CSCI 944 Perception and Planning

Mid-term Test (Chapter 1-4)

Chapter 1 - Introduction

1. **Describe your understanding of this course, i.e., What do you think this course is mainly about? What should be included in the course?**

   Open question

2. **What are the key elements of autonomous robot control systems?**
   The key elements of autonomous robot control systems include modeling robot kinematics and dynamics, selecting suitable sensors, controlling actuators, path planning, and flexible control policies.

3. **What are the differences between deliberative and behavior-based robot control architectures? Explain the idea of hybrid control architectures.**
   Deliberative control reasons about contingencies and plans solutions, but is slow to react and requires frequent replanning.
   Behavior-based control reacts quickly without models but has difficulty achieving complex novel tasks and predicting emergent behavior.
   Hybrid control combines deliberative planning with reactive behaviors.

4. **Based on your learning background and your requirements, please describe the knowledge, skills, and values you hope to gain through studying this course?**

   Open question

Chapter 2 - Sensor types & limitations

1. **What is a sensor? Explain how the sensor works.**
   A sensor is a device that measures a physical quantity and converts it into a signal which can be read and interpreted. Sensors provide robots with environmental feedback for localization, obstacle detection, safety.
   Sensors work by utilizing a transduction principle - the conversion of energy from one form to another.

2. **Explain the difference between active and passive sensors. Give at least two examples of each sensor type.**
   Active sensors emit energy into the environment and then measure the reflection, such as sonar, radar, or laser rangefinders. Examples of active sensors include ultrasonic sensor, LIDAR, and light sensor.
   Passive sensors only detect energy from the environment, such as cameras, microphones, or thermal sensors. Examples of passive sensor include CCD/CMOS cameras, infrared sensors, compass, and microphones.

3. **Give three examples of proprioceptive sensors used by robots. For each, state what property or quantity they measure.**
   Denote: (Proprioceptive Sensors - Internal state sensors; Exteroceptive Sensors - External state sensors)
   - Encoders measure wheel/joint rotation and velocity.
   - Accelerometers measure linear acceleration and tilt.
   - Gyroscopes measure angular velocity and orientation.

4. **Describe three strategies a robot can use to deal with errors and noise in sensor readings.**
   Strategies include using multiple redundant sensors, combining different sensor types, applying filters or error correction methods, and using fault tolerant algorithms that are robust to failures.

Chapter 3 - Visual perception & processing

1. **What is the goal of computer vision? Give some examples of computer vision tasks and applications.**
   The goal of computer vision is to develop computer programs that can automatically interpret and understand images and videos.
   Example tasks and applications include face recognition for security systems, object recognition for manufacturing inspection, optical character recognition for document digitization, motion analysis for autonomous vehicles, and medical image analysis for disease diagnosis.

2. **Explain the stereo correspondence problem in computer stereo vision. What are some approaches to addressing this problem?**
   The stereo correspondence problem refers to matching parts of one image to corresponding parts in another image taken from a different viewpoint. This is challenging because some regions may be visible in one image but not the other.
   Common approaches include correlation-based methods that match image patches, and feature-based methods that match image features like corners and edges. Constraints like epipolar geometry can also be used to limit potential matches.

3. **What are some advantages of active 3D scanning systems compared to passive stereo vision? What are some drawbacks?**
   Active systems like structured light and time-of-flight scanning actively emit energy and measure reflections, giving dense and accurate depth data.
   However, they only work for static scenes, have limited range, and can be expensive. Passive stereo is lower cost but struggles with untextured regions and has correspondence issues.

4. **Give three examples of how machine vision is used in industrial automation and quality inspection.**
   Machine vision is used to guide robots, scan codes on products, measure dimensions and alignments, detect defects, read serial numbers, check fill levels, and inspect assemblies.
   Common applications are in electronics, automotive, food, pharmaceutical, and semiconductor manufacturing.
5. **What is optical flow? How can it be used in visual motion analysis?**
   Optical flow represents apparent motion of patterns in an image sequence.
   It can be used to estimate motion fields, detect independently moving objects, navigate based on ego-motion, track moving targets, and determine time to contact and collision.

Chapter 4 - Perception based models

1. **What is the purpose of an internal world model for a robot? What kind of information does it contain?**
   The purpose of an internal world model is to allow a robot to keep track of its surroundings and make informed decisions about how to act.
   It contains information gathered by the robot's sensors, such as maps of spaces it has explored, locations of detected objects, and information about terrain traversability. The world model allows the robot to localize itself, plan paths, and reason about the results of potential actions.

2. **Explain the simultaneous localization and mapping (SLAM) problem. Why is it challenging?**
   SLAM refers to the problem of a robot building a map of an unknown environment while simultaneously keeping track of its own location within that map.
   It is challenging because the robot's location is uncertain, making it hard to build an accurate map. And without an initial map, estimating the robot's location precisely is difficult. SLAM methods address this "chicken and egg" problem by using techniques like feature extraction and Kalman filtering to iterate between estimating location and building the map.

3. **What are some key factors that determine the difficulty of mapping an environment?**
   Key factors are the size of the environment, noise in sensor data, perceptual ambiguity that makes locations appear similar, and whether there are cycles that allow error accumulation. Larger environments with lots of noise, ambiguity, and cycles are more difficult to map accurately.

4. **How do occupancy grid maps represent robot map information? What are their advantages and disadvantages?**
   Occupancy grids divide the environment into cells and estimate the probability each cell is occupied. They can incorporate noisy sensor data probabilistically. Drawbacks are high computation for fine resolution and difficulty dynamically resizing maps.