# Midterm Exam

## 16-311: Introduction to Robotics

Last Updated: 6 March 2017

Name: ____________________________________________

Andrew ID: ______________________

Team Number: _________

- You will have 1 hour and 15 minutes to complete this exam
- There are 5 sections on 20 pages. Make sure you have all of the pages. Write your Andrew ID on all the sections and keep your work in that section (they will be graded individually). There is a blank page after every section.
- When making drawings - be precise. Rounded edges should look rounded, sharp edges should look sharp, sizes should be close to scale. Neatness counts.
- Show your work. Partial credit may apply. Likewise, justify algebraically your work to ensure full credit, where applicable.
- It should be very clear what your final answer is, circle it if necessary.
- You may need to make certain assumptions to answer a problem. State them (e.g. what is optimal).
- You are allowed one handwritten one-sided reference sheet for the exam. No cell phones, laptops, neighbors, etc. allowed.
- Good luck and you can do it.

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# 1 Vision

Andrew ID: ________________________

In this section, our goal is to determine how far away Martial Hebert, Director of the Robotics Institute, is away from our camera using one single image and the real world distance between his eyes. Imagine that single-channel grayscale image below was taken using an NXT quadcopter:

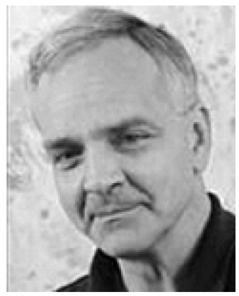

Figure 1: Martial Hebert.

We have been able to focus in on the portion of the image containing Professor Hebert's eyes based on height information for our quadcopter. The image below shows the portion of the image that we will be considering:

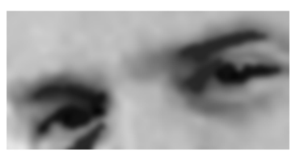

Figure 2: Part of the image that we expect to contain the eyes.

1. Below is a histogram showing frequency of pixel value in the cropped image containing the eyes. In this example, 0 represents a completely black pixel and 1 represents a completely white pixel.

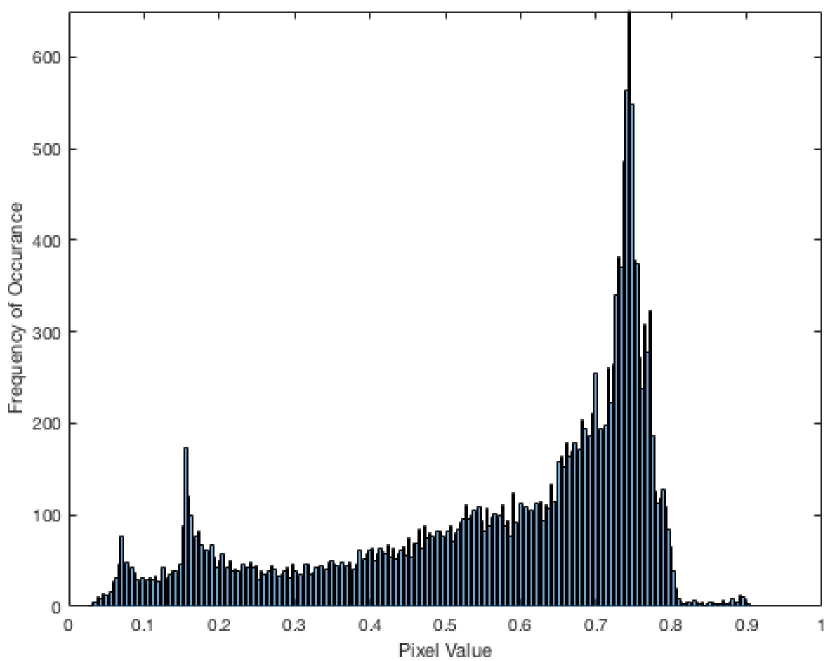


Figure 3: Histogram showing pixel value frequency.

Our goal is to separate pixels from Professor Hebert's pupils from non-pupil pixels. (The pupils are the black portion in the center of your eyes. The pixel value on the pupils are the darkest pixels in this image.) With this goal in mind, which value do you choose as a threshold for this image?

2. Why do you choose this value?

3. Using this value, record the approximate thresholded image on the grid below to the right. Feel free to block areas and label them once to save time.

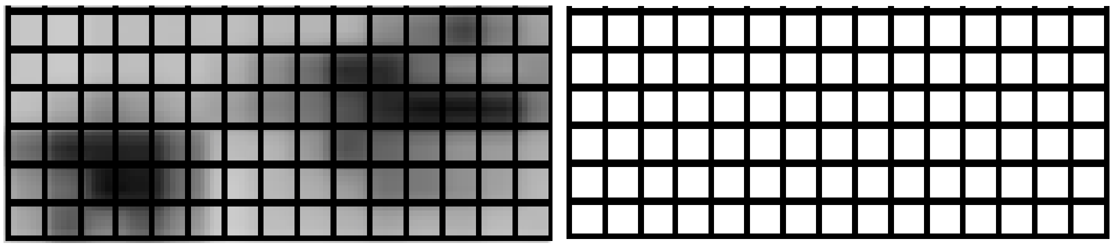

Figure 4: Predict the output of a threshold on the image on the left using your threshold value. Fill in the grid to the right such that background is 0 and foreground is 1.

4. The focal length of our camera is $f$. The real distance between Professor Hebert's pupils is $r$. In the image above, there are $p$ pixel per inch. How far away is Professor Hebert? Write your answer as a symbolic equation using $f$, $r$, $p$ and the number of pixels between pupils found from the threshold (you can use any metric and method that you like to come up with this number, as long as you justify your work).

5. Deva Ramanan came in and presented his research on identifying people. Answer ONE of the following questions: 1. What are two challenges that computer vision researchers must grapple with to rocognize objects? 2. What does foveal mean as it pertains to computer graphics? 3. Draw a symbolic diagram of a neural net and label your work.

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## 2 Control

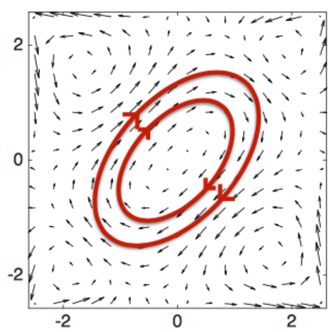
Andrew ID: ________________________

For this section, we will focus on PID control.

1. Do you need to have a model of your robot's dynamics or operation in order to employ a PID controller?

2. Why or why not?

3. Matt Travers came in to discuss control strategies for a quadruped walking robot. Please answer ONE of the following: 1. Very generally, what enabled this robot to perform so well over the rubble in the video he showed? (was it a great vision system, a detailed map, superior motors, etc.?) 2. What does CPG stand for? And what does this mean? 3. What is this a picture of?



4. We have made a go kart with unreliable steering. We are able to measure our position as a deviation from a center line (given as the position=0 line). We believe that it is possible to achieve a near 0 steady state in 2 seconds.

   Given the following output and desired level, how would you adjust (increase,decrease) the $K_p$, $K_i$ and $K_d$ coefficients (if at all)? Explain your choice briefly. There may be more than one correct answer. EXPLAIN YOUR CHOICE.

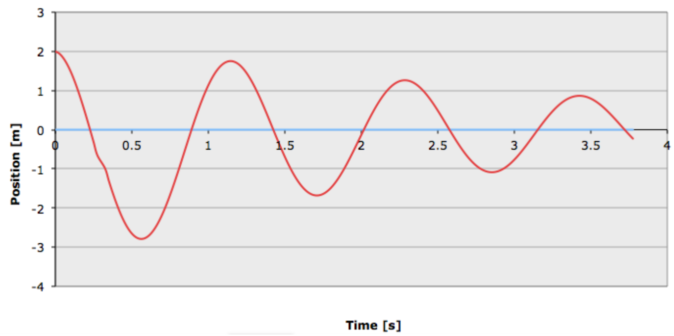



Figure 5: Sample position graph 1.

5. With the same go kart, given the follwoing output and desired level, how would you adjust (increase, decrease) the $K_p$, $K_i$ and $K_d$ coefficients (if at all)? Explain your choice briefly. There may be more than one correct answer. EXPLAIN YOUR CHOICE.

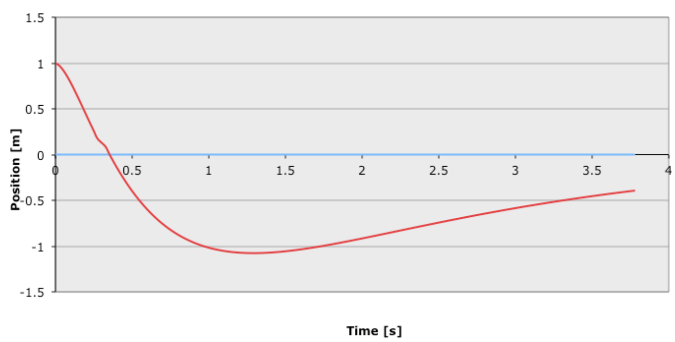



Figure 6: Sample position graph 2.

6. In any system, what can happen if your $K_i$ coefficient is too high?

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# 3 Path Planning

Andrew ID: ________________________

In this section we will review a wide variety of concepts and algorithms related to path planning.

1. Waypoint planner: Our robot and environment is shown below. Draw the locations where you would place vertices for a path planner using waypoints to navigate throught the following workspace. We want to place these points in such a way that we find the shortest path to the goal with respect to the L2 metric. You do not yet know where the start and goal locations will be, they could be anywhere in the free space. Place at least 9 waypoints.

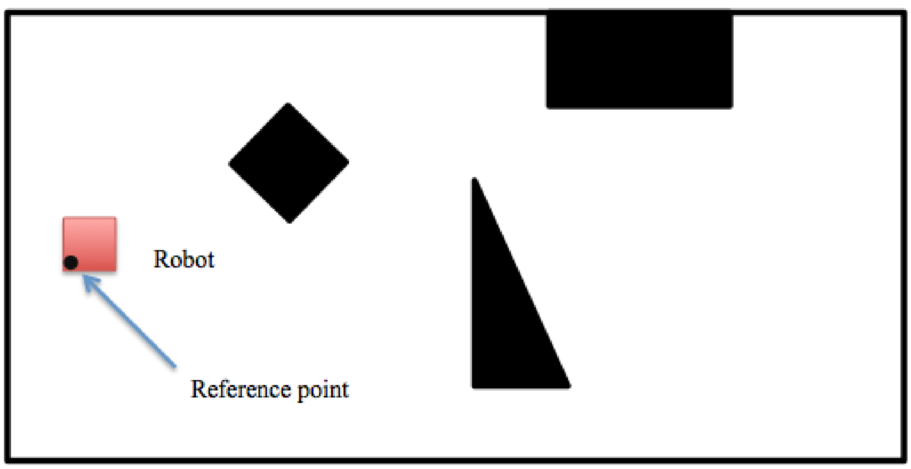


Figure 7: Robot workspace.

2. Why did you place the waypoints in these locations?

3. Please use the image below to answer the following questions.

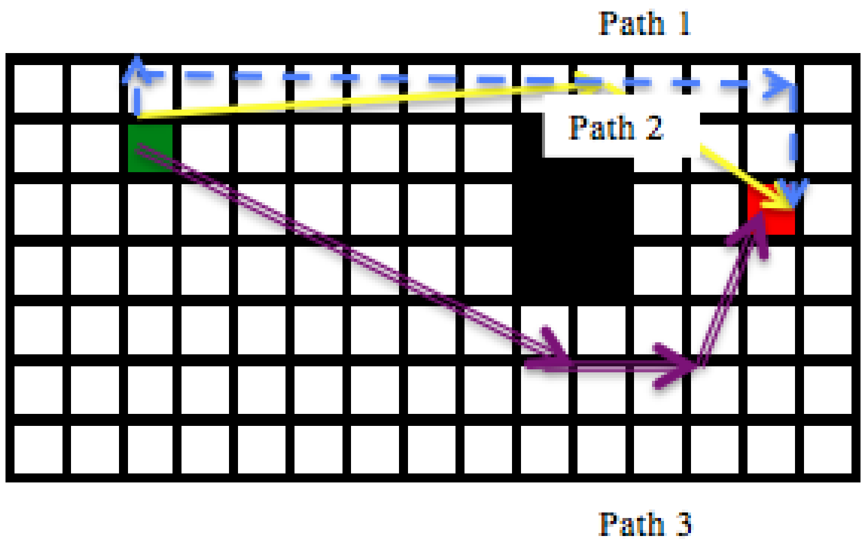


Figure 8: Various robot paths from start to goal.

Which of these paths is optimal?

4. Which one(s) of these paths is best with respect to the L1 metric?

5. Why is this path best with respect to the L1 metric? (to answer this question, describe the L1 metric or list the L1 metric values of this and every other path-it you can leave this in an unsimplified form)

6. Which one(s) of these paths is best with respect to the L2 metric?

7. Why is this path best with respect to the L2 metric? (to answer this question, describe the L2 metric or list the L2 metric values of this and every other path-you can leave this in an unsimplified form)

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# 4 Graph Search

Andrew ID: ________________________

This brief section will evaluate understanding of concepts related to graph search.

1. What are the two conditions that an algorithm must have in order to be complete?

2. Perform A* graph search on the following graph. The values in the circles represent heuristic values. The values on the line segments represent cost of that segment.

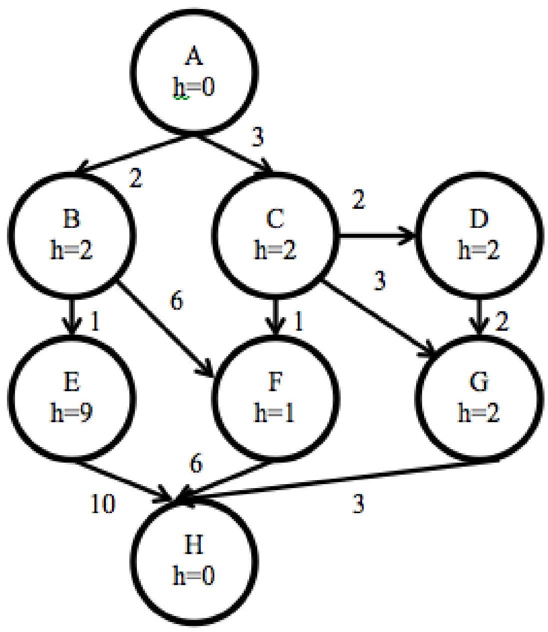


Figure 9: A* graph.

List the nodes that are EXPANDED in the A* algorithm above in the order in which they are expanded:

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# 5 Localization

Andrew ID: ________________________

The following questions cover concepts of localization covered in lecture and lab.

1. Why do we employ other sensors and localization tequniques instead of just relying on motor encoder values and odometry and dead reckoning?

2. We are considering a robot with omni directional wheels that only translates and does not rotate. This robot has an ultrasonic sensor pointed to its right. The filled in squares in the image below are obstacles where the robot cannot go. If the robot attempts to make a move where it would collide with a wall, it remains stationary at its current square.

   At time t=0, our sensor detects a wall. The image below represents our current guess for the location of our robot. Black cells represent wall and are impassable. Here, higher numbers represent higher probability of the robot being at that cell. Please note that the probabilities should sum to 1, but for simplicity in this test environment, we will not divide by the sum of these numbers.

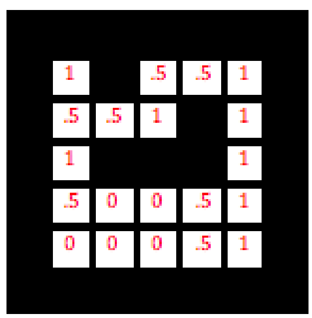


Figure 10: Time t=0 location predictions.

   Why are there areas of medium probability surrounding areas of high probability? (i.e. why does the guess not immediately fall off here?)

3. Our robot takes one move up where the top of this paper is up. Draw the resulting distribution of guesses for the robot's position. Your exact numbers will not be precise, just give reasonable estimates so we can tell what you are simulating.

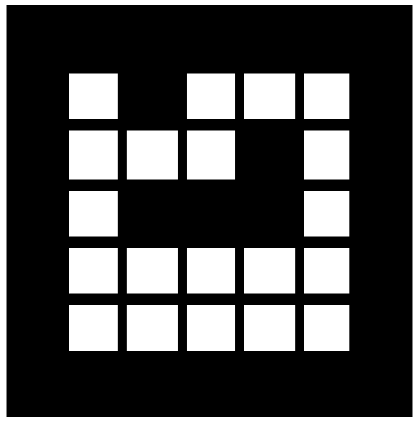

Figure 11: Location predictions after motion update.

4. At this new location, our robot's right wall sensor does NOT sense a wall. Draw the resulting guess of location:

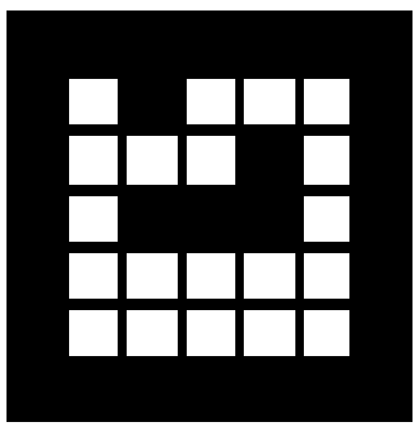

Figure 12: Location predictions after sensor update.

5. Place x(s) on the cells that you feel have the greatest chance of containging the robot.

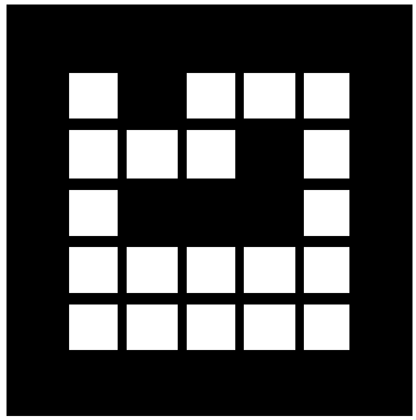

Figure 13: Final localization guesses.

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This is the end of the test.