Robotics USI 2021 - Questions and Exercises for Finals

May 7, 2021

1 Questions related to Localization

1) Darkness, in the dark human eyes have aliasing.
2) Estimating the exact position where we are between two m
ountains, we can't do that with just our eyes (inaccurate)

1. Sight is a powerful localization sensor for humans.
   - Discuss a case in which sight fails to provide a satisfactory localization for a human due to aliasing.
   - Discuss a case in which sight fails to provide a satisfactory localization for a human due to inaccuracy.
2. Can an extremely accurate sensor (zero systematic error, zero non-systematic error) be affected by aliasing when used for localization? If yes, make an example; if not, explain why
3. A differential drive robot has two actuated wheels, with a nominal radius of 35 centimeters. However, the left tire got a flat so the owners changed that with a new one with a new tread (real radius 35 centimeters), whereas the right tire is very worn (real radius 34.5 centimeters). The robot self-localizes based only on odometry from very accurate wheel encoders, starting from a precisely-known pose. Draw the resulting trajectory when the robot tries to follow a square path. Extra: discuss by how much the robot deviates from its expected path. Discuss the characterization of the odometry error.
4. Consider a 2D planar robot such as the Thymio, whose pose has three degrees of freedom; the belief about the robot pose is described in a 3D grid map in a Markov framework.

   The robot is equipped with a radio-based sensor that can detect the distance and relative heading of a landmark. The landmark location is exactly known and the sensor is very accurate.

   Discuss the effect of one reading of such sensor on the robot belief, then answer:
   - Does a single sensor reading allow the robot to pinpoint its pose, in case it had no prior belief about its pose?
   - Does a single sensor reading allow the robot to pinpoint its pose, in case, before the sensor reading, it was very sure about its orientation but completely unsure about its position?
   - Does a single sensor reading allow the robot to pinpoint its pose, in case, before the sensor reading, it was very sure about its position but completely unsure about its orientation?
   - Can the robot localize itself by repeatedly reading the sensor and rotating in place (assuming perfect odometry)?

2 Exercise

Consider a robot in a 2x2 grid world (periodic: left edge connected to right edge, and top edge connected to bottom edge). The robot may have four orientations: east, north, west, south, represented in the following as $\theta = \{E, N, W, S\}$.

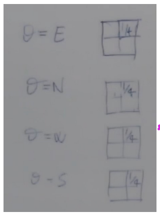
We want to use markov localization in order to recover its pose.

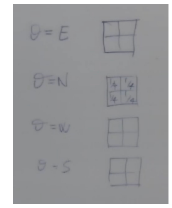
1. Present a possible belief representation for the robot's pose. Demonstrate the belief representation for the two cases:

4 * 2 = 16 possible states (positions * orientations)

1/4 on the north east corners of each orientation

1/4 only on the orientation Th = N

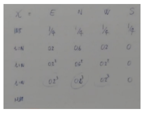


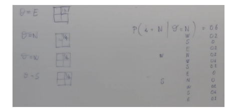


- For sure the robot is looking north, but we have no clue about where it is.
- The robot is at the north-east corner, but we have no clue about its orientation.

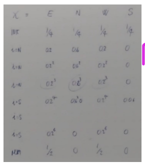
2. The robot is equipped with a compass sensor. If the robot is looking North, the compass will return north 60% of the times, east 20% of the times; west 20% of the times, and never south. Similarly, for other robot orientations the sensor will return $\theta + 90$ degrees 20% of the times, and $\theta - 90$ degrees 20% of the times.

   Formalize the sensor model using probability notation.



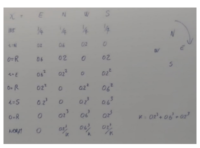


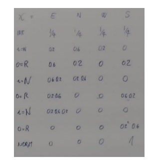
3. Explain what we know after each of the following sequences of events (at the beginning of each set, we know nothing about the robot pose). We know for sure the robot is not changing its pose.



   - the compass measures "North" three times (i=N, i=N, i=N),
   - the compass measures (i=N, i=N, i=N, i=S, i=S, i=S).
   - the compass measures (i=N, i=S, i=N, i=S, i=N, i=S).

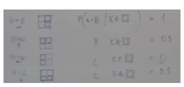
4. Does a finite sequence of compass measurements exist after which the robot is completely sure about the orientation component of its pose? If yes, provide one; if not, explain why.





5. Assume that the robot's odometry model is perfect. The robot senses that it is turning 90 degrees to the right after each timestep (o=right). Explain what we know after each of the following sequences of events (at the beginning of each set, we know nothing about the robot pose).

   - i=N, o=right, i=E, o=right, i=S, o=right
   - i=N, o=right, i=N, o=right, i=N, o=right



6. The robot is also equipped with a sensor that can detect whether the world boundary is exactly in front of the robot or not. If the boundary is exactly in front of the robot, the sensor will always return that there is a boundary (i=B). Otherwise, in front of the robot there is a cell. Then the sensor will return i=C with a 50% chance, or i=B with a 50% chance. Formalize the sensor model.

7. Discuss whether the robot could eventually localize its pose using only the boundary sensor, starting from a complete-ignorance belief (i.e., no clue about its current pose). Assume the robot can move as it wishes (rotation, or moving straight) and has perfect odometry.

3 Questions about Scan Matching

1. A planar laser scanner is mounted on a robot in such a way that it scans an horizontal plane; the scanner acquires one sample per degree with a 180 degrees aperture. Consider each of the following cases and discuss the results of ICP. The map is always exactly known.

   - The robot is in a rectangular room with no objects.
   - The robot is in a square room with no objects.
   - The robot is in a circular room with no objects.

2. In the case above, the point set of the laser scan is not uniform. Discuss when this might be a problem, and potential solutions

4 Questions about Path Planning

1. Among the algorithms we have discussed in class, which are suitable for planning for a nonholonomic vehicle such as a car? Motivate why.
2. Visibility graphs are sometimes used for planning for differential drive robots, even though these robots are nonholonomic; explain how this is possible.
3. Consider a robot arm in 3D with 6 degrees of freedom; the workspace contains a few obstacles; motivate why sampling-based planners are the best choice for motion planning
4. Explain how the local planner component of a sampling-based path planning algorithm could be implemented in case of a differential drive robot
5. Consider a 2D world with rectangular boundaries, containing one square and one triangular object. Draw the visibility graph and the Voronoi diagram.