# Portfolio Exam 2

## Sensor Fusion – Kalman and Particle Filter (Due date: 12.01.2024)

This portfolio corresponds to the task from the last semester. You can build on the implementation of the last semester. You should not copy any parts from the graded paper of the last semester (text, graphics). This would be considered plagiarism. Likewise, any kind of tool that generates text that is not directly based on your ideas will be considered plagiarism.

### Task P2.1

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 ($x, y$ as shown in the slides). The estimated ball position shall be subject to 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.
- The initial parameters of the Kalman Filter shall be adaptable.
- 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 deliverable for this task is the commented source code of your implementation.

### Task P2.2

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 P2.1. In addition, you need to consider how to deal with more than one ball flying at the same time. How do you estimate two positions from the density? How do you define your state?

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

### Task P2.3

Prepare a paper using the official IEEE template from [2] (format A4). The absolute maximum length of the paper is 6 pages.

The paper shall have the following structure:

- *Abstract:* One-paragraph summary of the paper. The Abstract provides a short overview of the paper.
- *Introduction:* What is the topic and why is it worth studying? The Introduction commonly describes the topic under investigation, summarizes or discusses relevant prior research, identifies open questions and problems and provides an overview of the research that is to be described in greater detail in the sections to follow.

- *Description of the Kalman and Particle Filter:* What did you do? A section which details how the work was performed. It typically features a description of the methods that were involved. A rule of thumb is that this section should be sufficiently detailed for another researcher to duplicate your research. You should also address the theoretical background of your specific problem solutions for the task at hand, taking into account the issues raised above.
- *Experiments and Evaluation:* How well does it work? The evaluation must show that your implmentation works correctly. Use appropriate datasets to represent specific properties of the algorithm and discuss them. Evaluate the accuracy of your implementation's estimation accuracy and explain your results with respect to the following parameters:
  - Different launch positions, launch directions and launch velocities of the ball(s).
  - Different time intervals between observations. Experiment also with the complete failure of the observations of different durations. How do you model this failure?
  - Different initial parameters.
- *Conclusion:* A brief summary and outlook of questions to be explored in the future.
- *References:* List of articles, books, etc. cited. A list of the sources that are cited in the paper.

An example paper [1] with different topic is available in this document's eLearning section. Compared to your paper it is too long, but contains all the parts above. Conceptually, sections I and II correspond to *Introduction*, III to V correspond to *Description of the Kalman and Particle Filter*. As you can see from this paper there are a number of (formal) criteria that characterize a good paper:

- Consistent mathematical notation, both as inline text and in separated, numbered equations.
- Very careful selection of suitable forms of presentation of results in graphs and tables, adapted to your message in each case.
- Extensive, in-depth discussion of the results and their backgrounds.

The deliverable for this task is a pdf version of your paper.

# References

[1] T. Fetzer, F. Ebner, L. Köping, M. Grzegorzek, and F. Deinzer. Recovering From Sample Impoverishment in Context of Indoor Localisation. In *International Conference on Indoor Positioning and Indoor Navigation*, pages 1–8, Sapporo, Japan, 9 2017. IEEE.

[2] IEEE Paper Template. `https://www.ieee.org/conferences/publishing/templates.html`.