Portfolio Exam 1

Sensor Fusion – Kalman and Particle Filter

Due date: 20.12.2024, 24:00

The deliverables for the following assignments are the commented source code of your implementations. Send me an email with a zip file attached. It is required that I receive the email by the specified time. The code should be structured so that I can use it myself. So please include a readme file.

We will discuss your solution after delivery. During this you should be able to present/explain your solutions, visualize results graphically, and change parameters. You do not need to prepare slides.

Please note that this time it is necessary to pass both portfolio tasks (Portfolio 1 Kalman/Particle Filter and Portfolio 2 BlackJack Player), as we only have two portfolio components. If you fail one, you will fail the entire course.

Task P1.1

Realize an implementation of the Kalman Filter in a programming language of your choice for a simulation of the ball-throwing example from the lecture slides. The task of your Kalman Filter is to estimate the position and velocity vector of the ball only from the observed erroneous positions over time.

Your implementation shall be flexible in the sense that it can handle the following variations:

- Simulate the trajectory of a ball with the parameters *launch position* (especially the height above an imaginary ground), *launch speed* and *launch angle* of the ball.
- Simulate the observation of the ball position (x, y). The estimated ball position shall be subject to high uncertainty and it shall be possible to parameterize this uncertainty. In addition, the time span between two observations shall be variable and the observations shall be able to drop out completely over a certain period of time. It is necessary that the position of the ball is also estimated during the time of the sensor failure.
- The initial parameters of the Kalman Filter shall be adaptable/randomized.
- The normally distributed noise on transition and observation should be adjustable. This means that the covariance matrices $\boldsymbol{R}$ and $\boldsymbol{Q}$ shall be set as a parameter in the Kalman Filter.
- **The inital position and flying direction of the ball are unknown. You can only assume that the ball starts within a range of 10×10 meters around the real starting position.**

Task P1.2

Realize an implementation of the Particle Filter in a programming language of your choice for a simulation of the ball-throwing example from the lecture slides. The task of your Particle Filter is to estimate the positions and velocity vectors of **two** balls flying simultaneously only from the observed erroneous positions over time.

Your implementation shall be flexible in the sense that it can handle variations similar to the ones from Task P1.1. In addition, you need to consider a couple of things:

- How to deal with more than one ball flying at the same time?
- How do you define your state? Think intensively about what the transition model and the evaluation model should look like in the case of two balls.

- How do you estimate two positions from the density? If the density of the ball positions is multimodal, select a suitable method that can determine the positions of the two balls.
- You are not able to distinguish between the two balls. They are indistinguishable from an observational point of view.
- As with Task P1.1, the starting position and other starting parameters are just as unknown and cannot be specified more precisely. You should handle both the case where the starting positions and directions of the balls are very similar and the case where the positions and directions are clearly different in a closed approach.

Note: There is more than one good approach here. Thus, there is no clear best solution approach in this task.