EBERHARD KARLS UNIVERSITÄT TÜBINGEN

MATH. - NATURWISS. FAKULTÄT
FACHBEREICH INFORMATIK
KOGNITIVE SYSTEME · PROF. A. ZELL

Mobile Robots

Summer Semester 2013
Assignment 9

due date: 02.07.2013, presentation: 09.07.2013
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Exercise 1 Transforming Distributions (12 points)

You are given an differential drive robot with the model presented in the lecture. Its model parameters are $l = 15\text{cm}$, $\alpha_l = 0.05$, $\alpha_r = 0.05$, $\alpha_\phi = 2/180 \cdot \pi$. We have an uncertain estimation of its pose for $t = 0$: $x_0 = \mathcal{N}(\mu_0, \Sigma_0)$ with

$$\mu_0 = \begin{pmatrix} 0\text{m} \\ 0\text{m} \\ 0° \end{pmatrix} \qquad \Sigma_0 = \begin{pmatrix} (2\text{cm})^2 & 0 & 0 \\ 0 & (2\text{cm})^2 & 0 \\ 0 & 0 & (2°)^2 \end{pmatrix}.$$

At time $t = 1$ the robot measures its odometry values with $s_{l,1} = 30\text{cm}$ and $s_{r,1} = 20\text{cm}$. Estimate the distribution of the robot's pose for time $t = 1$ using the following two methods:

Note: It takes very long and is error prone to calculate this by hand. You are encouraged to use a script language or CAS of your choice to solve this problem. Python, Matlab, WxMaxima or Octave might be good choices. Please also hand in the source which produced your solution.

(a) **Monte Carlo Sampling with $n = 5$ samples:** For the sampling you need random values drawn from the distribution of the model parameters. Determine the distribution $\mathcal{N}(\mu, \sigma^2)$ for every model parameter of the differential drive. You are given the following five parameter configurations drawn from their distributions. Use this parameters to calculate the pose for every sample at $t = 1$. Calculate the mean μ_1 and the Covariance Σ_1 for the resulting pose. (5 Punkte)

Sample Number	u'_1	ϕ'_1	x'_0
1	$(0.3076, 0.2016)^T$	-0.0046	$(0.0013, 0.0016, 0.0067)^T$
2	$(0.3361, 0.1951)^T$	-0.0108	$(0.0376, -0.0061, -0.0068)^T$
3	$(0.3053, 0.2054)^T$	-0.0301	$(-0.0018, -0.0083, -0.0025)^T$
4	$(0.3083, 0.1971)^T$	0.0004	$(0.0094, 0.0182, 0.0080)^T$
5	$(0.3137, 0.2004)^T$	0.0355	$(-0.0141, -0.0219, -0.0360)^T$

(b) **Unscented Transform:** Determine the composed vector of the mean $\overline{\mu}$ and the covariance matrix $\overline{\Sigma}$, which includes all the uncertainties of the model. Then generate the sigma points X_i and the transformed sigma points Y_i. Determine the weights $w_{i,m}$ and $w_{i,c}$. Use these values to estimate the resulting distribution $\mathcal{N}(\mu_1, \Sigma_1)$. Use the parameters $\alpha = 0.1$, $\kappa = 0$, $\beta = 2$.

Exercise 2 Comparison of Transformation Methods (3 points)

In this lecture, you studied three methods to estimate transformed distributions. State the advantages and disadvantages of these methods regarding the efficiency and accuracy.

Exercise 3 Particle Filter (5 points)

You are given the following state of three particles of a Particle Filter: $x'_1 = (1\,\mathrm{m}, 1\,\mathrm{m})^T, x'_2 = (0\,\mathrm{m}, 2\,\mathrm{m})^T, x'_3 = (0\,\mathrm{m}, -1\,\mathrm{m})^T$. You are also given the measurement $\hat{z} = 1\,\mathrm{m}$ and the sensor model $h(x) = \sqrt{x_1^2 + x_2^2}$ with $\hat{z} \sim \mathcal{N}(h(x), (0.01\,\mathrm{m})^2)$. Calculate the weight w_i of each particle.