UNMESH MASHRUWALA
Innovation Cell
IIT BOMBAY

Recruitment Assignment-2020

Instructions:

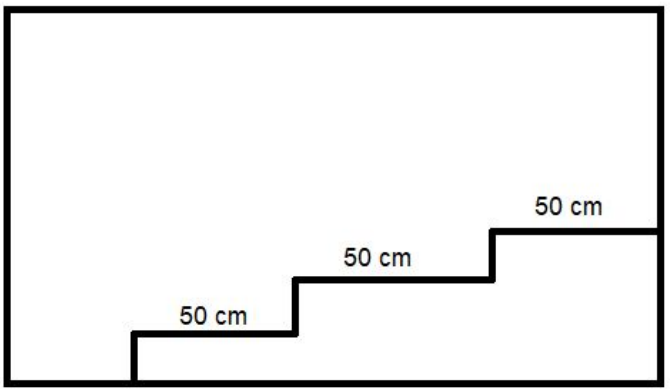
- There is one question in Section A; it is **compulsory for all** to attempt.
- There are five questions in Section B. You have to answer **only two out of the five questions.**
- Therefore, every applicant has to submit the solutions to **3 problems in total.**
- Marks for section A will be awarded based on the uniqueness of your answer as well as the level of details to which you write.
- Marks for section B will be awarded based on the amount of research you do on the topic and your level of understanding of the same.
- **Do not attempt more than two questions** in section B**.** In such a case, we'll grade the first two and ignore the rest.
- The answers are to be submitted in the form of a report **no longer than 3 pages per question**, the format for the same can be found here. Fill in your personal details properly.
- Deadline for submitting the answers is **3rd July, 11:59 pm.**
- Mention all the references used for answering the questions at the end of your answer.
- We do not expect you to have prior technical knowledge required for answering the following questions, so **feel free to use any online resources** like online discussion forums, journal papers or even books.

ALL THE BEST!

Section A- Ideation

Question A)

Give a description of how you would design a heavy duty robot capable of lifting payloads of upto 5kgs. The bot has to climb three stairs with step size between 8 cm to 15 cm. The three step sizes can be different or same and the bot will have to climb all three stairs and also return back. After each step there is a resting spot with dimension at least 50cm*50cm. The robot should not topple while performing the task. You are expected to elaborately explain the mechanical and electrical design with proper reasoning for why a particular component/s is/are used.



Do elaborately explain the methods/ideas used for ensuring the following:

- preventing toppling
- size of of the robot
- Wheel orientation/mechanisms (mechanical as well as electrical) used for climbing and descending the set of stairs

Suppose this robot is to be made autonomous. What are the sensors you will require for perception tasks? Justify your choice of sensors keeping the parameters like effectiveness and cost in mind. How will you use the sensor data for decision making (aspects like motion planning and control)?

Section B- Technical

Your evaluation will be done on the extent of research you do and understanding of the topic in the allotted time of 3 days over the questions given below. **Refrain from copying directly from online resources even after understanding of subject matter**. Please read all the questions before answering any two.

Question B.1)

Suppose you are working in a UAV team working on fixed-wing drones. You are developing a big heavy duty plane of a 2 meter wingspan weighing around 6 kgs.

a) What changes, from the point of view of design, can be made to a rectangular wing's planform to increase efficiency, minimizing wing tip vortex, reducing wing twist, increasing wing loading etc.?

b) You have to write your solution keeping in mind the manufacturability of the wing. Include the weight constraints and select the materials appropriately.

c) How will you provide support to your structure?

You can include diagrams to support your answer.

Note: Most designs will cater to a few favourable qualities and not all. Give a proper explanation for the trade-offs made while making the choices. You can even think of your own design.

(Assume that you start with a rectangular wing, do optimizations step by step and justify each one of them. For example tapering, dihedral etc)

Question B.2)

Assume that you are a part of the control subsystem of a team developing India's first self-driving car. You work for providing optimal control to the vehicle based on the path given by the path planner.

a) Formulate the problem, explicitly stating what it means to "control" the vehicle. What is it that you know about the vehicle at a time step and what are you trying to achieve using that? Is the formulation of the problem a linear model? Is there any need for constraints of any kind? If yes, list them with appropriate justification.

Hint: Think from the perspective of a human driver.

b) Having formulated the problem clearly, describe an approach that can be used to achieve the goal.

c) One of the more advanced approaches to do this is by using a branch of Machine Learning called Reinforcement Learning (RL). Can you briefly describe how this can be formulated as an RL problem, i.e. define the states, rewards, and actions as used in the context of RL?

Note:

i) The description for the above parts need not be mathematical but should be clear and to the point.

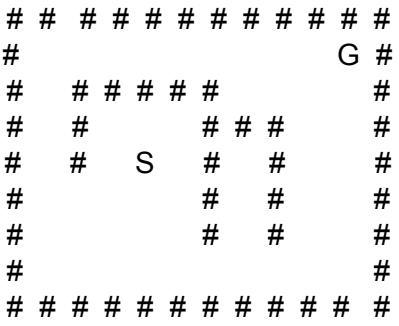
ii) For part (c), you need not have prior knowledge of RL. An introductory read on what is RL should be enough to answer the part.

Question B.3)

An autonomous system has a number of essential components. One of them is the path planning subsystem. In simple words, a path planning algorithm takes your initial position and your goal position into account and generates a path connecting both ensuring that your system (robot) does not hit any obstacles in between.

a) What are global and local path planning algorithms? Which of them are useful in what cases?

b) In the following situation, rank A*, RRT and RRT* algorithms, in their order of preference. Also, comment on goal sampling and heuristic to improve the results further.



# = obstacle
S = start
G = goal

Hint: consider all the costs

c) Comment on which one among A* and RRT* algorithms would have a better overall performance for dynamic path planning on a large grid.

d) What are some of the issues with the RRT* algorithm due to which its use in path planning for a self-driving car or fixed wing plane is limited?

Question B.4)

You have made a small robot which is to be left in a dark room. The robot is supposed to navigate through the room and make a map of the area that can be navigated.

a) What is the algorithm you would use and what sensors you would require without any constraints on budget.

b) Explain the different parts of the algorithm (with the help of diagrams, if necessary).

c) Now that you have a working algorithm, how would you scale that idea to be implemented for a self-driving car which is to be completely autonomous in the campus? (Can add new sensors and modify the algorithm).

d) What advantages and disadvantages would this (algo on car) have with respect to already available navigating softwares which only uses GPS?

Question B.5)

Any autonomous robot needs a system to observe the environment to be able to make decisions related to its motion and other tasks. This is formally known as the task of “perceiving” things or the “Perception” Task. This includes observing static as well as dynamic agents in the environment in which the robot is operating.

a) Perception related tasks have to be done on the go for a self-driving car. For a start, list some of the tasks which are required for perception.
b) Let’s focus on visual perception for the subsequent parts of the question. One of the tasks in perception is the task of object detection. List 2 challenges which were faced by object detection algorithms which have been solved in the recent approaches (2015 or later). Also mention at least one challenge which still remains to be solved and is a major barrier to object detection performance.
c) Usual implementations of common methods for achieving these are often slow in computation. To tackle this, many different techniques have been proposed. List the different techniques, how can they be applied to our problem and how it is better than single network implementations? Include approaches in brief and results from (at least two) previous research works to support your answers.`
d) One thing we do for tackling moving objects is dynamic obstacle tracking which builds upon object detection, which is done by creating a 3D point cloud of the environment. Given a 3D point cloud, how would you apply the k means algorithm on it? Create a simple flowchart of the algorithm you would use and explain the steps involved.

THE END