CMPE 185 Autonomous Mobile Robots

Midterm review

Dr. Wencen Wu
Computer Engineering Department
San Jose State University

Midterm

- October 10, 2024 from 10:30am – 11:45am
- **NO** make up exam
- Closed book, closed note.
- A combination of multiple choice problems, short answer questions, mathematical questions, open/explanation questions

Robot locomotion

- Locomotion concepts
  - what is robot locomotion?
  - what are the most important issues in locomotion?
- Types of mobile robot locomotion? (legged, wheeled, flying, swimming)
- What is DOF? What is gait?
- Wheeled robots:
  - types of drives. (Differential drive, Ackerman-like, synchro drive, tricycle/bicycle drive, omnidirectional drive)
  - pros and cons
- Other types of mobile robots?

Robot locomotion – Sample problems

- Legged systems are easier to control compared to wheeled systems, and they can overcome many obstacles that are not reachable by wheeled systems.
  - False

- What are the most important issues in locomotion that were discussed in class?
  - Stability
  - Characteristics of contact
  - Type of environment

Coordinate Transformation

- Cartesian coordinates v.s. Polar coordinates
- Transformations between them

- Global (inertial) frame v.s. local (body) frame

- Position in local frame → position in global frame
- Rotation matrix

- Velocities in local frame → velocities in global frame

Sample Problems

- A range sensor mounted on a robot detects an obstacle at position $[-1, 2]^T$. Suppose the robot is at position $[1, 0]^T$ in the inertial frame with orientation $\pi/3$. What is the position of the obstacle in the inertial frame?

$$^{I}\boldsymbol{p} = R\,^{R}\boldsymbol{p} + {}^{I}\boldsymbol{q}$$

Mobile robot kinematics

- Definition of kinematics
- Types of motion of single bodies

- (Differential) Forward kinematics: definition, general steps
  - How to calculate how wheel speeds affect the robot velocities in global frame

- (Differential) inverse kinematics: definition, general steps
  - Determine the speed of the wheels to obtain the desired velocities of the robot

- Unicycle model (two forms, design for one model and implement another model)

Mobile Robot Odometry

- Wheel encoders, odometry, dead reckoning

- How to determine the next position of the robot p' from the current position and the readings from wheel encoders?

- Odometry errors, modeling uncertainty in motion

Sample Problems

- Forward kinematics deals with the problem of determining the pose of a robot given a set of actuator positions.
  - True

Suppose a self-driving car equipped with a 2D range sensor starts at position x = 1.0m, y = 2.0m, with heading $\theta = \pi/4$. The range sensor detects an obstacle and returns a reading of $\alpha = -\pi/6$ and $d = 1.0$m.

1. (10 points) What is the position of the obstacle in the global coordinate frame?
2. (10 points) For the same car, suppose the wheel radius is 0.3m and the length of the axles is 1.6m. For the wheel encoder, the total ticks per revolution is 50. After a while, 20 ticks were recorded for the left wheel, and 40 ticks were recorded for the right wheel, will the car collide with the obstacle? Write down all your work.

Navigation and control

- Two models of the mobile robot kinematics: design for one, and implement the other

- Open-loop v.s. closed loop control
- Feedback control system basic components
- Time-domain specifications
- Dynamic models: continuous v.s. discrete time models

- P control and PID control
  - Properties of each part

Sample Problems

- Proportional control (P-regulator) can help reduce the steady-state error to zero.
  - False

- List three time-domain specifications for a control system
  - rise time
  - settling time
  - overshoot
  - etc.

Perception: sensors

- Why perception?
- Sensor types?
  - proprioceptive v.s. exteroceptive; passive v.s. active
- Common sensors for mobile robots
  - wheel encoders, GPS, IMU, range sensors, cameras
  - usage of different types of sensors
  - characteristic of different types of sensors
  - common types of range sensors (sonar, radar, lidar, infrared…)

Sample Problems

- Vision sensors are active sensors and exteroceptive sensors.
  - False

- Compared to Radar measurement, the resolution of LiDAR measurement is much lower.
  - False

Perception: feature extraction

- What is the line extraction problem
- Three main problems: How many? Segmentation. Line fitting/extraction
- Line extraction
  - line representation: polar coordinate
  - weighted least squares

- Line extraction algorithms
  - split and merge
  - linear regression
  - RANSAC
  - Hough-transform

Sample Problems

- List at least three line extraction algorithms we discussed in class
  - Split-and-merge
  - linear regression
  - RANSAC
  - Hough-Transform

- RANSAC line extraction algorithm can deal with outliers, i.e., points which do not satisfy a model.
  - True

Perception: computer vision and image processing

- What is computer vision?
- Camera: does a single camera measure distance?

- Image filtering:
  - why filters?
  - types of filters? (linear, shift-invariant…)
  - how does a filter work? (template, moving average)

Perception: Learning-based Object Detection

- Types of learning
- Key players in learning algorithms
- Machine learning v.s. deep learning
- What is the structure of a neural network
- Various architectures of deep learning
- ……

- Thank you!