Czech Technical University in Prague
Faculty of Civil Engineering
Department of Microenvironmental and Building Services Engineering

Doctoral Thesis Review

PhD candidate: **Ing. Jiří Cígler**
Title: **Model Predictive Control for Buildings**
Supervisor : prof. Ing. Vladimír Kučera, DrSc., dr.h.c.
Supervisor specialist: doc. Ing. Lukáš Ferkl, Ph.D.
Reviewer : prof. Ing. Karel Kabele, CSc.

1. Originality and significance of PhD thesis

Problem of HVAC systems control related to human comfort perception is very relevant topic, especially in relation with recent world wide stress on energy savings together with rising requirements on indoor environment quality. Next main point, related to the presented topic, is development of modern control systems and questions linked with their control strategy with new energy efficiency requirements aiming to reduce energy use in buildings. I consider this topic as very up-to-date and important. I appreciate modern and integrated approach to this topic.

2. Evaluation of appointed objectives accomplishment

The work is organised as set of work is organized as a set of four major publications of the author with comments, introduction and state-of-the-art chapter.

The main objectives of the work are:

- Evaluation of MPC Energy Savings Potential on a Real Building
- Development of a MPC Formulation Less Sensitive to Model Mismatch and Prediction Errors
- Development of a Computationally Tractable PMV Based MPC

Each presented paper is assigned to the given objective and in additional comments are explained links between specific objective and paper results.

The appointed objectives reflect the range of focused topic and it is possible to declare, that objectives were met in whole range.

3. Appropriateness of the methodology adopted

Presented work has 79 pages, chapters describing own contribution of the PhD candidate including summary, conclusion, recommendation for future work are on 54 pages. The work contains all relevant parts of this kind of work including PhD candidate own publications list and CV. Language and formal layout as well as chapters order are in

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accordance with the requirements imposed on this type of qualification work. I appreciate correct spelling, reflecting care taken about this work.

Figures and diagrams are properly described and referred, minor mistakes as duplication of the pages 34 and 51 as well as several equations is given by this format of PhD thesis, where are presented papers.

Work is systematic, logical and documents PhD candidate ability to use methods of scientific work to solve given problem. Author used scientific methods of literature review, analysis, mathematical modelling and simulation, laboratory and in situ measurements. Chosen methods are adequate to solved topic.

The number of references and way of use it in the presented work confirms high quality of this work and is symptom of deep analysis of the problem, done by the PhD candidate.

4. Quality and/or accuracy of results, new outcomes

Results of the work are applicable in the practice. It is possible to highlight results of virtual experiments with different types of control algorithms supported by real building monitoring and measurements. Considerable is also "future work", which declares direction of next steps for researchers in this field. Presented results are significant contribution to future development and adoption of MPC method for HVAC systems control. I appreciate sensitivity analysis of PMV calculation (pg.37) resulting into simplified PMV calculation method.

5. Opinion of practical use of presented results for practise or future science development

Results of the work are immediately applicable in practice. It is possible to highlight results of experiments with real building as well as web based approach to setting up the controller in other building. Considerable is also "future work", which declares direction of next steps for researchers in this field. Of course, measurement results are based on one building and one heating period and for making of general more accurate conclusion about energy savings potential will be necessary to extend number of monitored buildings.

6. Questions

As the paper, presenting BuildingLab tool does not describe all details of modelling and simulation used in this context, my questions are to complete image about the PhD candidate approach in this field:

- Could you describe, which model in TRNSYS did you use for description of ceiling heating - i.e. layout and properties of the layers, environment on the "other side" of the ceiling?
- Did you take in account solar radiation with realistic weather conditions?
- Which temperature was controlled in the model – operative or air temperature?
- How did you take in account ventilation – did you calculate with fresh air, which temperature, distribution pattern?

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- Could you explain, how to measure operative temperature in real building (if it is possible..)?
- Do you think, that for heating period modelling is the best to use south orientation of the windows in the model?

7. Evaluation

The main part of this work is based on published results, where PhD candidate is one of co-authors of the presented papers. In three cases is PhD candidate first author with contribution of 55-60 % of the paper, in one case third author with contribution of 25 %. Papers were published in high quality per reviewed scientific journals, where only original results could be published, so there is no doubt about quality of the results. Taking in account additional text and comments, I see the main contribution of the author in this teamwork is in the field of setting of optimization problem, tuning of the controller and implementation of control strategy.

I recommend to accept this work and appoint Ing. Jiří Cígler after successful PhD defence title PhD.

Singapore, 28.7.2013

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