Autonomy Field Exam – Cognitive Robotics

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 manage a portion of the Mars Exploration Rover mission. Your rover is currently at the landing site. The rover needs to cover a long-distance traverse to a remote site that has geological features that are of interest to the scientists on earth. You have reconnaissance (i.e., a detailed map) to the resolution of 50m of the planet.

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. Motion planning:

Begin by describing what algorithm you might use to navigate the rover from the landing site to the remote site. The rover should take the path that minimizes the total power expended. The rover is only capable of trajectories with a finite radius of curvature.

2. Diagnosis:

Suppose the rover suffers mechanical and electrical failures during the traverse. Please describe an algorithm for providing a model-based diagnosis capability that, given a system model and a set of observations, returns the probabilistically most likely diagnosis.

The models employed by the diagnosis engine are provided by the designers; they are encoded in a representation of your choosing. The capability must handle multiple simultaneous faults. A diagnosis can either specify a set of faulty components and their likelihood of failure, OR a set of component failure modes and their likelihood; this is your choice. Your algorithm need not identify unmodeled failure modes.

3. Additional Question: Cognitive Robotics

Failures may take multiple forms, including (but not restricted to) broken model constraints, unexpected correlations between variables, or unexpected changes to vehicle dynamics. Specifying a model of the rover under all these conditions is infeasible. Please describe an algorithm for inferring the presence of unmodelled failures. You may wish to restrict your discussion to the inference of one of the above types of failures.

Autonomy Field Exam – Estimation and Inference

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Autonomy Field Exam – Human Factors Engineering

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3. Additional Question: Human Factors Engineering

The rover sends data and telemetry back to a ground control station. Human operators then decide day-to-day missions that the vehicle must then execute. Because of communication limits, the human operators only have partial awareness of the rover situation, including its position, local environment, etc.. Please name two forms of bias that can occur in the display of the rover data that can cause humans to have incorrect situational awareness.

Autonomy Field Exam – Machine Learning

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3. Additional Question: Machine Learning

The vehicle contains an ablating laser and gas chromatograph. By vaporizing the surface of a rock, processing the vapor with the gas chromatograph and collecting statistics of the vapor's spectrum, the vehicle can recognize different rocks. Please describe an algorithm for classifying vaporized rock spectra. Please also describe the training process for the classifier.

Autonomy Field Exam – Machine Vision

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3. Additional Question: Machine Vision

There is no GPS on Mars, but there is an overhead satellite that is tracking the rover using camera imagery. The satellite can estimate its own position using knowledge of celestial navigation, and can therefore infer the position of the rover from the image. The satellite also has the 50m-resolution map of the Martian surface. Please describe an algorithm for tracking the rover and estimating the rover's position from a single camera image.