State Estimation Techniques for Nonlinear Stochastic Systems and Application to Continuous Glucose Monitoring Systems

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The first part of the talk will deal with the recursive state estimation of discrete time nonlinear stochastic systems. Some basic results will be presented with emphasis on the Kalman Filter and its nonlinear variants (EKF,UKF,GHKF). The possibility for heuristic modifications of nonlinear Kalman Filters will be illustrated, and then the talk will focus on the systems that consist of linear dynamical systems interconnected through static nonlinear characteristics. For them, it is possible to avoid integration on the space space, which may be of high order, reducing it to the solution of some linear systems and low-order integration. This way, more accurate calculations can be made. Additionally, a novel quadrature technique, alternative to the Gauss-Hermite quadrature, specially designed for nonlinear filters using norm minimization concepts will be presented. Finally, improvements for the Auxiliary Particle Filter and the Unscented Particle Filter will be presented briefly. The results of the comparison of the proposed techniques with the standard ones in suitable examples show that in some cases the improvement is drastic.

The second part will deal with the application of filters to data from a Continuous Glucose Monitoring System (CGMS). The importance of the CGMS in the construction of an Artificial Pancreas will be explained and the problems of CGMSs will be described. Filters based on the Kalman Filter and on the Particle Filter will be presented, designed using simple models of the system dynamics. The application of the filters to experimental data from ICU patients shows that the use of filters leads to significant reduction of the glucose estimation error.

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