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**Review on the Doctoral Thesis of Ing. Eva Žáčeková titled**

**„Identification for Model Predictive Control under Closed-loop Conditions"**

*Content of the Thesis*

The dissertation investigates the problem of modeling and parameter estimation for model predictive control (MPC), and more specifically the problem of generating persistently exciting control inputs for closed-loop operation of MPC is addressed. The Thesis is structured into two parts: The first one covers the problem of identification of multivariate state-space models for MPC, while the second one is dedicated to MPC with persistent excitation. The core of the Thesis are five journal and one conference publication, two of them associated with the first part and four dedicated to the second part of the work.

The Thesis formally consists of five Chapters, the first one being an introduction and motivation, the second one describing the state of the art, the third one summarizing the contributions of the author, the fourth containing MPC relevant identification (MRI); the fifth presenting MPC with persistent excitation, and the sixth being the conclusion.

Overall, the Thesis covers both the theoretical foundations of modelling, estimation and MPC design and the specific extensions and modifications necessary for obtaining a practical application tool. Especially the application area of building automation is targeted by the practical results of the work.

*Appraisal and Discussion of the Thesis*

The topic of the thesis of Mrs. Žáčeková is of high interest for the scientific community. Especially in building automation the task of the model design is the greatest obstacle to a spread of MPC as an advanced control method. The contributions of the Thesis to overcome the associated problems are substantial, and it is no question that the Thesis and the publications therein represent an important means for the further development of Science.

The main results and contributions of the Thesis are two-fold, according to the structure of the work:

1. The contributions to model predictive control relevant identification (MRI) are contained in two journal papers. The first one presents the basic idea and the application to a modern office building. Although most of the theoretical part is based on results of literature, the application to a real building is done in an effective and transparent way. I very much liked the convincing part of model selection and verification, and the fact that this model in in use today in the building's control highlights the importance of the contribution.
   The second paper extends the MRI concept to bilinear building models. It presents a new concept for MRI based on either using only output predictions for calculating the current regressor or a combination of measured an predicted outputs is utilized. Such a model for a simple building is then used in a nonlinear MPC formulation, and the different formulations are compared. Another nice feature of the paper is the fact that the quantization of the control variable has been explicitly considered in the optimization algorithm, which is often neglected in literature.
2. The contributions to MPC with Guaranteed Persistent Excitation are contained in four papers of the Thesis. Both from the scientific and from the application point of view this is the larger part of the Thesis' contributions. Key idea is using the Fisher information matrix as an indicator for persistent excitation of the MPC's control input. Three optimization variants are presented which differ in the number and selection of future control inputs to be optimized. Furthermore, the concept is extended to MPC control problems where the output variable is constrained to a zone with upper and lower bounds. Another extension of the Thesis covers bilinear and polynomial systems thus extending the applicability to an important class of nonlinear systems. All algorithms have been tested and validated on measured data from real plants, and the effectiveness is proven in the publications.

The scientific work conducted in the Thesis is a very fine example of successful development of theoretical solutions for practical and application oriented problems. Especially in the building automation area the results of the work will certainly have a lasting impact. In order to come up with a practically working solution for this application area, several solutions of different problems have been providedclearly all of which are necessary to be solved on a high scientific level.

The main goals and contributions of the work have been stated in the thesis (both Chapter 3 and the Conclusion); correspondingly, the scientific publications of Mrs. Žáčeková are listed, and her individual contributions are detailed. All objectives have been completely fulfilled, the framework for effective identification of suitable building models has been presented, and the resulting performance is illustrated by simulation results and comparisons to state-of-the-art control and estimation algorithms.

The work has been conducted in a methodically correct and adequate way; citations of references are extensive and up to date. The theoretical treatment of the problem including the development of a suitable optimization problem together with tailored solver algorithms poses a challenge by itself. The list of Mrs. Žáčeková's publications is impressive: Four Journal papers (two of them first authorship) and one under review, and 22 other publications in quality journals and international conferences demonstrate a prolific scientific work . Overall, the publications in peer reviewed quality journals and conferences prove that the scientific quality of the work meets international standards.

Mrs. Žáčeková has clearly proven that she is capable of applying existing methods to new and challenging modeling and estimation problems, and that she can adapt and extend state-of-the-art algorithms where necessary.

All elements of creative scientific work are contained within the thesis. Additionally, Mrs. Žáčeková has proved that she is able to master different complex methods and tools to investigate a given estimation and control problem, and to cover thus all aspects of a sound theoretical foundation for the development of a functional application solution.

Some specific questions related to the contents would be of additional interest:

- MPC with Guaranteed Persistent Excitation makes use of maximizing the minimal eigenvalue of the information matrix. Besides this so-called E-optimality there exist also other optimality criterions such as A-optimality (minimizing the trace of the inverse information matrix) or D-optimality (minimizing the determinant of the information matrix). Especially D-optimality is often used in design of experiments for dynamic systems. Would it be possible to adapt the proposed algorithms also to D-optimality?
- Is there a simple possibility to enforce no zone violations in the output (hard constraint) for the Guaranteed Persistent Excitation in the Zone MPC? What effect could be expected on the parameter estimation?

**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 the Degree of Ph.D.**

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