Midterm Exam 16-311 Intro to Robotics

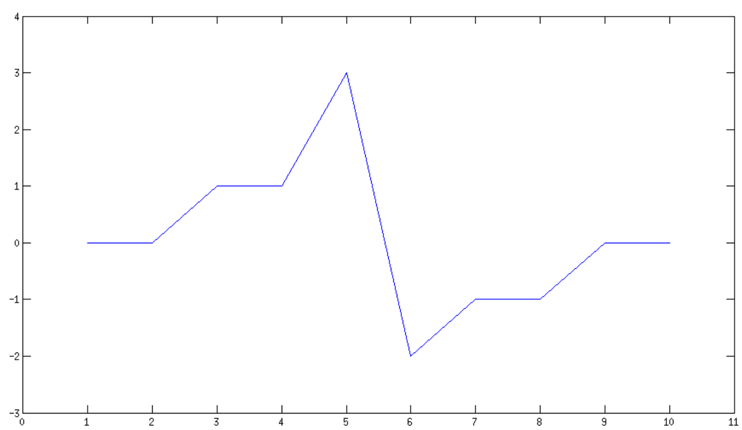
Name:____________________ Team: ____________________

- You will have 1 hour and 15 minutes to complete this exam
- There are 6 questions on 13 pages. Make sure you have all of them.
- 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 $\rightarrow$ Likewise, justify algerbraically 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* crib sheet for the exam. No cell phones, laptops, neighbors, etc. allowed.
- Good Luck!

1 Convolution and Vision - 18 pts

a) Create a 3×3 mask that could be used as a $45°$ diagonal edge detector for lines with negative slope in an image (3 pts). How would this differ from a mask for detecting lines with a positive slope (3 pts)?

b) Given an image:



$$image = \begin{bmatrix} 0 & 0 & 1 & 1 & 3 & -2 & -1 & -1 & 0 & 0 \end{bmatrix}$$

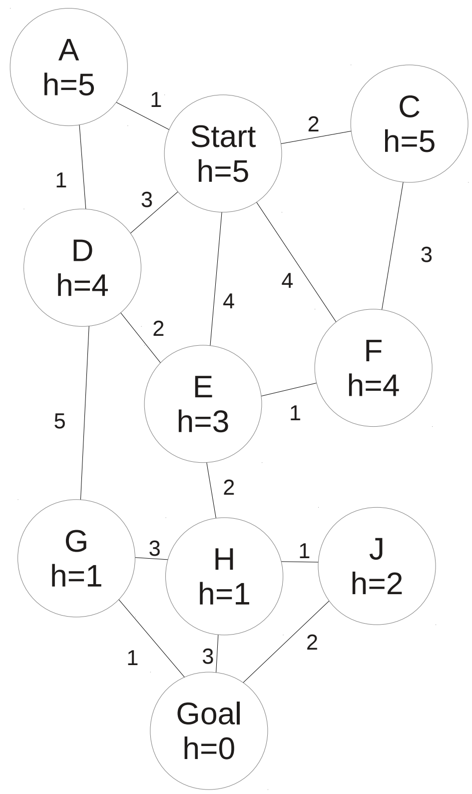
Can you design a 2×1 mask that would perform a rough approximation of the derivative (3 pts)? how about a 3×1 mask that approximates the second deriviative (3 pts)?

c) What are some uses for the threshold function? (2 pts)

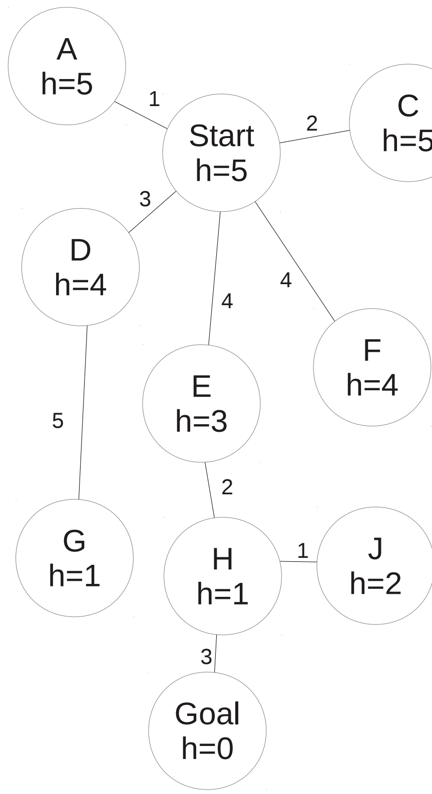
d) What can you do with a histogram (2 pts)? how can this be used to improve the contrast (1 pt)? how can it help pick threshold values (1 pt)?

2 Graph Search - 24 pts

a) Perform the A* search algorithm on the following graph. For each step, write the full open and closed list. When expanding nodes, break ties by opening the nodes in alphabetical order (assume *Goal* is last alphabetically) (9 pts).



b) A spanning tree is a method for reducing a cyclic graph to a tree. One way to construct a spanning tree is to simply remove edges until there are no more cycles but the graph remains connected. An example spanning tree for the above graph is:

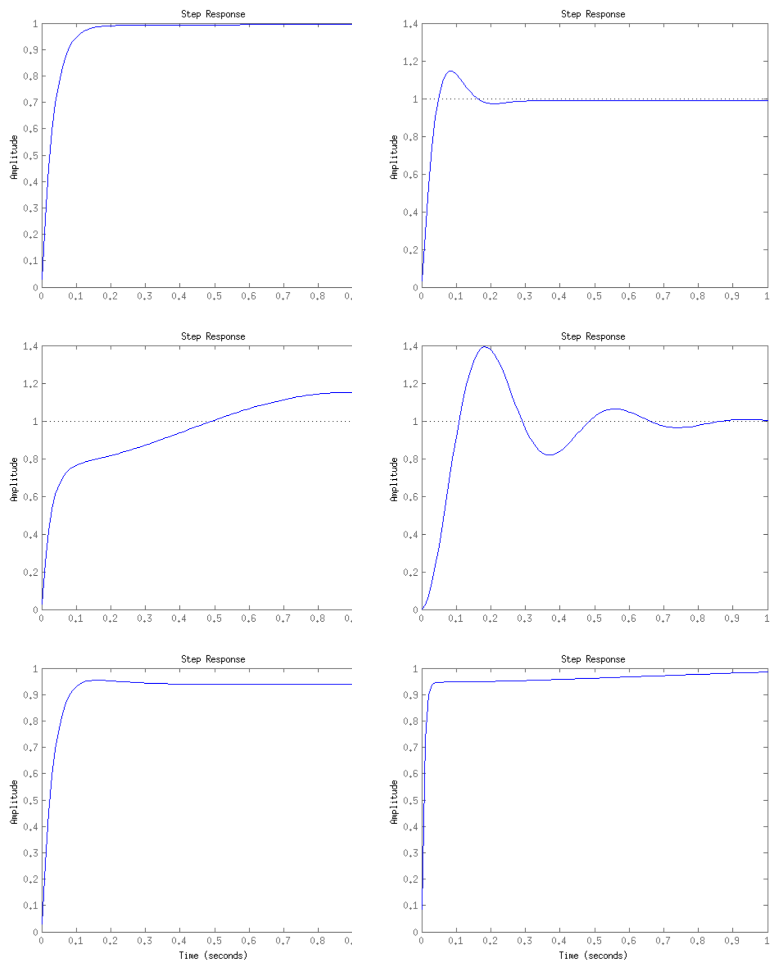


The order that you remove the edges can have a significant impact on the length of the resulting path. For this question you will first develop an algorithm to generate a tree from a cyclic graph using a breadth first search starting with the *Start* node as the root. Next you will do the same but use a depth first search. Both algorithms should be written concisely in pseudocode (use the back as necessary) (4 pts each).

Draw the resulting trees from performing your two algorithms (5 pts). Assume nodes are added to the trees in alphabetical order when an option exists (assume the root is at *Start* and *Goal* is last alphabetically). Would either of these algorithms get the same results as A*if you added nodes by selecting the one with the lowest cost edge first? why or why not (3 pts)?

3 PID Control - 10 pts

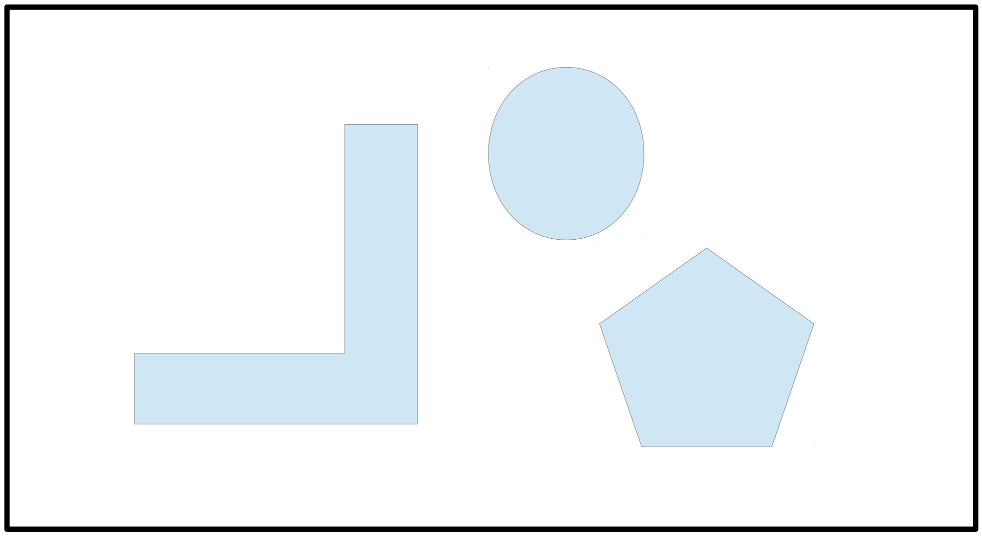
You are given the following response curves for a PID controller. The first one is the desired response, the remainder have had one parameter adjusted either up or down. Which gain would you need to tweak to improve the performance and in which direction (i.e. what would you have to do to get back to the desired response)? For each drawing

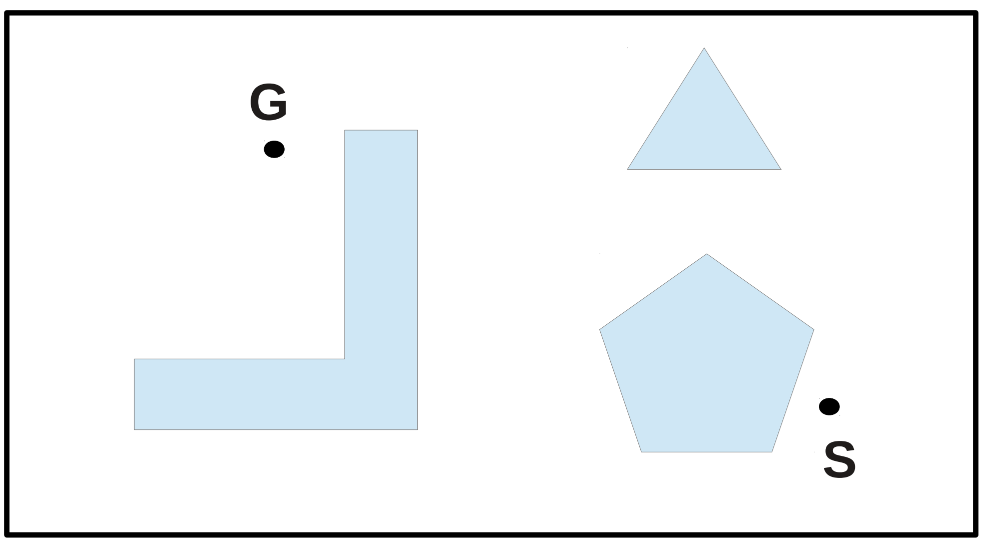


(e) (f)

4 Voronoi Diagrams, Visibility Graphs - 24 pts

For this section assume a point robot. a) Draw the Voronoi diagram for the following figure (5 pts):



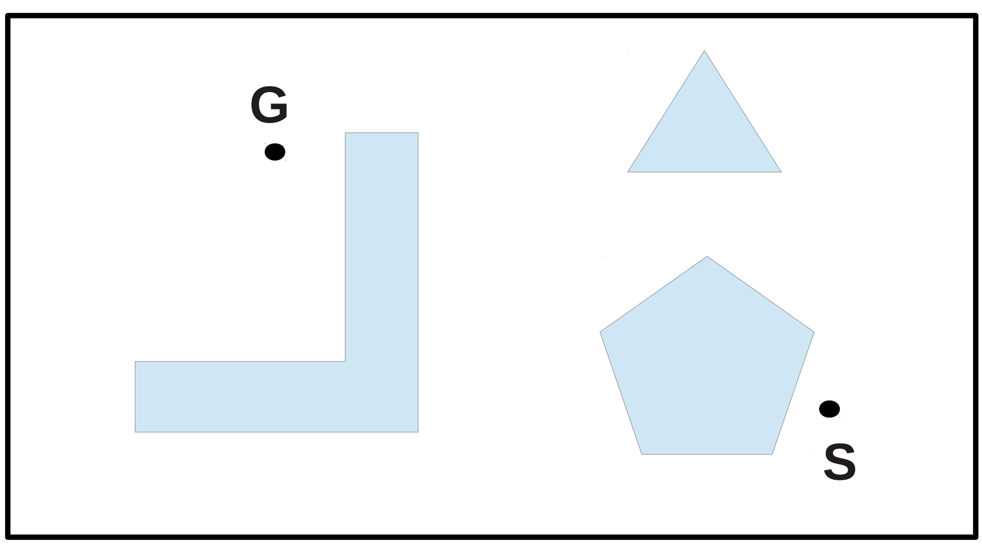


b) Draw the visibility graph (4 pts). Highlight the shortest path between S and G using the L2 metric (1 pt). Why is this the shortest path (2 pts)?

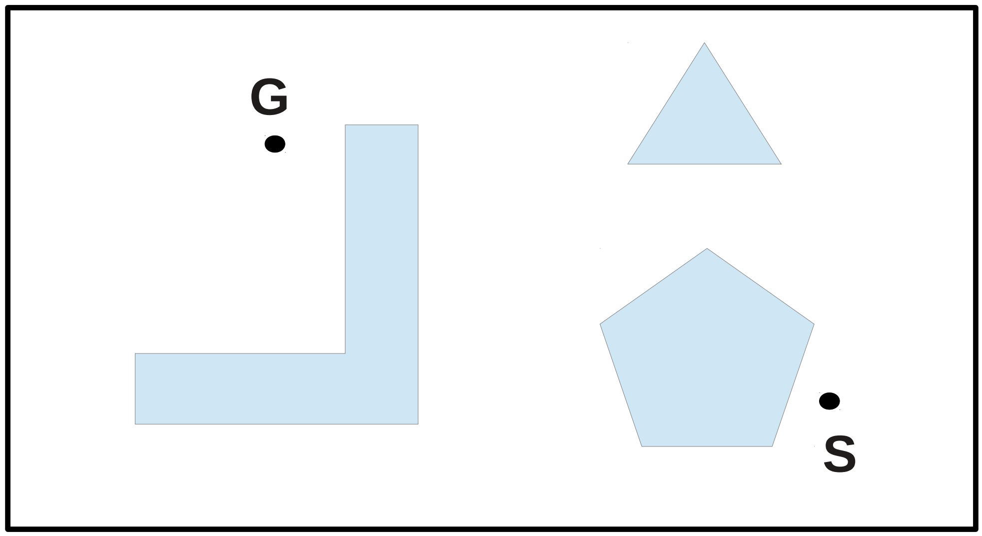
By connecting just the vertices of polygons would we get a path if this were a 3-D environment? would it be the shortest path? why or why not (3 pts)?

Why did I change the circle into a triangle (2 pts)?

c) Draw the path returned by the bug2 algorithm (3 pts).

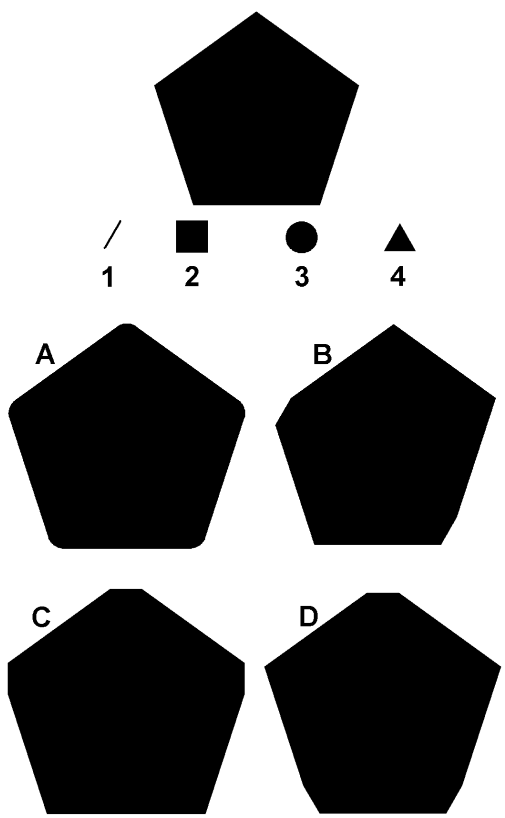


c) Draw two different paths that are both the shortest path by the L1 metric (may partially overlap or cross)(2 pts each).

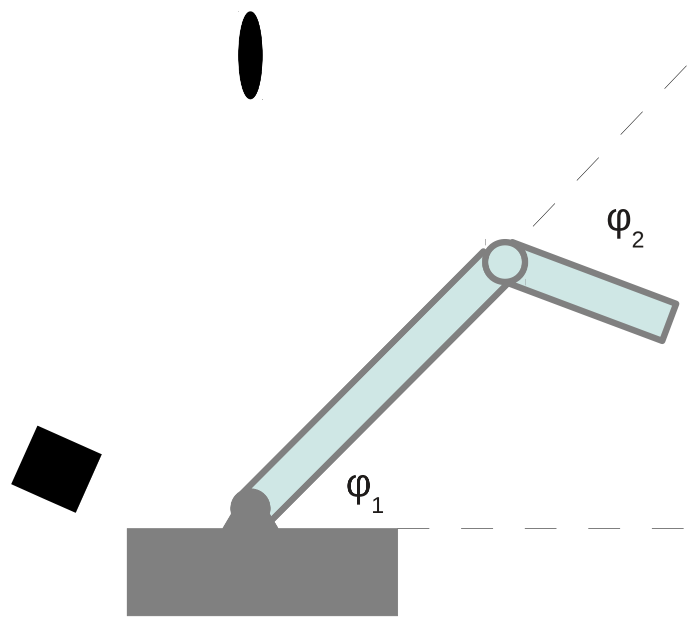


5 Configuration Space - 18 pts

a) Match the configuration space with the robot shape (2 pts each):



b) Draw the configuration space for the following two-link manipulator. Assume the base joint φ_1 is restricted to $0 - 180°$ (10 pts).



6 Guest Speakers - 6 pts

Match the topic to the speaker:

Abhinav Gupta	Vision
Branko Sahr	Manufacturing in Aerospace
Chris Atkeson	Optimal Control