University of Technology Nuremberg
Department of Engineering
Lecture: Introduction to Mobile Robotics
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Sheet 6

Topic: Sensor Models

Exercise 1: Distance-Only Sensor

In this exercise, you try to locate your friend using her cell phone signals. Suppose that on a map, the university campus is located at $m_0 = (10, 8)^T$, and your friend's home is situated at $m_1 = (6, 3)^T$. You have access to the data received by two cell towers, which are located at the positions $x_0 = (12, 4)^T$ and $x_1 = (5, 7)^T$, respectively. The distance between your friend's cell phone and the towers can be computed from the intensities of your friend's cell phone signals. These distance measurements are disturbed by independent zero-mean Gaussian noise with variances $\sigma_0^2 = 1$ for tower 0 and $\sigma_1^2 = 1.5$ for tower 1. You receive the distance measurements $d_0 = 3.9$ and $d_1 = 4.5$ from the two towers.

(a) Is your friend more likely to be at home or at the university? Explain your calculations.

(b) Implement a function in Python which generates a 3D-plot of the likelihood $p(z|m)$ over all locations m in the vicinity of the towers. Furthermore, mark m_0, m_1, x_0 and x_1 in the plot. Is the likelihood function which you plotted a probability density function? Give a reason for your answer.

(c) Now, suppose you have prior knowledge about your friend's habits which suggests that your friend currently is at home with probability $P(\text{at home}) = 0.7$, at the university with $P(\text{at university}) = 0.3$, and at any other place with $P(\text{other}) = 0$. Use this prior knowledge to recalculate the likelihoods of a).

Exercise 2: Sensor Model

Remark: This exercise is to be solved without Python.

Assume you have a robot equipped with a sensor capable of measuring the distance and bearing to landmarks. The sensor furthermore provides you with the identity of the observed landmarks.

A sensor measurement $z = (z_r, z_\theta)^T$ is composed of the measured distance z_r and the measured bearing z_θ to the landmark l. Both the range and the bearing measurements are subject to zero-mean Gaussian noise with variances σ_r^2, and σ_θ^2, respectively. The range and the bearing measurements are independent of each other.

A sensor model

$$p(z \mid x, l)$$

models the probability of a measurement z of landmark l observed by the robot from pose x.

Design a sensor model $p(z \mid x, l)$ for this type of sensor. Furthermore, explain your sensor model.