CSCE 452/752 Robotics and Spatial Intelligence, Fall 2024

Review Sheet for Test 1

This review sheet is intended as a guide to help you prepare for Test 1.

Format

- The test will be conducted in person, on paper.
- The test will cover material from the first third of the course, up to and including **September 16**. This includes the first 8 sets of lecture notes and the first project.
- The test will be designed to be completed in **75 minutes**.
- No notes nor electronic devices are permitted. Questions will be structured so that computations typically requiring a calculator will not be required.

Some types of questions to expect:

- Questions similar in spirit to the homework assignments.
- Questions in a similar format to the homework assignments, but covering different topics.
- Questions that probe your understanding of specific terms introduced in the lectures.
- Questions that probe your understanding of basic ROS concepts from Project 1.
- Questions that probe your understanding of important diagrams or figures from the lectures.

The question formats will include both multiple choice ("Choose A, B, C, or D") and short answer questions ("Solve", "Draw", "Explain", etc.).

Remember that the homework assignments are graded on the basis of making a **reasonable good-faith attempt** to solve the problem. That is, receiving full credit on the homework is not a sign that your answers were correct.

1. Introduction

- What is a robot? Defining characteristics. Mount Fuji illustration.
- Why is robotics hard? The fundamental problem.
- Why can't we focus strictly on computing issues?
- Four fundamental problem types. What does each problem type ask the robot to do?

2. Robot hardware

- Actuators: motors (simple DC and gearhead), stepper, servo, linear actuator.
- Sensing: encoder, infrared sensor, camera, RGBD sensor, sonar, lidar, IMU, compass, GPS, inclinometer

- Modes of locomotion
- Proprioception and exteroception
- Evaluating sensors: Active vs passive. What is the difference? Which sensor types are active? Which are passive? Proprioception vs. exteroception. Criteria for evaluating sensors.

2b. Robot hardware case study

- Nothing in particular form this set, though it does have some good examples of sensors and actuators from the main hardware lecture.

3. Differential drive locomotion

- Drive vs. steered vs. passive wheels.
- States, actions, transitions. What are they? Notation for each. x, X, u, U, f. State transition equation.
- Using the differential drive ICC equations. Special cases for differential drive movement. Updating the state for a diff drive.
- Navigate with a differential drive to a given target.

4. Introduction to ROS

- What is ROS? Why is software like ROS necessary? Distributed computation. Code reuse. Seamless simulations.
- Meanings and relationships between various ROS objects: packages, nodes, topics, publishers, subscribers, messages
- What is the ROS graph?
- What ROS concepts are used for one-way many-to-many communication? Two-way one-to-one communication?
- No specific questions about the details of Project 1, but the main ROS concepts explored by that project may appear on the test.

5. Other wheeled systems

- What is an ICC? How to find ICC? What assumptions is this analysis based on? What happens if no ICC exists?
- How to find the ICC.
- ICC analysis for bicycle, synchro, tricycle, and Ackerman drive.
- Alternatives to simple wheels for terrestrial navigation.

6. Navigation: Bug algorithms

- Basic model. How does the robot move? What can it sense? Be able to tell if the Bug algorithms are applicable in a given situation.
- Why doesn't the naive optimistic algorithm ('Bug0') work?
- Online vs. offline algorithms. Planning and execution interleaved vs. forming a complete plan before moving. Be able to apply these concepts to all of the navigation algorithms we've learned.

- Hit points and Leave points
- Bug1. Be able to execute the algorithm. Be able to state and explain an upper bound on path length. What if the goal cannot be reached?
- Bug2. Be able to execute the algorithm. Be able to state and explain an upper bound on path length. What if the goal cannot be reached?
- Comparison between Bug1 and Bug2. Be able to explain when Bug1 is better. Be able to explain when Bug2 is better.

7. Navigation: Visibility graphs

- Applicability: Under what conditions can the visibility graph method be used?
- Definition: What are the nodes? What are the edges? Be able to draw the visibility graph for a given set of obstacles.
- How do we know that the shortest path must be along the visibility graph?
- Difference between visibility graph and reduced visibility graph. Be able to identify edges that are in the visibility graph but not in the reduced visibility graph.

8. Navigation: Potential fields

- When are potential fields applicable? Intuitive explanation of how potential fields work.
- Domain and range of the potential function. Robot follows the negative gradient of the potential function.
- Definition of typical potential function as sum of attractive and repulsive forces. Details for attractive and repulsive components.
- Notation: x, $U(x)$, ζ, η, Q_i^*, d_i
- Local minima. What are they? Why do they cause problems for potential fields? Possible solutions.

Provided equations

These equations will appear, without any explanation, on the cover sheet:

$$R = \left(\frac{\ell}{2}\right)\frac{v_r + v_l}{v_r - v_l} \qquad \omega = \frac{v_r - v_l}{\ell}$$

$$\begin{bmatrix} x' \\ y' \\ \theta' \end{bmatrix} = \begin{bmatrix} \cos(\omega\Delta t) & -\sin(\omega\Delta t) & 0 \\ \sin(\omega\Delta t) & \cos(\omega\Delta t) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x - c_x \\ y - c_y \\ \theta \end{bmatrix} + \begin{bmatrix} c_x \\ c_y \\ \omega\Delta t \end{bmatrix}$$

$$U_{\text{goal}}(x) = \frac{1}{2}\zeta[d(x, x_{\text{goal}})]^2 \; U_{\text{obst}}^{(i)}(x) = \begin{cases} \frac{1}{2}\eta\left(\frac{1}{d_i(x)} - \frac{1}{Q_i^*}\right)^2 & \text{if } d_i(x) \le Q_i^* \\ 0 & \text{if } d_i(x) > Q_i^* \end{cases}$$