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Expert opinion on the PhD thesis of Jaroslav Tabacek

Please find below my summary of the contributions and my recommendation of the thesis *State estimation and fault detection with reduced error sensitivity to parameters* by *Jaroslav Tabacek.*

The thesis deals with the classical problem of state estimation in dynamic system, which has been a very active research area since 1960 when Rudolph Kalman first published what is today known as the Kalman filter. This filter outputs an estimate of the state together with its uncertainty in terms of a covariance matrix. The input to the algorithm is the measurable inputs and outputs to the systems *and* a model of the system. The focus on this thesis is the case where this model is not exactly known, as is required in the Kalman filter, but instead has a number of parameters that are affected by an uncertainty. As an example, one of the first applications of the Kalman filter (KF) was for the moon landers in the Apollo program. The dynamic system can be modeled from the laws of physics, where Newton's laws are exactly known, but parameters such as mass and air drag of the vehicle might not be known exactly. The thesis deals with this problem by modifying the Kalman gain in the filter to be less sensitive to variations in such parameters, while still providing a reliable and trustworthy estimate of the state. This is what is referred to as the desensitized Kalman filter (DKF).

Chapter 3 provides the main contributions of the thesis. Here the DKF is derived for several different assumptions and special cases of the model. One particular interesting case appears when the uncertain parameters only occur in the dynamics, not in the measurement model. In this case, a more precise derivation of the DKF can be made with relaxed assumptions, and this is called the exact DKF (XDKF). The DKF and XDKF then become the working horses of the thesis and the remaining chapters apply these filters to well-known application areas.

- Chapter 4 generalises DKF and XDKF to nonlinear systems, where essentially the classical linearisation technique as in the famous extended KF is used.
- Chapter 5 applies DKF and XDKF to the IMM framework with fault detection as the intended application. IMM was developed for systems with multiple modes or uncertain parameters in the 1990's, and is today used in many target tracking systems for instance. IMM is also part of the toolbox in the fault detection literature.

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- Chapter 6 deals with distributed implementations of DKF and XDKF where each node runs a filter without full information from the other nodes.
- Chapter 7 generalises Chapter 6 in the same way as Chapter 5 generalises Chapter 3, from a centralised implementation to a distributed one with incomplete information.

The results are supported by simulations using illustrative examples and a simplified building model.

The main contribution is the thorough derivation and treatment of the DKF and XDKF, with several applications to related state estimation problem from literature. This is the strong part, with several innovative and original contributions, where the derivation of the XDKF is the highlight.

What might be lacking is a broader perspective of the problem with reflections on alternative approaches. The problem of uncertain parameters are certainly not new. As a first alternative, practitioners use dithering to circumvent the problem. The main idea here is to compensate for model errors by increasing the noise covariances. This can be done by studying how each parameter uncertainty contributes to the state uncertainty and thus can be seen as state noise, and similarly for the measurement model. To get a quantitative addition to the state noise, a stochastic description of the parameter uncertainty would be needed, which is assumed not to be the case in this thesis. The other standard approach is to augment the state vector with the uncertain parameters. This is a more general approach, which I would judge to be the main competitor to DKF and XDKF.

Overall, the thesis is very well written and presented. The contributions and peer reviewed publications that are covered are sufficient to pass the threshold. Thus, the author of the thesis proved to have an ability to perform research and to achieve scientific results. I do recommend the thesis for presentation with the aim of receiving a Ph.D. degree.

Sincerely yours,

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