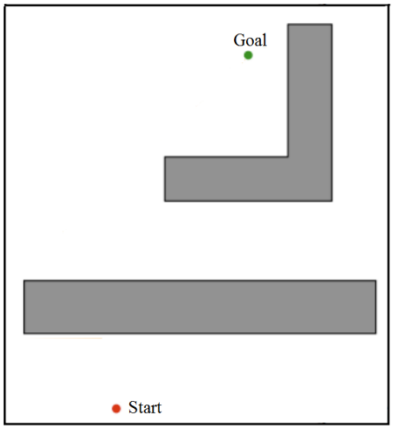
ENPM661, Take Home Final, Due May 18, 11:59PM NO EXTENSIONS

1) Assume that each of the expressions below gives the processing time $T(n)$ spent by an algorithm for solving a problem of size n. Select the dominant term(s) having the steepest increase in n and specify the lowest Big-Oh complexity of each algorithm. (4 Points)

Expression	Dominant term(s)	$O(\ldots)$
$5 + 0.001n^3 + 0.025n$		
$500n + 100n^{1.5} + 50n \log_{10} n$		
$0.3n + 5n^{1.5} + 2.5 \cdot n^{1.75}$		
$n^2 \log_2 n + n(\log_2 n)^2$		
$n \log_3 n + n \log_2 n$		
$3 \log_8 n + \log_2 \log_2 \log_2 n$		
$100n + 0.01n^2$		
$0.01n + 100n^2$		
$2n + n^{0.5} + 0.5n^{1.25}$		
$0.01n \log_2 n + n(\log_2 n)^2$		
$100n \log_3 n + n^3 + 100n$		
$0.003 \log_4 n + \log_2 \log_2 n$		

2) Show the paths that would be generated using Bug1 and Bug2 algorithms for the following map. (3 Points)



3) Calculate the parametric of the 3rd order (cubic) Hermit Spline given the following points and tangents (expressed as derivatives vs s). (3 Points)

$$p_1 = \begin{bmatrix} 1 \\ 1 \\ 5 \end{bmatrix} \quad p_2 = \begin{bmatrix} 1 \\ 5 \\ 5 \end{bmatrix} \quad \frac{dp_1}{ds} = \begin{bmatrix} 2 \\ 5 \\ 2 \end{bmatrix} \quad \frac{dp_2}{ds} = \begin{bmatrix} 10 \\ 0 \\ 2 \end{bmatrix}$$

NOTE: this can be accomplished by treating the different dimensions of the problem separately in terms of s, such that x = g(s), y=f(s), and z = h(s), and then combining them into a vector (the calculations for each dimension do not affect each other).

4) Use your answer from question 3 to calculate the (x,y,z) value of the Spline when s = 0.5. (2 Points)

5) Assume the manipulator arm in figure 1. You are provided the following transformations between the various coordinate frames: (2 Points)

$${}^{L}_{A}T\ ,\ {}^{L}_{B}T\ ,\ {}^{E}_{B}T\ ,\ {}^{F}_{A}T\ ,\ {}^{D}_{E}T\ ,\ {}^{F}_{E}T\ ,\ {}^{W}_{F}T$$

Given a point ${}^{W}p$ expressed in the *W* coordinate frame, determine its value in the *L* coordinate frame.

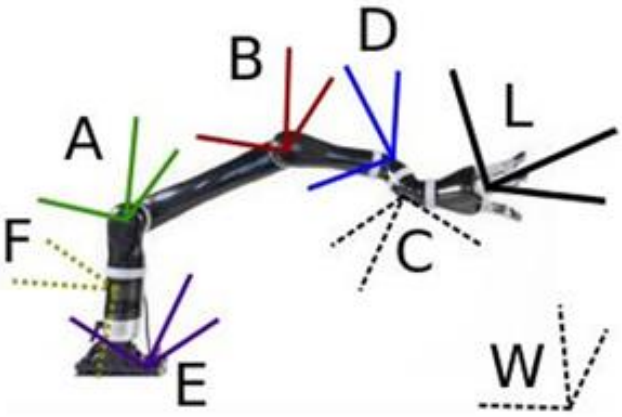


Figure 1

6) Describe FIFO-Queue and FILO-Queue and use POP(), INSERT(), TOP() to show how they work in practice. What kind of Queue is used for Depth First search and Breath First search? (3 Points)

7) Which of these methods return optimal path and which one return feasible path: BFS, DFS, Dijkstra, A*, weighted A*, RRT, RRT* (2 Points)

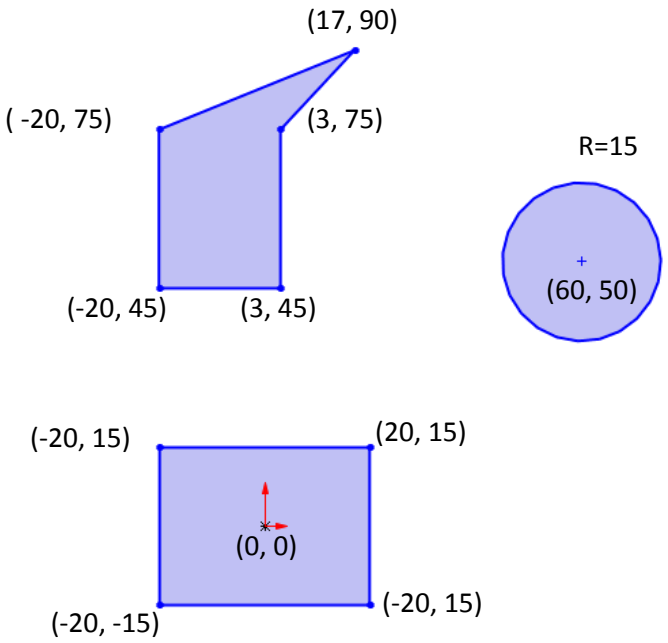
8) What kind of Queue is used when implementing 1) Dijkstra, 2) A*, and 3) ARA*? (2 Points)

9) If we have enough time for pre-computation/offline search which of the following methods would be preferred, Dijkstra or A*? Explain. (2 Points)

10) What does “admissible” mean for a heuristic function. (1 Point)

11) What is Bi-directional Search and how can we keep the balance between search trees in Bi-directional RRT? (2 Points)

12) Write down the set of half plans and semi-algebraic functions to represent the free space of the following workspace: (4 Points)



13) What does “exact algorithm” mean? (1 Point)

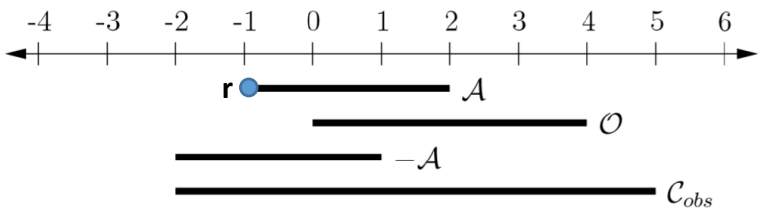
14) Show the reference point for the robot A by following Minkowski difference calculations. If point r is considered as the reference point for the robot, what will be the new obstacle space? (2 Point)

- $C_{obs} = O \ominus A(0)$

$$\mathcal{A} = [-1, 2]$$

$$\mathcal{O} = [0, 4]$$

$$\mathcal{C}_{obs} = [-2, 5]$$

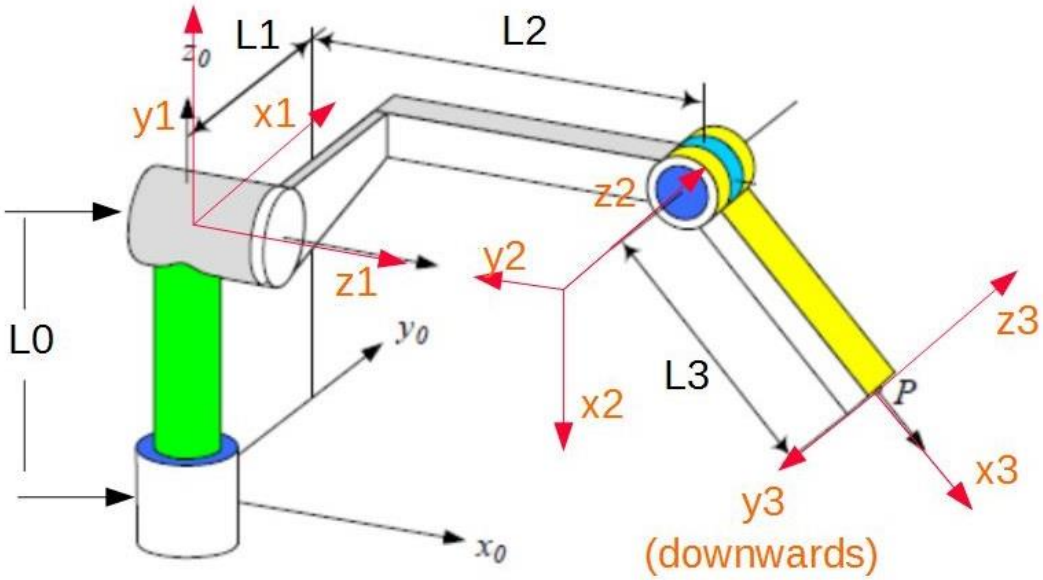


(Source: LaValle, S. M. Planning Algorithms, 2006)

15) Calculate the heuristic function value based on the Manhattan distance for the following state of a 15-puzzle problem. (2 Points)

16) Derive the rotation matrices for rotations about x, y and z axes. Show steps. (3 Points)

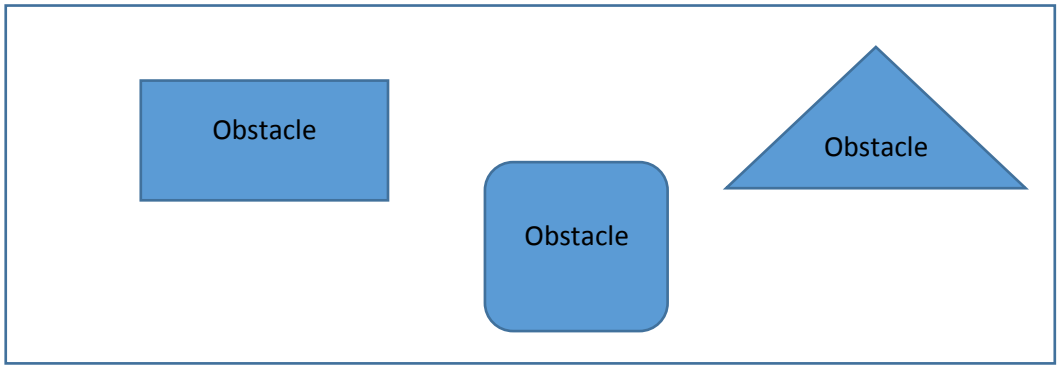
17) Derive the DH parameters for the following Manipulator: (3 Points)



18) What is the difference between a deterministic roadmap and a probabilistic roadmap? (2 Points)

19) What is the role of Stopping-configuration sub-function in RRT method? Draw a flowchart for the implementation of this sub-function. (3 Points)

20) Assuming the configuration space is the workspace in the following figure, draw the visibility graph and label the nodes. (2 Points)



21) Which method is preferable when we prefer when there is an environmental uncertainty, backward search or forward search? Explain. (2 Points)

22) How did you implement non-holonomic constraints for project 3? Describe. (3 Points)

23) Design a scenario for 3 robots where velocity tuning method fails to a return solution. (2 Points)

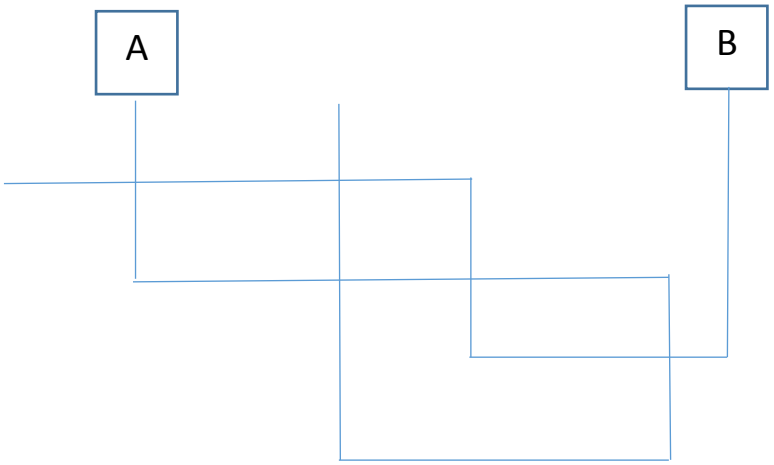
24) What is the difference between RRT and RRT*? (2 Points)

25) What is the difference between Halton sampling and Hammersley sampling? (2 Points)

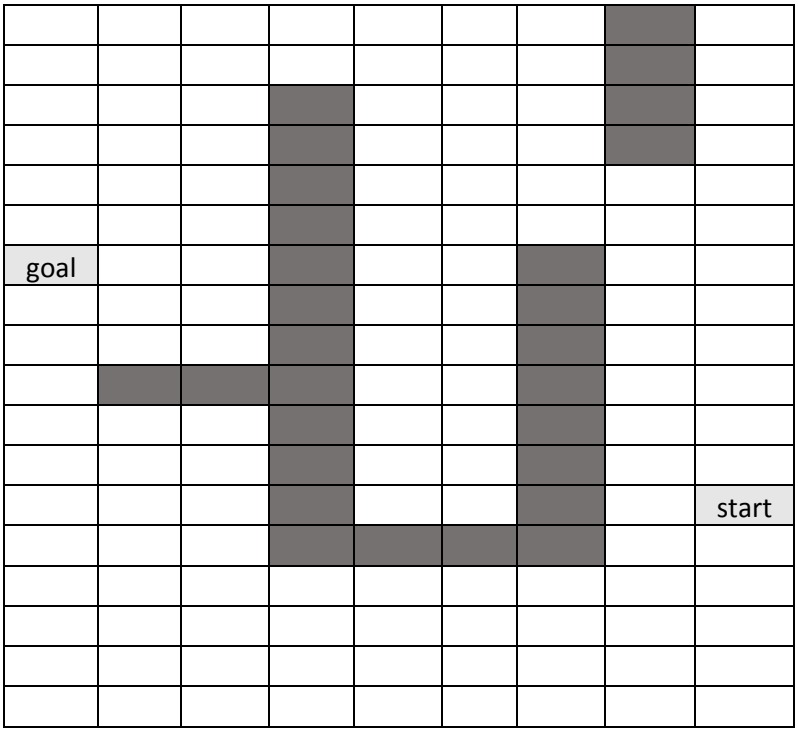
26) What are the applications of parametric curves for path planning? Which type of parametric curves can be used to define circles and other similar shapes? (2 Points)

27) For which method do we implement an inconsistent set? How can maintaining an inconsistent set improve the performance? In this method, how would maintaining a closed set improve the performance? (2 Points)

28) Sketch the state space for the two robots moving along the fixed paths shown below and show a velocity tuning graph. (3 Points)



29) Show a feedback plan for the following map (8-connected space). (2 Points)



30) What is the difference between location uncertainty and action uncertainty? (2 Points)