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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1 Vision

Andrew ID: ________________________

In this section, we will use computer vision techniques to estimate how far a lunar rover has travelled. For this example, we have a camera pointed down at the ground. Assume that the suspension of the rover keeps it at the same height and parallel to the ground at all times.

1. Using the following image of a 5x5 patch of lunar terrain, make a histogram of the pixel values. Label the x and y axes.

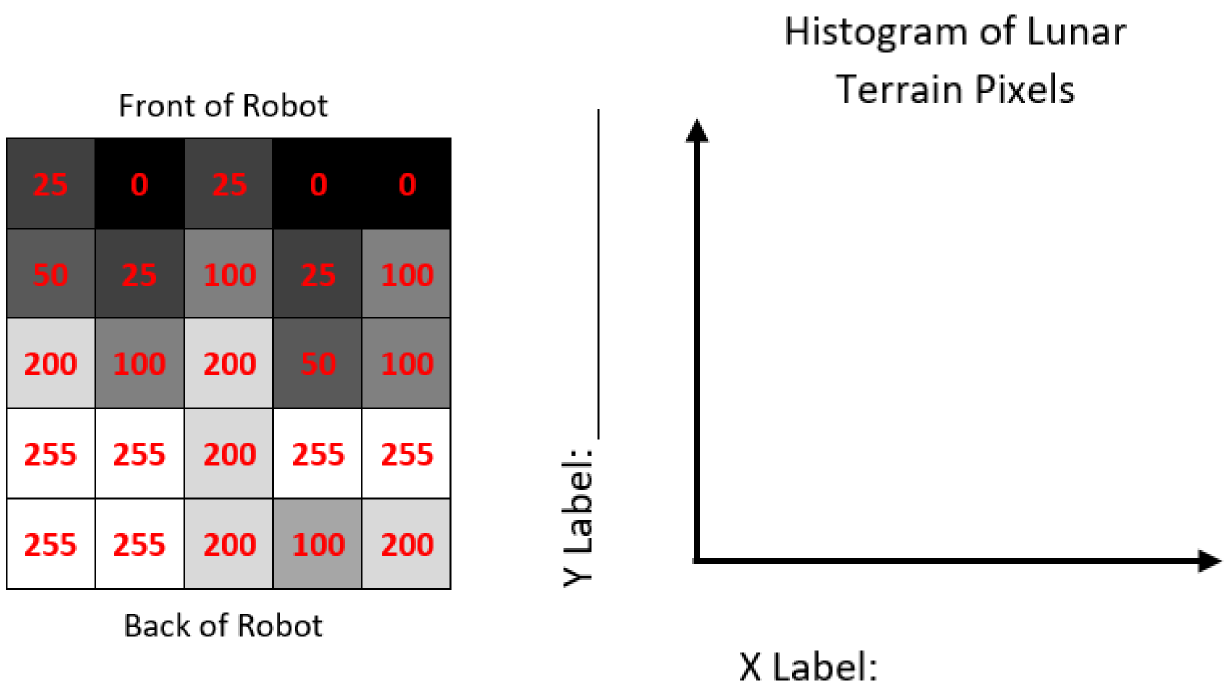

Figure 1: Left: 5x5 patch of pixels of lunar terrain. Right: blank histogram. FILL IN THIS GRAPH.

2. What is one use of a histogram of pixel values?

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3. We take another image of the lunar terrain under the robot 0.1 seconds later. Note that there are some pixels in common between the two images. If our vision system's resolution is 1 pixel per inch, the image plane is 3 inches behind the lens and the lens is 10 inches away from the ground, how far has the robot travelled from image 1 to image 2? Include at least one symbolic equation as well as your final answer with correct units (does not need to be simplified).

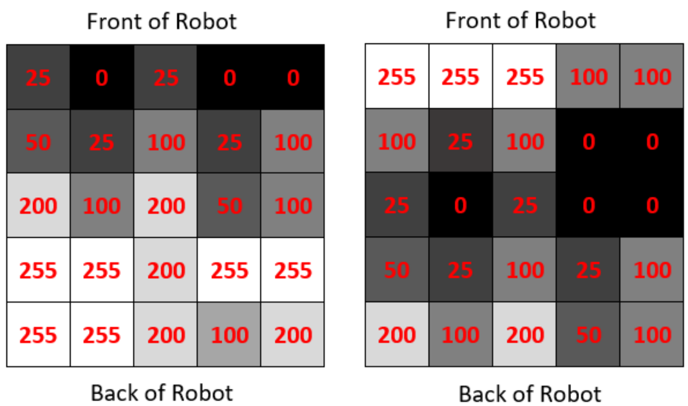

Figure 2: 5x5 patch of lunar terrain before (left) and after 0.1 seconds (right).

4. What is one possible problem with determining distance travelled using this method with a 5x5 pixel patch? Assume that you can maintain the distance and angle from the ground perfectly. Think of another possible issue.

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5. If our rover is not able to maintain parallel distance from the ground, would a second camera be able to inform us of the robot's distance from the ground?

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6. What is one positive and one negative ramification of placing two stereo cameras very close together?

   Positive: ______________________________________

   ____

   Negative: ______________________________________

   ____

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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?

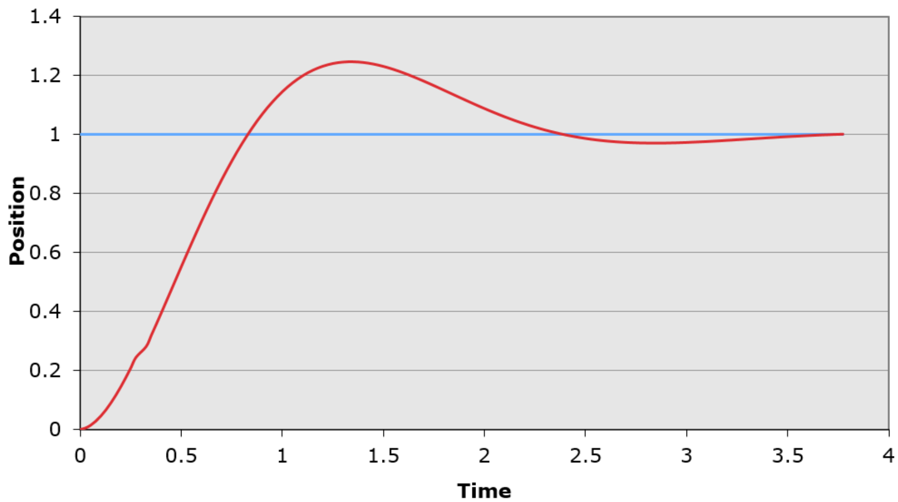

Figure 3: Graph with rise time error too high.

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

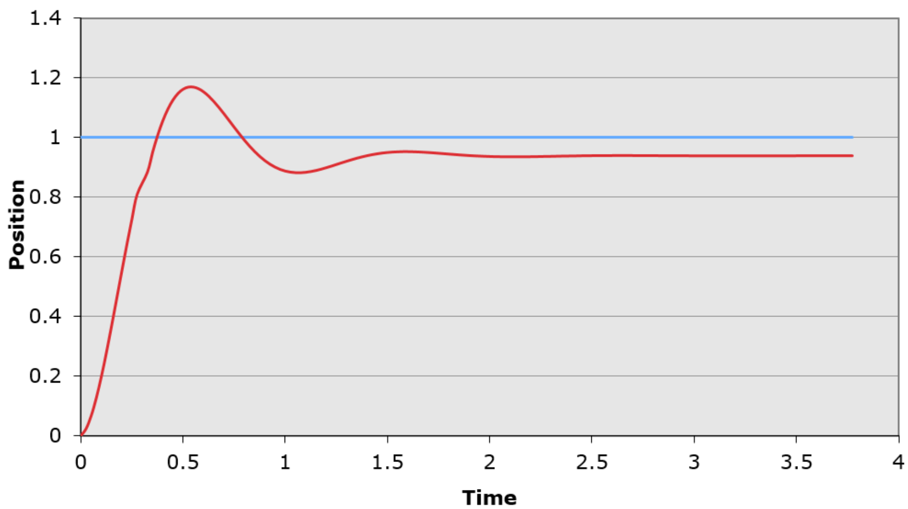

Figure 4: Graph with steady state error too high.

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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.

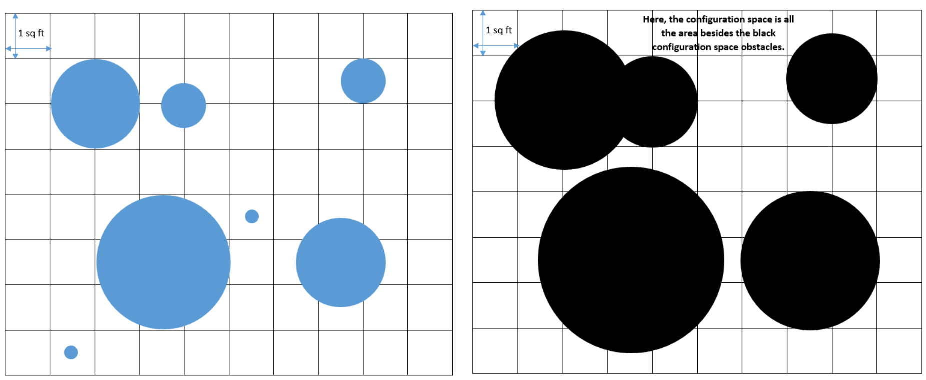

Figure 5: Workspace (left) and configuration space (right) for omnidirectional rover.

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

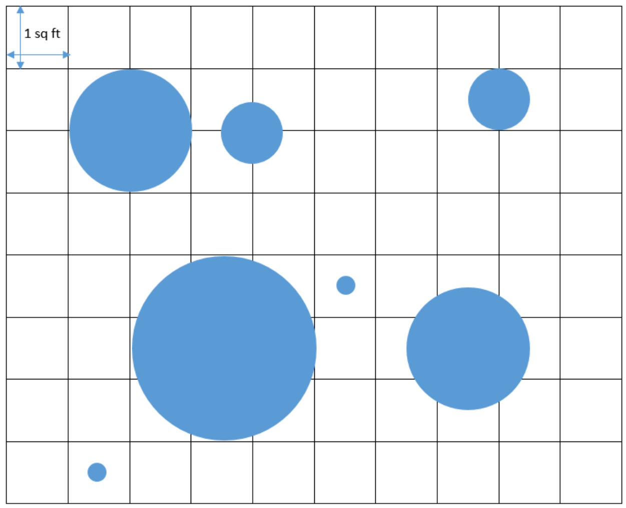

Figure 6: Empty configuration space. DRAW ON THIS FIGURE.

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:

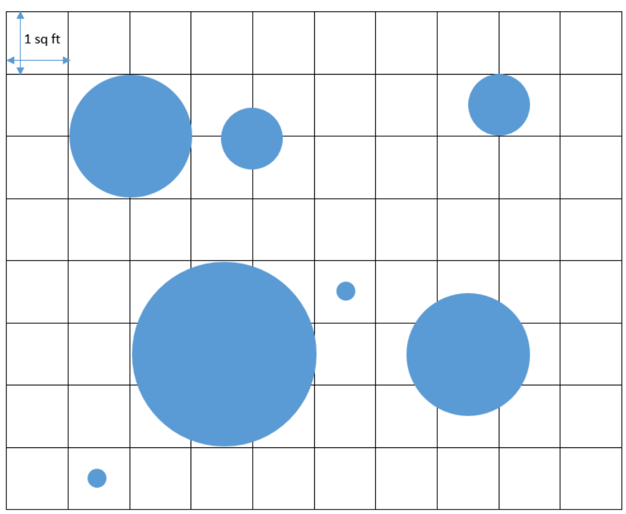

Figure 7: Empty configuration space. DRAW ON THIS FIGURE.

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)?

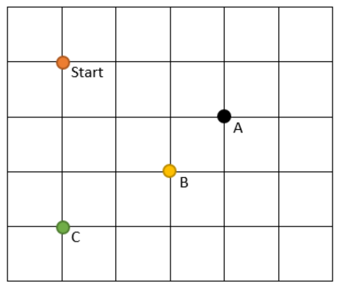

Figure 8: Example points.

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)?

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

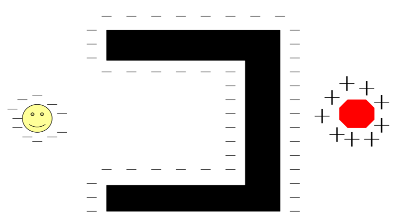

Figure 9: Example of a local minimum situation.

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.

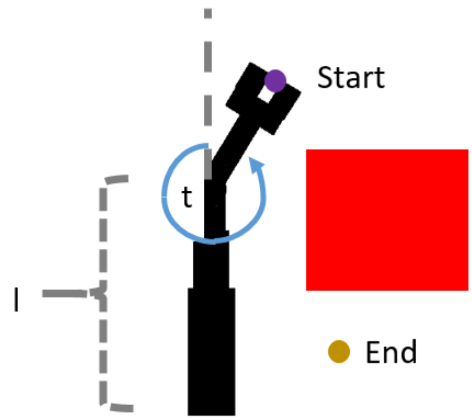

Figure 10: Prismatic-revolute robot.

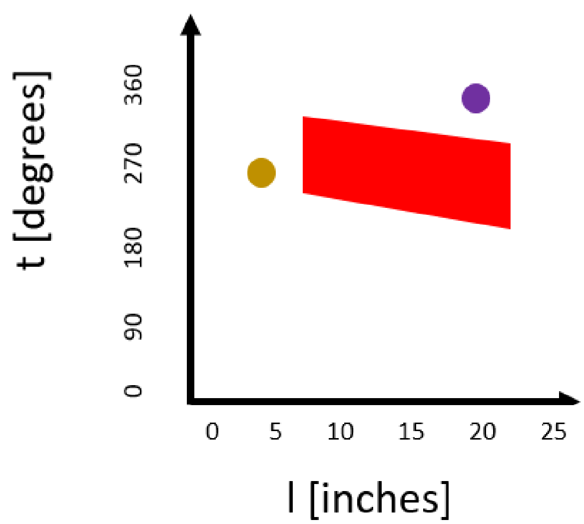

Figure 11: Configuration space. DRAW ON THIS DIAGRAM.

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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.

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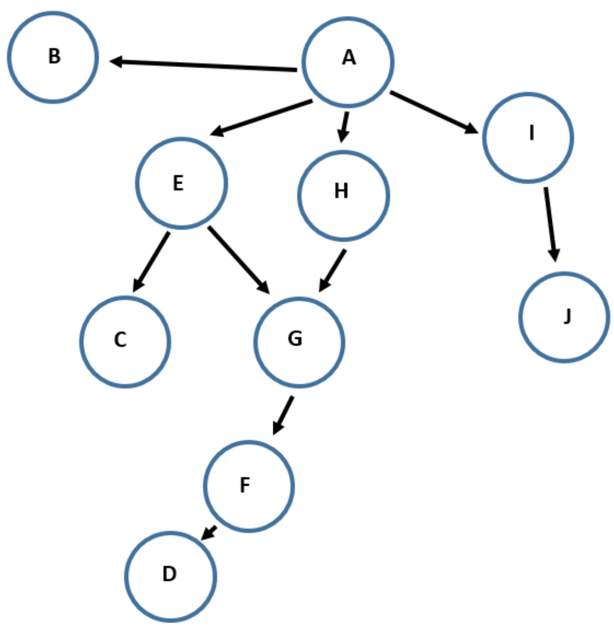

Figure 12: Sample tree for BFS and DFS.

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.

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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.

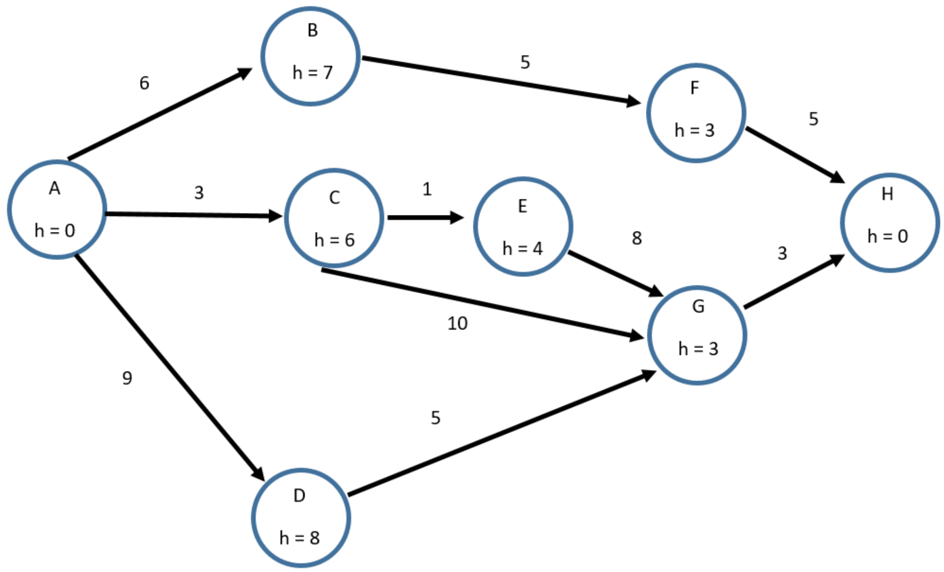

Figure 13: A* graph.

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:

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

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

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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?

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

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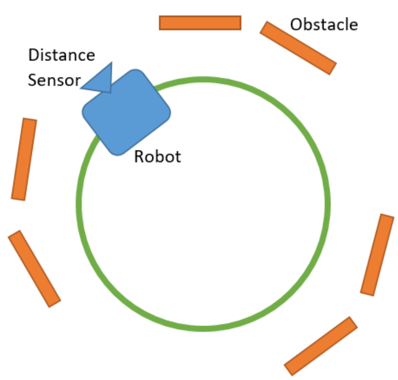

Figure 14: Example track configuration like Lab 6.

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?

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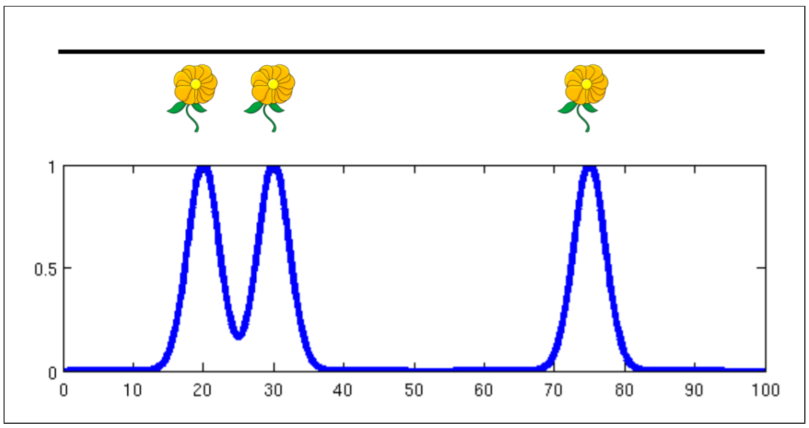

Figure 15: Belief state before movement.

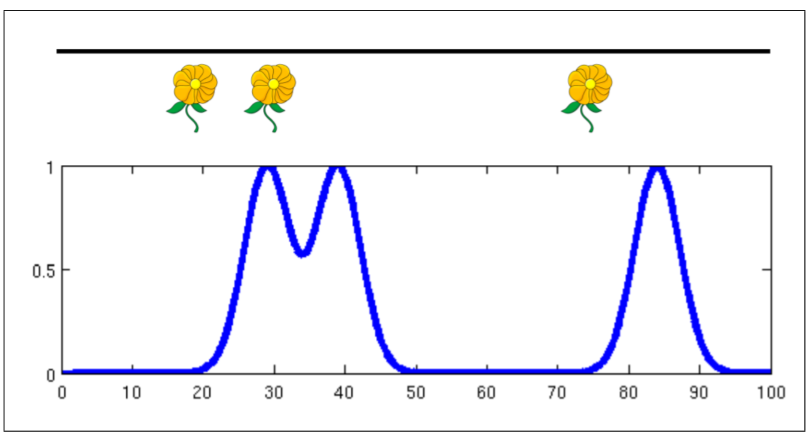

Figure 16: Belief state after movement.

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.

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

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This is the end of the test.