Midterm Exam

16-311: Introduction to Robotics

2018

Name: ____

Andrew ID: _______________________

Team Number: _________

- You will have 1 hour and 15 minutes to complete this exam
- There are 6 sections on 22 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 separately). There are blank pages throughout the sections.
- 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 two-sided reference sheet for the exam. No cell phones, laptops, neighbors, etc. allowed.
- Good luck and you can do it.

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2 Control

Andrew ID: ________________________

For this section, we will focus on robot control.

1. In the example above with the lunar rover, how fast would we need to spin our motors in revolutions per minute if we want the tangential speed at the wheel rim to be 1 inch per second? The robot's wheel is 10 inches in diameter (you do not need to simplify your answer).

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2. Why is the phrase "encoder error" misleading?

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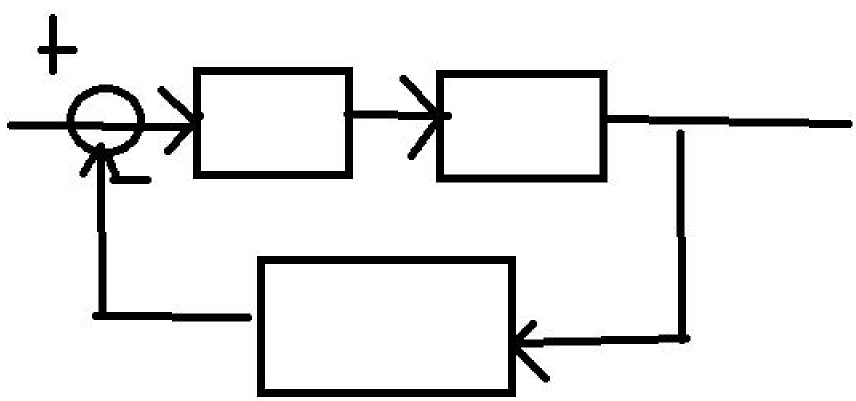
3. Draw a block diagram of a controller with feedback. Include the following labels in boxes or on arrows: Plant, Desired State, Controller, Sensor, and Actual State:



4. In the graph below, how would you change the Kp term in order to decrease the rise time?

Increase Kp

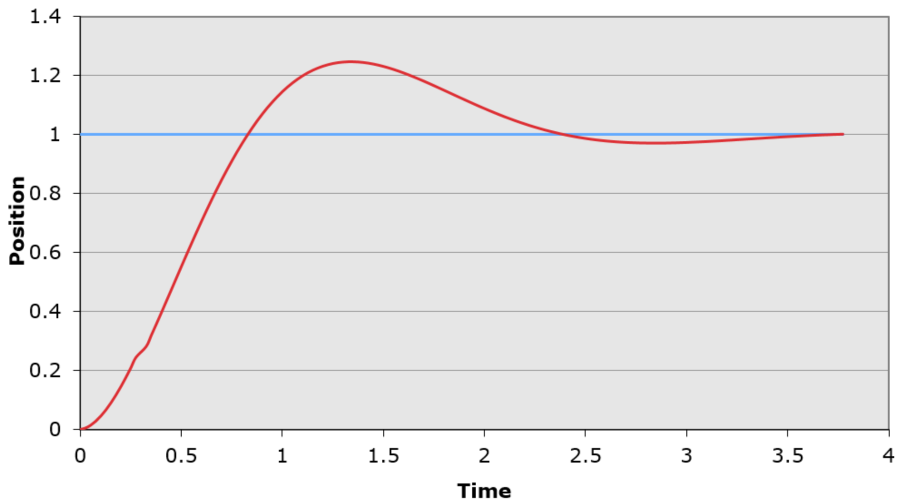


Figure 3: Graph with rise time error too high.

5. In the graph below, what are two methods that you could use to decrease the steady state error?

Increase i term, add feed forward

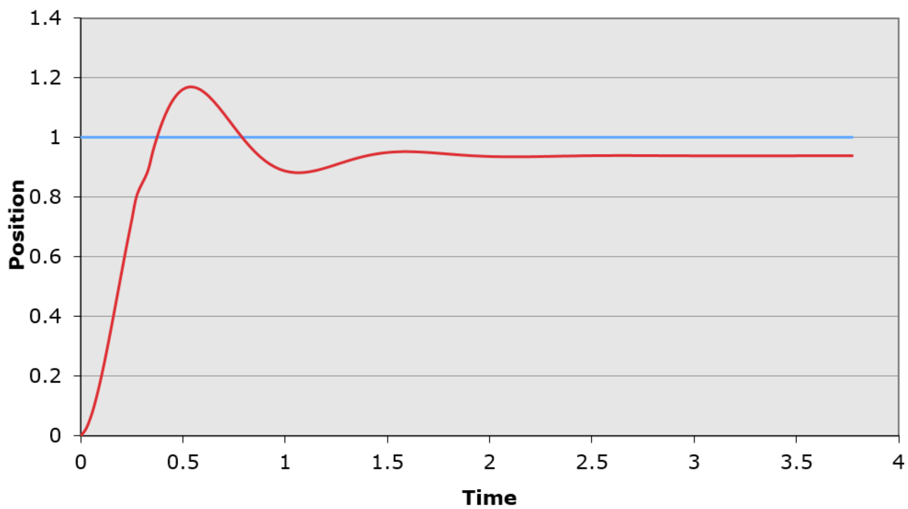


Figure 4: Graph with steady state error too high.

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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. The following image shows the work space and configuration space for an omnidirectional rover.

   The obstacles in this image are rocks of different heights. We can assume they are all HEMISPHERES so that their height is equal to half their diameter.

   The rover has a track (distance from left wheel to right wheel) of 12 inches (1 block) and we can approximate the rover as a circle. The rover's ground clearance is 5 inches.

   Assume that this representation of configuration space is correct for the robot in question with the reference point at the center of the robot. Note that the rover cannot get on any object that exceeds its ground clearance. But it can go over any obstacle that has a smaller height than its ground clearance.

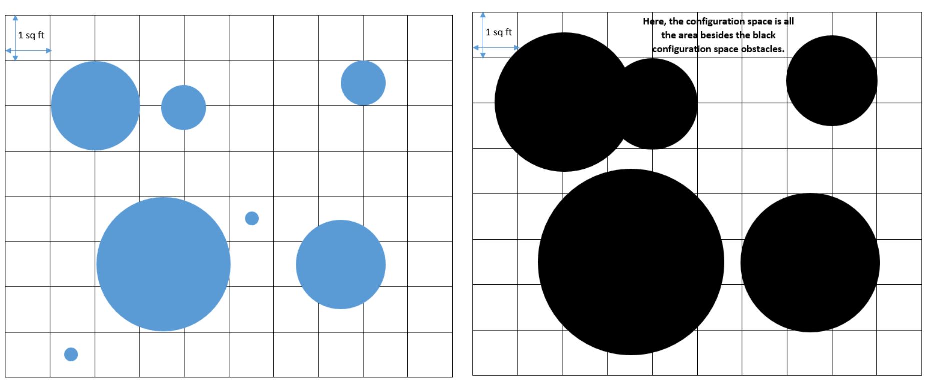

Figure 5: Workspace (left) and configuration space (right) for omnidirectional rover.

Draw how this image would change if our track (distance from left wheel to right wheel) increased to 24 inches:

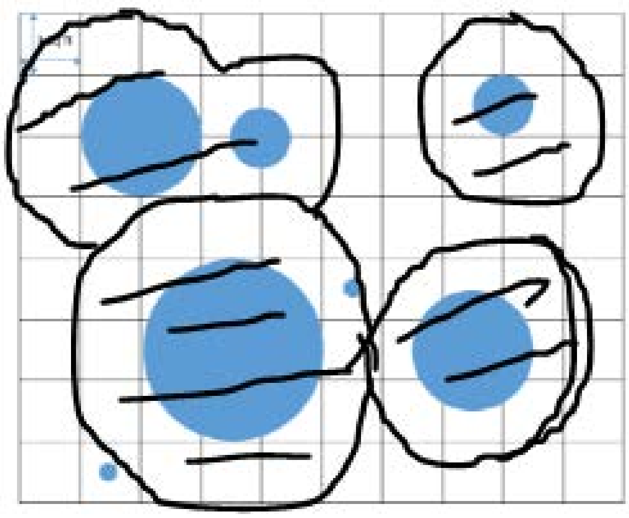

Figure 6: Empty configuration space. DRAW ON THIS FIGURE.

2. Draw how the first configuration space would change if our rover has this increased track and also has an increased ground clearance of 9 inches:

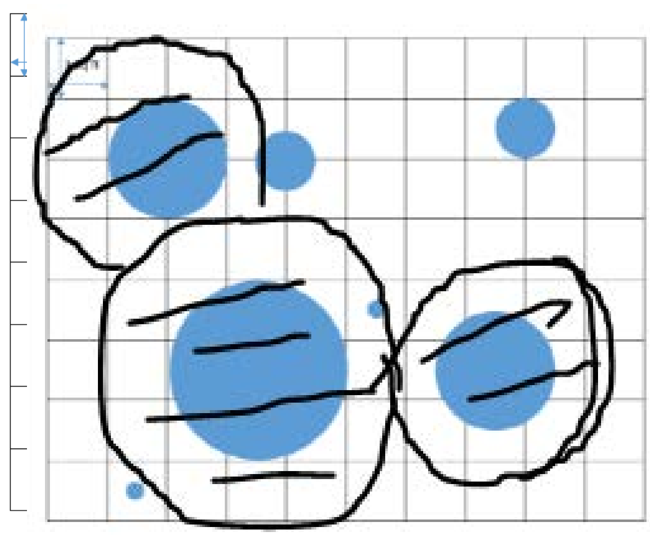

Figure 7: Empty configuration space. DRAW ON THIS FIGURE.

3. Which of the following points is closer to the start with respect to the L1 metric? How far is it with respect to this metric (you can leave your answer unsimplified)?

C is three units away

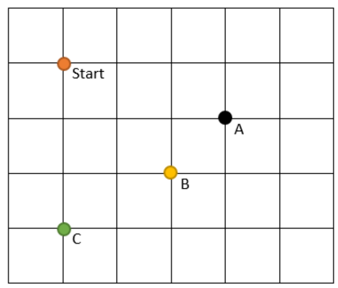

Figure 8: Example points.

4. Which of the above points is closer to the start with respect to the L2 metric? How far is it with respect to this metric (you can leave your answer unsimplified)?

c is three units away

5. If we employ a potential function, how can we handle the times when we get stuck in a local minimum?

Either fill that area with repulsive units or randomly nudge robot in a direction until free.

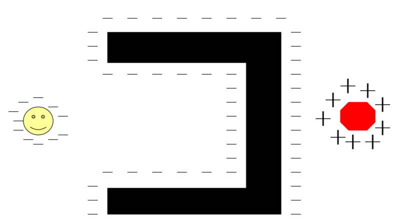

Figure 9: Example of a local minimum situation.

6. For the following arm, draw the shortest path from start configuration to end configuration by the L2 metric in the configuration space on the bottom image. Assume that the prismatic link (the first link) can not be negative nor wrap around but the revolute joint (with angle t) can be in any direction and wrap around.

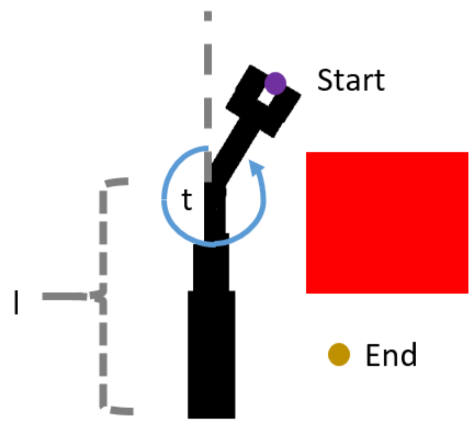

Figure 10: Prismatic-revolute robot.

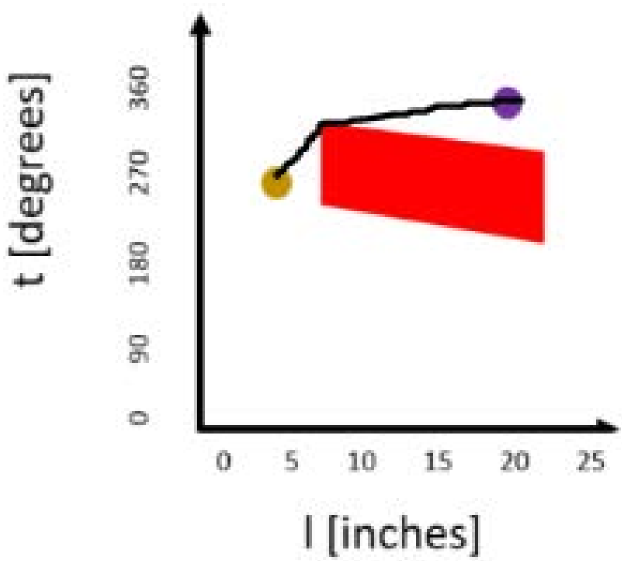

Figure 11: Configuration space. DRAW ON THIS DIAGRAM.

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4 Graph Search

Andrew ID: ________________________

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

1. For the graph below, list the nodes that you would visit in the order that you would visit them if you were performing a breadth first search. Break ties alphabetically.

   BEHICGJFD

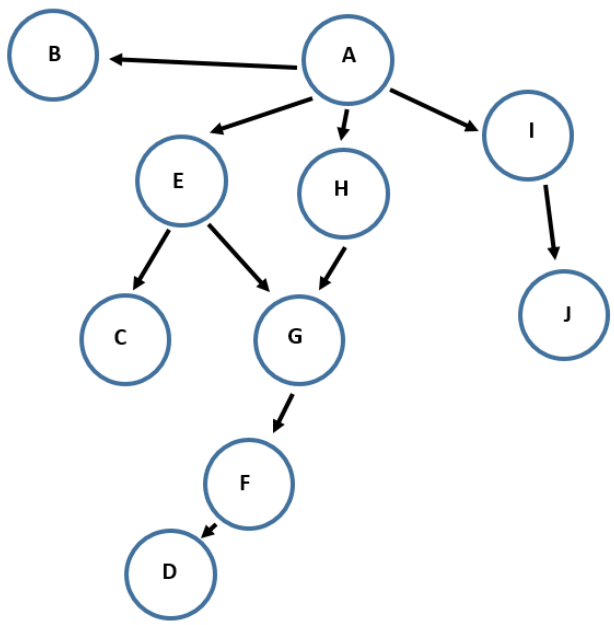

Figure 12: Sample tree for BFS and DFS.

2. For the same graph, list the nodes that you would visit in the order that you would visit them if you were performing a depth first search. Break ties alphabetically.

   BECGFDHIJ

3. Assume that the following nodes are waypoints that scientists have plotted on the moon. Note that each edge between two node has an associated cost with it that takes into account distance, terrain, and solar effects. The numbers inside the circles represent the heuristic guess of the distance to the goal which, for this example, is euclidean distance. You start at node A and there is a key rock formation at node H that you are trying to get to.

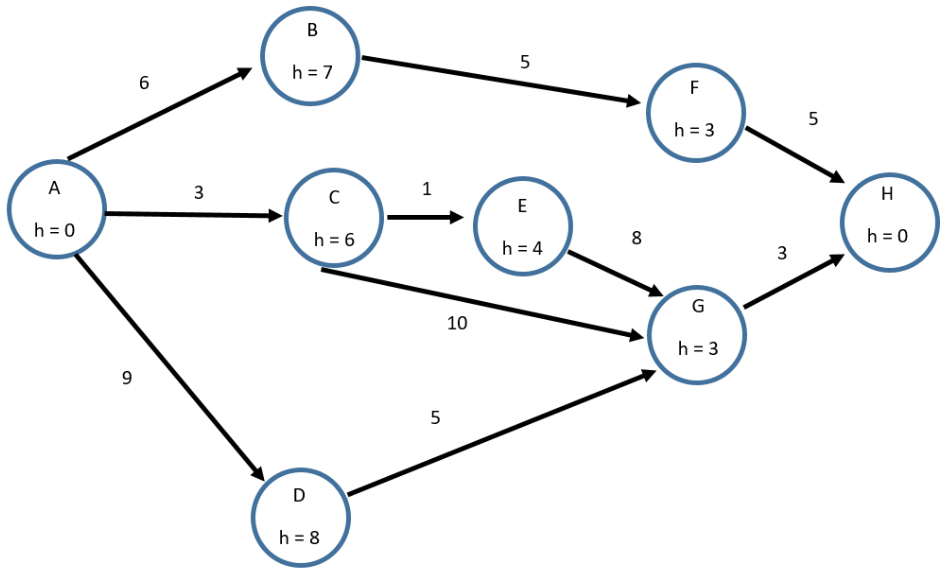

Figure 13: A* graph.

Using A*, find the path from start to goal. List the nodes that are EXPANDED in the A* algorithm above in the order in which they are expanded:

ACEBFGH

4. What is the shortest path for this graph (list the nodes and the final cost)? Did you find it through A*?

ACEGH

5. How would you perform this search differently if you were using Dijkstra's Algorithm instead of A*?

Would not use heuristics.

5 Localization

Andrew ID: ________________________

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

1. Why can we not always use absolute sensors like GPS to tell our robot exactly where it is at all times?

   GPS does not work in small spaces, highly wooded areas, areas with a lot of buildings

2. Why can we not localize on the following circular track with obstacles?

   This is radially symmetric, so we would have no way of distinguishing one third from another third.

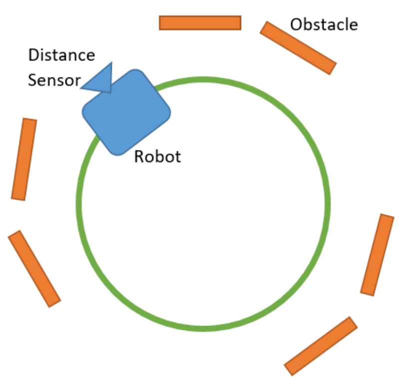

Figure 14: Example track configuration like Lab 6.

3. In class we looked at a an example of a robot moving in one dimension by a series of flowers. The first image below shows the belief of the robot's position before a movement. The second image shows the robot's belief state after the movement. Why might the peaks spread out when we updated our probabilities during this motion model?

Movement causes more uncertainty because you may move more or less than you expect.

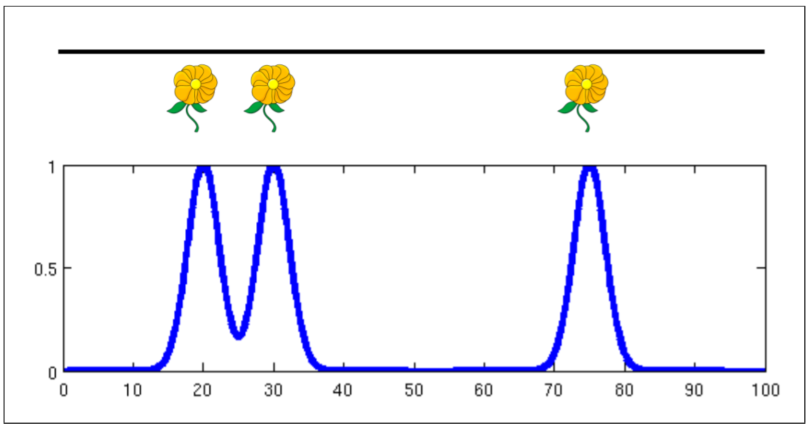

Figure 15: Belief state before movement.

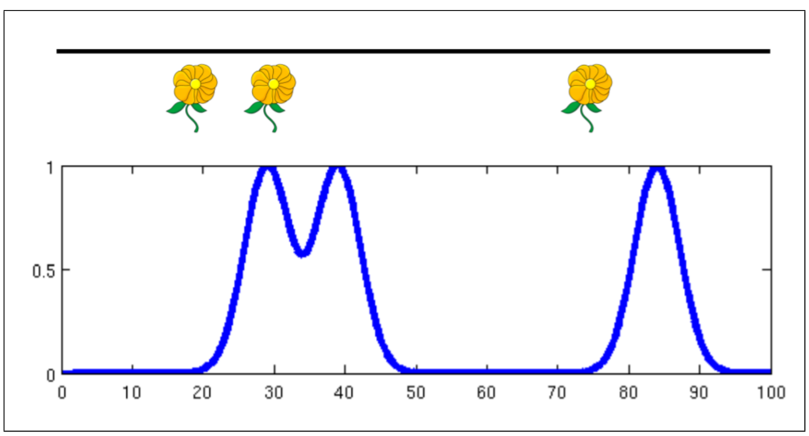

Figure 16: Belief state after movement.

6 Guest Speaker Topics

Andrew ID: ______________________

Select ONE of the following questions to answer in two sentences:

1. Earlier this semester, Prof Kris Kitani gave a presentation on wearable sensors. Describe (in one sentence each) two of the nine applications for wearable sensors that Professor Kitani mentioned.

   Many: object recognition, action recognition, video summarization, social saliency gaze analysis, privavy preservation, activity prediciton, social interactions, affordance estimation.

2. How did Prof Kantor "make lemonades from lemons" or perhaps more accurately, wine, during his trip to Chile?

   Used pipeline for tiny grapes, turned out to be useful to someone there

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This is the end of the test.