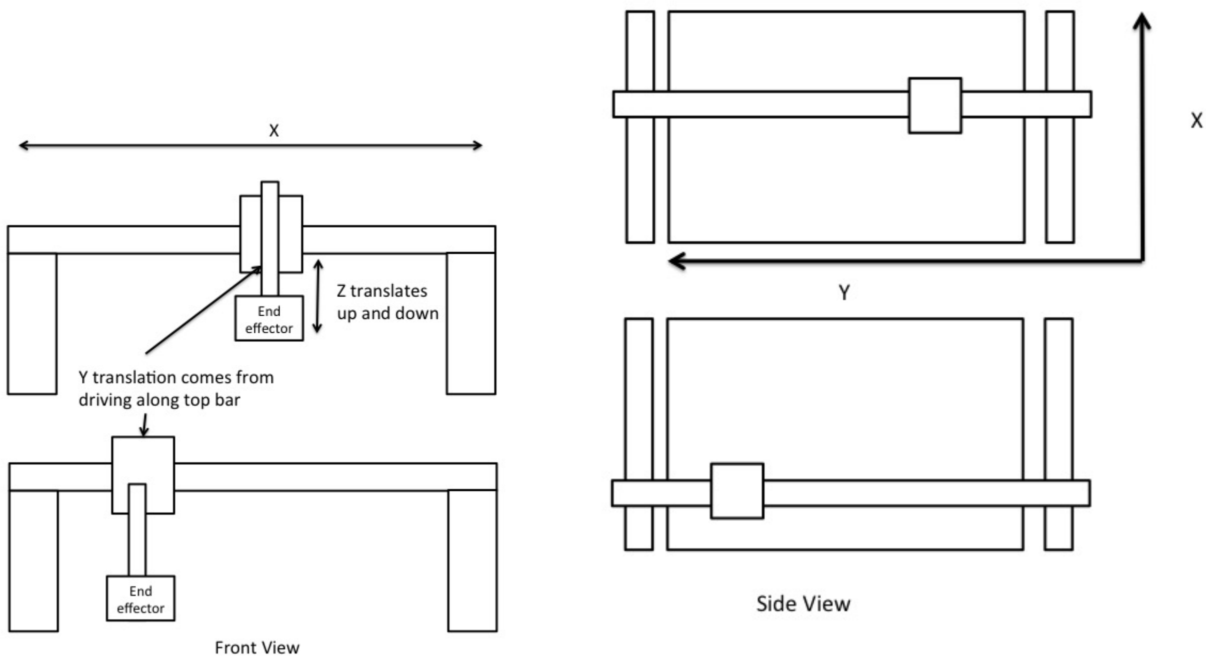
Question 4.3 (4 points):
Finally, draw the belief state after another 50 time steps.



Question 4.4 (4 points):
Has the robot determined its position? Give a new repeating movement sequence the robot can execute to finish localizing and indicate where it will converge to.



5. (16 points) **Configuration Space**
For this question all coordinates are given as (x,y,z) triples or (x,y) pairs where z is assumed to be 0.



This robot has 3 linear actuators: one actuator moves in x, one moves in y and one moves in z with an end effector attached to the the end of the z actuator.

This robots end effector is a cube of 10cm in x, 10cm in y, and 10 cm in z. All distance measurements are given with respect to the center of the bottom face of the end effector cube.

The end effector can translate in z from 0cm to 100cm, from x of 0cm to 100cm, and from y of 0cm to 100cm. The super structure of the arm is outside of the robots workspace so the robot will not run into itself. However the workspace does have a containing wall of height 40cm that encompass the perimeter of the workspace that the end effector has to worry about.

One cube is located such that the bottom right corner is at (30 cm,30 cm) and the top left corner is at (40 cm,40 cm). The height of this cube is 10cm.

One cube is located such that the bottom right corner is at (60 cm,60 cm) and the top left corner is at (70 cm,70 cm). The height of this cube is 10cm.

One rectangular prism is located such that the bottom right corner is at (40 cm,40 cm) and the top left corner is at (60 cm,60 cm). The height of this rectangular prism is 5cm.

Question 5.1 (2 points):
Draw the joint 1,joint 2 configuration space of the board at a z height of .25cm.

Question 5.2 (2 points):
Draw the joint 1 and joint 2 configuration space of the board at a z height of 5cm

Question 5.3 (2 points):
Draw the joint 1 and joint 2 configuration space of the board at a z height of 7 cm

Question 5.4 (2 points):
Draw the joint 1 and joint 2 configuration space of the board at a z height of 12 cm

Question 5.5 (8 points):
Now plan a path to move the end effector from (15 cm,15 cm,.5 cm) to the location (85 cm,85 cm,.5 cm). Draw a sketch of the path of the end effector.

Question 5.6 (2 points):

What distance metric did you use why?