Albert-Ludwigs-Universität Freiburg | Institut für Informatik
Lecture: Introduction to Mobile Robotics
Summer term 2009 | Prof. Dr. W. Burgard

Sheet 4

Topic: Motion and Sensor Models

Submission deadline: Tuesday 19.5.2009 (before class)

Exercise 1:

Let a robot be equipped with wheel encoders and on-board software that transforms the physical measuring data into time-discrete odometry measurements $\langle \hat{\delta}_{rot_1}, \hat{\delta}_{trans}, \hat{\delta}_{rot_2} \rangle$.

1. Derive equations for the calculation of the end-pose $\langle x', y', \theta' \rangle$ after a performed motion $\langle \delta_{rot_1}, \delta_{trans}, \delta_{rot_2} \rangle$ from a start-pose $\langle x, y, \theta \rangle$.

2. Let the robot start at pose $\langle x, y, \theta \rangle = \langle 0m, 0m, 0^\circ \rangle$ and obtain the following subsequent odometry measurements:

$$\begin{aligned} \hat{\delta}^1_{rot_1} &= 10^\circ \\ \hat{\delta}^1_{trans} &= 3m \\ \hat{\delta}^1_{rot_2} &= 10^\circ \end{aligned}$$

$$\begin{aligned} \hat{\delta}^2_{rot_1} &= -20^\circ \\ \hat{\delta}^2_{trans} &= 10m \\ \hat{\delta}^2_{rot_2} &= -10^\circ \end{aligned}$$

   Please assume perfect measurements and calculate the exact pose of the robot.

3. How would your pose estimate for the first movement look like under the following simple error model? Please draw the movement and pose estimates into one diagram.

$$\begin{aligned} \hat{\delta}_{rot_1} &= \delta_{rot_1} \pm \varepsilon_{rot_1}, & \varepsilon_{rot_1} &= 5^\circ \\ \hat{\delta}_{trans} &= \delta_{trans} \pm \varepsilon_{trans}, & \varepsilon_{trans} &= 0.5m \\ \hat{\delta}_{rot_2} &= \delta_{rot_2} \pm \varepsilon_{rot_2}, & \varepsilon_{rot_2} &= 10^\circ \end{aligned}$$

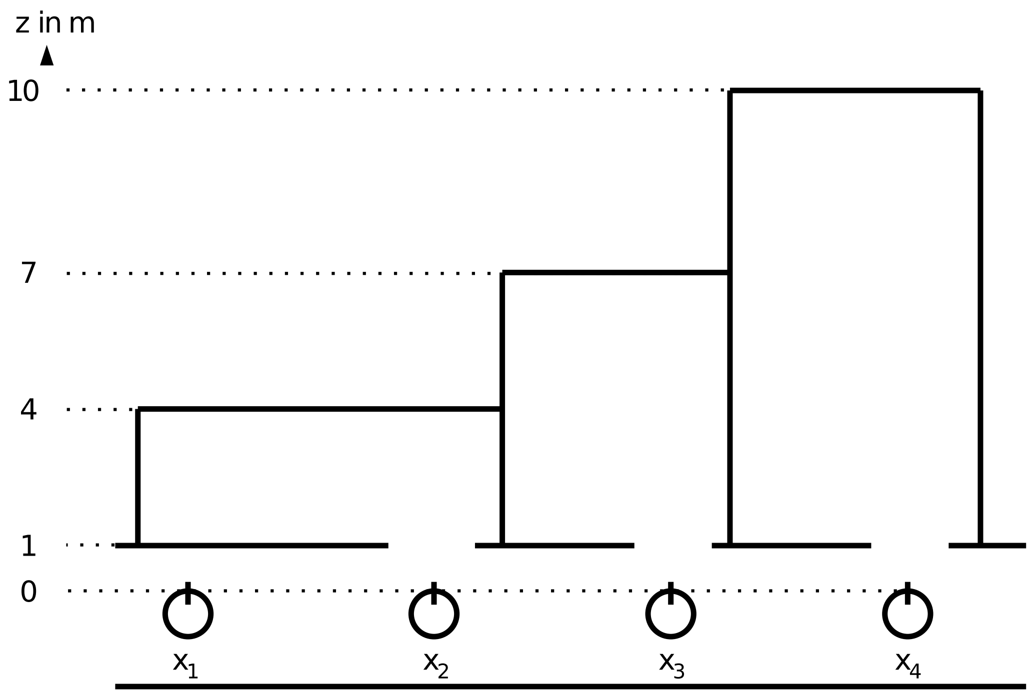

Figure 1: Map

Exercise 2:

A robot moves along the middle of a corridor with a given accurate map, as depicted in the figure. At some of the given locations x_i it takes measurements z_k of the distance to one side, using one laser beam. Every measurement is corrupted only with additive Gaussian noise $\mathcal{N}(\mu, \sigma)$ with $\mu = 0m$ and $\sigma = 1m$. The scanner range is assumed to be unlimited. The measured distances are $z_1 = 1m$, $z_2 = 2m$, $z_3 = 5.4m$, $z_4 = 8.6m$, $z_5 = 9m$. The mapping between z_k and x_i is unknown.

1. For each measurement, determine the most likely robot pose by calculating the probabilities for each position given the measurement using Bayes' rule. Assume an equally distributed *prior*. The *evidence* term (denominator) can be neglected, but the probabilities should be scaled such that $\sum_{i=1}^{4} P(x_i|z) = 1$.

2. The robot believes that taking measurements at the positions x_2 and x_3 is in general four times as likely as doing so at x_1 and x_4. Use this prior information to recalculate the probabilities of (2.1).

3. Suppose the laser scanner is not as ideal as above, and reports a faulty measurement of $z = 1m$ in 50% of all cases, no matter the actual distance. How does this change the results of (2.1) and (2.2)?

Exercise 3:

Each measurement $z = \{(\psi^1, d^1), \ldots, (\psi^N, d^N)\}$ obtained from a laser range scanner, consists of a set of N range measurements d^i (with direction ψ^i).

Write an *Octave* program that reads a file containing measurements from a laser range finder. Each line in the file corresponds to a measurement and has the following format:

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timestamp x y theta start_angle angular_res n_readings [readings]
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- *timestamp* indicates the time at which the measurement was made.
- x, y, and *theta* indicate the pose of the robot at the moment of the measurement (assume that the pose of the robot and the range scanner are exactly the same).
- *start_angle* is the direction ψ^1 of the first range reading d^1.
- *angular_res* is the angular difference $\psi^{i+1} - \psi^i$ between range readings.
- *n_readings* the number of range readings
- *readings* the range readings

Download the files *log1.log* and *log2.log* from the web page and plot the end point of each range reading d^i for every measurement in a global reference frame. You should obtain, for each log file, a map of the environment. What do you think is the cause of the difference between the two resulting maps? (Note: try ignoring range readings that are unusually long, for example, 25m.)