Autonomy Field Exam – Alborz Geramifard

Instructions:

- You have one hour to prepare for these questions, followed by a 45 minute oral examination. Please remember that both the preparation time and the examination time is closed book.
- There are three questions listed below. The third question is specific to the area of autonomy you listed when you registered for the field exam. You may choose to answer any **two** of three questions.
- Good luck!

Problem setting:

Your job is to implement a series of capabilities for the DARPA Urban Challenge. The MIT vehicle is an Ford Land Rover that has been modified to drive autonomously. It is equipped with laser sensors, cameras, radar, a GPS/INS system and computers. The vehicle has to plan collision-free trajectories through the world, it has to know where it is, it estimate the position of vehicles around it, and it has to make decisions about where to go.

We would like you to discuss three technologies that the vehicle will use. In each case, first frame the problem. State the problem precisely in English, and then formally. Make explicit any assumptions and key design decisions. Then, sketch an algorithm for solving the problem, at the level of rough pseudo code. Explain any key design decisions, and explain how different parts of your algorithm draw from other algorithms, such as those mentioned above.

1. Planning:

At the beginning of the race, the urban challenge vehicle is given a graph of the environment, where each node in the graph describes a GPS waypoint, and each edge between a pair of nodes in the graph states that there exists some path through free space that connects the nodes. Each edge is labelled with the length of the path between the nodes.

Please describe an algorithm for computing the shortest path through the graph from the current vehicle location to a specific destination.Assume that the graph is at least 1,000,000 (one million) nodes, and that the graph has degree 100. Ignore any issues related to how to execute the path. Assume that there are no other cars or dynamic obstacles in the world.

Please be prepared to justify your choice of algorithm.

2. Inference:

Assume that the vehicle is being tracked by a sensor network. Each sensor is embedded in the ground at some known location, and every second broadcasts a single bit: whether it can see the vehicle or not. The sensors are noisy, and you do not know the noise characteristics of the sensors. The sensors are independent, except that they share a clock; they broadcast their messages synchronously. The sensor network does not know the destination of the vehicle. You, however, know the locations of the sensors and the route graph from question 1.

Please describe a model and inference algorithm for estimating the entire trajectory of the vehicle at the end of the race. Again, assume that there are no other cars or dynamics obstacles in the world: each sensor only detects the one vehicle. There are no more than 10 sensors in the world.

Does you answer change if there are more than 100 sensors in the world?

3. Cognitive Robotics

The motivation for the DARPA Urban Challenge problem is a package collection problem. You know you start each morning at 6am at a central “FedEx” depot, and you know that there are a finite set of known places where packages may be collected and brought back to the FedEx depot. Each package has one of three priorities; each level of priority means that the package has to be returned to the depot by a certain time of day: highest priority packages have to be collected and brought to the depot by noon, medium by 3pm and lowest priority by 8pm. You know how long it takes to drive between all pairs of locations.

Imagine that each morning you are handed a list that describes which locations have packages that day and the priority of each package.

Please describe what model and inference algorithm you would use to solve this planning problem each morning.

Autonomy Field Exam – Karl Kulling

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3. Algorithms for estimation & inference

In the urban canyon, GPS is known to have multi-path effects, which cause the GPS state estimate to become erratic, or completely lost. These effects can often be mitigated in the short term by fusing the GPS with estimates from an inertial sensor to generate a fused state estimate. The state estimation techniques are usually probabilistic in nature, so that the uncertainty of the state estimate can be measured.

Please describe what model and inference algorithm you would use to estimate the position in GPS co-ordinates and orientation of the urban challenge vehicle given GPS position measurements from a single antenna and a 6-axis inertial measurement unit. You can assume that the GPS measurements are in the GPS co-ordinate frame and are position (x, y, z) only. The inertial measurements are in the body frame of the vehicle, and are the accelerations of the vehicle along three axes $(\ddot{x}, \ddot{y}, \ddot{z})$ and the angular velocities $(\dot{\theta}, \dot{\phi}, \dot{\psi})$ around the same axes.

Autonomy Field Exam – David Wang

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