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

Mobile Robots

Summer Semester 2024
Assignment 10

TAs: Andreas Ziegler, Benjamin Kiefer, Martin Meßmer
Due: 09.07.2024, 10:15

Exercise 1 Kalman filters (6 Points)

(a) Shortly explain the Extended Kalman filter. Explicitly state the difference to the standard Kalman filter. (2 Points)

(b) Shortly explain the Unscented Kalman filter. Explicitly state the difference to the Extended Kalman filter. (2 Points)

(c) Shortly explain the Particle filter. Explicitly state the difference to the other filters. (2 Points)

Exercise 2 Multiple Objects Tracking (14 Points)

The Kalman filter (KF) is often used to track moving objects by assuming an initial state and the noise covariance. As shown in Fig. 1, there are four robots moving around and they generate four actual trajectories. The robots are recorded by a camera mounted on the ceiling. Each robot has a known start pose, but the camera cannot distinguish the individual robots. The state of one robot can be described as:

$$\mathbf{x}_t = [x_t, y_t, \dot{x}_t, \dot{y}_t, \ddot{x}_t, \ddot{y}_t]^T, \tag{1}$$

where $x_t, \dot{x}_t, \ddot{x}_t$ denote its position, velocity and acceleration, respectively. For simplicity, you may assume a constant acceleration model.

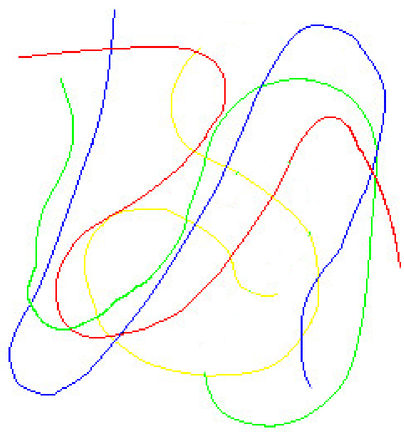

Fig. 1: Ground-truth trajectories.

(a) Derive the state transition matrix $\boldsymbol{A}_t$ and the measurement matrix $\boldsymbol{C}_t$. Assume that the camera measures directly the 2D positions of the robots.
Hint: Each measurement $\boldsymbol{z}_t$ describes the measured position of **one** robot. (4 Points)

(b) The *assigment10.zip* file from Moodle contains a small python framework and files containing a list of measurements (*measurements.txt*) and the start positions of the robots (*start.txt*). Implement the Kalman filter prediction step to predict the four robot positions.
The controls $\boldsymbol{u}_t$ are unknown and can be left out. Use **one** KF per robot. The process noise $\boldsymbol{R}_t$ and the initial covariance matrix $\boldsymbol{\Sigma}_0$ of the KFs are given in the code. (4 Points)

(c) Implement a function that establishes correspondences between the four measured positions and the four robot positions. It should use the current (predicted) state and covariance. (3 Points)

(d) Now add the Kalman update step into your tracking program. Plot the estimated trajectories. The measurement noise $\boldsymbol{Q}_t$ is given in the code. (3 Points)