12. 12.

Slovak University of Technology in Bratislava
Faculty of Chemical and Food Technology
Department of Information Engineering and Process Control
Radlinského 9, SK–812 37 Bratislava, Slovakia

STU
FCHPT

doc. Ing. Milan Polívka, Ph.D.,
Vice-Dean for Doctoral Study and Science
Faculty of Electrical Engineering, CTU in Prague
Czech Republic

Prof. Ing. M. Fikar, DrSc.
Tel.: ++421 (2) 59.325-367
E-mail: miroslav.fikar@stuba.sk

4. 12. 2018

Our Ref.: MF/18/ez

Subject: Report on PhD thesis

Dear doc. Ing. Milan Polívka, Ph.D.,

I have been appointed as a reviewer and a member of the evaluation committee for the PhD thesis of Eva Žáčeková "Identification for Model Predictive Control under Closed-loop Conditions".

The thesis contains 120 pages and it is presented as a collection of published papers with some introductory overview.

The first three chapters contain overview of the thesis. The first describes motivation for model relevant long-range multistep identification of dynamical systems coming from control and from building climate control in particular. Long-range identification is considered as the proposed control framework is based on Model Predictive Control (MPC).

The second chapter introduces the literature review and state-of-art. The first part covers works of Shah and coworkers in nineties where long-range control relevant identification was studied. The core of the thesis relies heavily on works of Lauri who modified the method and set it as optimisation problem. The second part concentrates on MPC control design problem with added persistent excitation condition coming from model identification problem.

Chapter 4 deals with the first contribution of the thesis: model relevant identification (MRI) to be used for development of MPC controllers. For linear systems, paper in *Applied Energy* proposes grey-box identification of MIMO state-space models to minimise multistep prediction errors assuming a priori information. Results were applied in simulations and in identification and control of real buildings at CTU and in Belgium.

For a class of non-linear systems – polynomial systems, simplifications are proposed in *Control Engineering Practice* to reduce the complexity of the problem. These include minimisation of multistep prediction error in linear part and one-step prediction error in nonlinear part.

Chapter 5 presents the second contribution of the thesis: MPC with guaranteed persistent excitation. The author developed novel algorithms based on two-stage procedure. In the first one, a standard MPC problem is solved. The second stage perturbs the obtained MPC controller so that a certain bound on information matrix is respected while the performance deterioration of MPC is constrained by design. Several variants of the second stage are proposed: perturbation of

actual control only, optimisation of control sub-sequence, and semi-receding horizon (open-loop optimisation). Presented results are journal paper in *Journal of Process Control* and *IEEE CDC* conference. A submitted paper to *Journal of the Franklin Institute* deals with a generalisation to zone MPC. Another conference paper (*IEEE CCA*) deals with polynomial systems.

The publication activity of the author is very high even when considering the average number of authors per paper. Four journal publications related to the thesis are all in high impact journals and the PhD student is the first author in half of them. All these are already cited and show impact to the control and identification community. There are another 5 journal publications that are denoted as not thesis related but fit nicely into the proposed framework and show that the author can work in an interdisciplinary team and to provide synergies.

The thesis is reasonably well written, with only some formal errors and typos. It contains contributions both from theoretical point of view as well as practical applications of the methodology.

I meet the author at several international conferences. Her presentations were always interesting and studied topics attracted a lot of attention, especially practical implementation of MRI strategies in MPC. As the number of citations indicate, the proposed topic is highly actual and relevant.

To conclude, the submitted thesis complies in my opinion with the regulations concerning PhD study at CTU in Prague. The author of the thesis proved to have an ability to perform research and to achieve scientific results. I recommend the thesis for presentation with the aim of receiving a Ph.D. degree.

Sincerely yours,

Miroslav Fikar