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Review of Ph.D. Thesis "Estimation of the stochastic properties of controlled systems" by Ing. Peter Matisko

Reviewer: Prof. Ing. Miroslav Šimandl, CSc.

Significance for Automatic Control and Robotics. Optimal estimation provides the foundation for modern study of systems. The advantage of an optimal estimator is that it makes the best utilization of the data and the knowledge of the system and the disturbances. The disadvantage is that it may be sensitive to modelling errors. In view of this, it is very important to have a clear understanding of the assumptions under which an estimation algorithm is optimal and how they are related to the real world. The description of measurement and process noises is often considered to be known, e.g., in optimal filtering algorithms, although in real situations it is usually not the case. So, this work deals with estimation of the system stochastic properties. Therefore, the topic of the thesis is relevant for automatic control and robotics.

Aim. The thesis attempts to achieve the following aims:
1) Analyze stochastic properties of linear dynamic systems,
2) Summarize, develop and compare algorithms for performance evaluation of the Kalman filter,
3) Develop an approach for estimation of the noise covariance matrices,
4) Develop a method for detection of a colored noise and a noise shaping filter,
5) Analyze the quality of the noise covariance estimation algorithms by Cramer Rao bounds.

Contents of the thesis. The text comprises of seven chapters and six appendices. It is well structured and in accord with the aims of the thesis.
The starting point, Chapter 1, is a brief introduction, motivation and aims specification. Chapter 2 introduces state estimation of the linear stochastic systems. The next chapter presents optimality tests for the Kalman filter. Chapter 4 deals with estimation of the noise covariances of the linear stochastic system. Besides the current methods, new methods are designed and compared with the standard approaches. Detection of a colored noise and shaping filter identification is presented in Chapter 5. In Chapter 6, the stress is laid on the calculation of the CR bounds as a tool for an evaluation of the filter quality. Finally, a summary of thesis results is given in Chapter 7.

Technical correctness and quality of presentation. The topic requires deep knowledge of the filtering theory, mathematical modelling of stochastic systems, estimation methods and system identification. The structure of the manuscripts and achieved results confirm that the author has the necessary knowledge and an ability to carry out research. A thorough description of the state-of-the-art of the individual areas is also a positive aspect of the manuscript. The thesis satisfies conditions of a creative scientific work and is technically sound.

Besides these positive aspects, the text also contains minor technical inconsistencies and typographical errors e.g.:

- Page 5, if v(t) and e(t) are correlated, then the state of the system is x(t) and y(t)
- Page 10, Equation 2.14, Estimate is conditioned

- Page 11, Line 2, The Kalman filter is for Time variant linear systems, description of the initial state is necessary
- Page 17, Line 1-3, What is the reason?
- Page 17, Line 7, variance 1/N *R*R see equation 3.7
- Page 19, Equation 3.18 and 3.20 are obviously wrong
- Page 20, Line 8, several Kalman filters? Only one Kalman filter, the others are filters
- Page 21, y is output or innovation?
- Page 28, Example 3
- Page 29, Tab.2, lines 1-3, increasing data, the worse results, why
- Page 38, Algorithm, step 2, part 4) instead step 2 should be step 3
- Page 43, in step 4 should be mentioned, that Q and R depends on theta(i), Q,R=f(theta(i))
- Page 44, Equation 4.30, 4.31
- Page 67, Shaping filter identification
- Page 74, Tab. 12, different filters but not the Kalman filters
- Page 77, Section 6.2, The upper index N emphasizes that vector contains N data samples but in page 79, first line is different and also in equation 2.4
- Page 91, Šimandl et al. (2001) instead 2006

Reaching of the aims and new results. The author has met the all above mentioned objectives in Chapters 3-6, where several original results were presented. The main new results, new proposed methods and algorithms, are the following:

- optimality tests for " the Kalman filter ",
- a method for the noise covariance estimation,
- detection algorithms of colored noise and shaping filter design,
- quality evaluation of noise covariance estimation methods by the CR bounds.

The results were presented in peer- reviewed articles in international journals (International Journal of Adaptive Control and Signal Processing, Journal of Mechanical Engineering and Automation) and at prestigious IFAC meetings.

Conclusion. The text under review contains several new results in state estimation of linear stochastic systems. The author of the thesis has proved to have an ability to perform research and to achieve scientific results. It is my understanding that this manuscript fulfills the conditions laid on Ph.D thesis. I recommend the Ph.D thesis to the defense.

Questions:

1. Why do you think that the point estimate by the ALS method, page 30, last sentences in 4.1, does not provide any additional information about the accuracy?
2. Can you compare numerical demands (time demand) of the algorithms presented in tables on pages 52-55 for the considered examples?

Pilsen, August 20, 2013

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