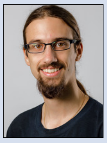

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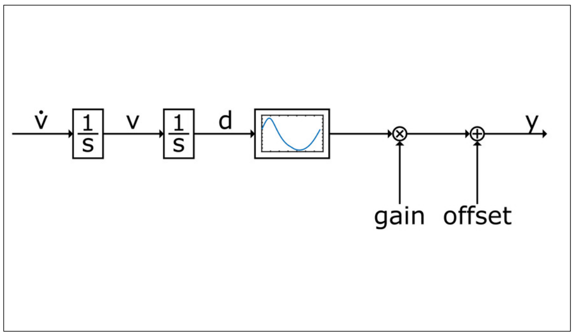
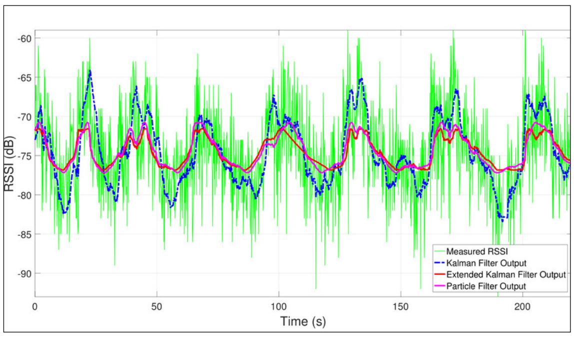
Particle Filter for Lap Tracking

Investigation of the Feasibility of Particle Filters for Lap Tracking

Representative image of the Skateathon in Zug, Nov 5, 2017. Photographed by Heinz Mathis.



Block diagram showing the linear movement model and the nonlinear measurement approximation.



Unfiltered and filtered signals of the received signal strength.

Introduction: Many sports clubs organize sponsoring events to provide a good infrastructure. Lap-based performance activities like running are common. Usually, each athlete recruits his sponsors who pays an amount of money for each of the athlete's completed rounds within a given time. The ice-hockey club SCRJ Lakers Nachwuchs organizes an annual sponsoring event, called Skateathon, where the athletes skate laps on the ice rink within 6 minutes. In a previous project, a solution was developed where each athlete gets equipped with an actively-powered transmitter. To count the laps of each athlete, the signal strength of the transmitters is measured on a laptop outside the rink. Counting laps based on the signal strength is possible because it is related to the distance between the receiver and the transmitter.

Objective: The measured signals of the transmitters are very noisy due to fading. The filter so far used is a standard Kalman filter. This filter allows a threshold based counting. However, the true underlying nonlinear system of the athlete skating on the ice rink and the nonlinear path loss of the measured signal strength can not be modeled. This thesis focuses on the development of a nonlinear filter to improve the standard Kalman filter. A filter that can account for all varieties of nonlinear behaviors is the particle filter. The goal of this thesis is to investigate the possibilities and the performance of a particle filter for this filtering problem. For a more complete comparison of the filters, the extended Kalman filter which can partially account for nonlinear behaviors, but with a much lower computational effort, is also investigated. The focus does not lie on real time counting because this can already be achieved with the existing filter.

Result: The resulting filter design can be used in post-processing to improve the amount of counted laps of the linear filter. Both, the extended Kalman and the particle filter contribute to the final solution. The filters are based on a linear movement model with a nonlinear measurement model. The nonlinear measurement model is approximated using ice rink parameters. The length and the width of the ice rink but also the receivers position are used to generate the approximation. The extended Kalman filter works well with the chosen model. Problematic is the symmetry of both directions of rotation that can lead to occasional losses of multiple laps due to estimating a rotational direction change. Thus, a check of the sign of the rotation velocity is implemented. To detect failures that occur due to poor parameter estimation, an Allan-variance like analysis is done in parallel. If a failure is detected, a change in the sign of the rotation velocity or a high difference between the Allan-variance like result and the extended Kalman filter result, the particle filter is initialized. The particle filter has the big advantage of being able to simply correct impossible states but it comes with a huge computational cost compared to the extended Kalman filter. Using both algorithms combines the advantages. Threshold counting is omitted because the linear movement model allows a direct conversion to a total amount of laps. First live measurements revealed fewer missed laps than the previous RFID-based system. Post-processing with the extended Kalman filter and the particle filter further improves the results.