Scanning the Issue

Special Issue on Sequential State Estimation

Sequential state estimation is basic to the study of dynamical systems, be they of a linear or nonlinear kind. The traditional tool for solving this fundamental estimation problem has been the Kalman filter and its extended form. The Kalman filter was developed by R. Kalman in 1960. In Kalman's classic paper [1], the derivation was based on a state-space model, governed by two assumptions: 1) linearity of the model and 2) Gaussianity of both the dynamic noise in the process equation and the measurement noise in the measurement equation. Under these two simplifying assumptions, derivation of the Kalman filter leads to an elegant algorithm that propagates the mean vector and covariance matrix of the state estimation error in an iterative manner. Moreover, the Kalman filter is optimal in the Bayesian setting under the above-mentioned assumptions.

To deal with the state estimation in nonlinear dynamical systems, the traditional approach has been to use the extended Kalman filter, which is derived through linearization of the state-space model. Indeed, for much of the 20th century, the Kalman filter and its extended form established themselves as the tools for solving linear and nonlinear sequential state estimation problems.

Unfortunately, many of the state estimation problems encountered in practice are nonlinear and quite often non-Gaussian too, thereby severley limiting the practical usefulness of the classical Kalman filter and its extended form. This Special Issue is devoted to recent developments in sequential state-estimation procedures that overcome the limitations of the Kalman filter.

The Special Issue consists of ten papers organized as follows.

The paper by Julier and Uhlmann deals with a novel transformation, known as the unscented transformation, which is designed to propagate information in the form of mean vector and covariance matrix through a nonlinear process. The unscented transformation, coupled with certain parts of the classic Kalman filter, provides a more accurate method than the extended Kalman filter for nonlinear state estimation.

The bulk of the Special Issue, consisting of the next six papers, is devoted to particle filters, which are rooted in Bayesian estimation and Monte Carlo procedures. The attractive feature of particle filters is their general applicability, in that they can be applied to nonlinear and non-Gaussian dynamical systems, thereby overcoming the major limitations of Kalman filters. This extraordinary capability is, however, achieved at the expense of increased computational complexity. Nevertheless, particle filters are configured in such a way that they do lend themselves to parallel implementation.

A summary of the six papers on particle filters begins with the paper by Andrieu *et al.* and presents a detailed overview of the various facets of particle filters. The next paper, by Haykin *et al.*, discusses the application of particle filters to the tracking of multiple-input, multiple-output (MIMO) wireless channels and compares the results, using real-life wireless data, against other state-estimation procedures.

The third paper of this group of six, by de Freitas, *et al.*, discusses the application of a particle mixture of Kalman filters to the difficult problem of real-time diagnosis in mobile robots. The following paper, by Kwok *et al.*, also discusses real-time implementation of particle filters, supported by experimental results using a mobile robot. Then, the paper by Chen and Rui discusses the application of particle filters to sensor fusion for object tracking and presents a real-time speaker tracking system based on the proposed framework. Finally, the paper by Pérez *et al.*, discusses the application of particle filters to visual tracking, a problem that is made difficult by the inherent ambiguity of the visual world.

The last three papers of the special issue address other procedures for sequential state estimation. In the first, Lo and Yu discuss a novel filtering framework based on recursive neural networks for state estimation. Next, the paper by Kirubarajan and Bar-Shalom presents an overview of probabilistic data association for target tracking in different scenarios. The last paper, by Schell *et al.*, discusses the tracking of highly maneuvering targets using a data-driven approach.

It is hoped that this Special Issue will prove to be of valuable interest to a wide range of readers of the PROCEEDINGS OF THE IEEE, whose research requires the solution to difficult sequential state estimation problems.

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