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Review by Lieve Helsen, KU Leuven (Belgium)

To what extent the subject of the thesis is relevant to current needs of the scientific community
Today a lot of effort is put in research concerning the development of MPC of HVAC systems in buildings. The bottleneck in MPC development for HVAC systems in buildings is the development of a simple but accurate dynamic system model to be used in the controller. The work of Samuel Privara is focused on building modeling and identification for predictive control, thus trying to eliminate this bottleneck, or at least developing methodologies to derive appropriate building models for predictive control. This work can thus be classified as very relevant to current needs of the scientific community.

To what extent the main objectives of the work have been fulfilled
The main objectives of the work are defined as:

- To perform a survey of the currently available approaches
- To select and analyse the suitable approaches
- To find a solution to the specific problems of building modeling techniques
- To develop the model selection and validation methodology

The candidate has fulfilled all these objectives, and even more, the related work is all published in peer reviewed papers (as clearly listed on p.71 of the text), which means that the work has been reviewed and approved by international experts within the field. The published work scores very high in both quality and quantity (8 journal papers of which 5 as first author, and 13 conference papers of which 2 invited and 4 as first author). The candidate has been able to convert the teamwork into synergy, thereby acting as the main researcher/author in an impressive number of publications. An h-index of three at the end of a PhD is excellent (however, it is not clear from the text what the duration of the PhD research work was).

To what extent the methods used in the thesis have been appropriate
The methods used in the thesis originate from system and control engineering theory. They are not just copied to the HVAC in buildings application as such, but critically reviewed to select and analyse suitable approaches. None of them could be used without any modification. A real translation was needed, leading to e.g. incorporation of prior information in statistical methods for system identification since the quality of the monitored data is not high enough. Moreover, monitored data and detailed building simulation models were used, which requires knowledge and insight from a completely different discipline. Validation of the detailed building simulation models has not been described. Have these models been validated? By experimental data? Or by comparison with other (benchmark) models?

What the main results and contributions of the work are
The main results can be summarized as:

- For low complex buildings (with few inputs/states) grey-box modeling should be recommended as it retains the physical properties and structure of the modeled system.
- When a large building (with tens or hundreds inputs/states) is considered, statistically-based approaches become a useful tool.
- Statistically-based approaches require data of certain quality, which are often not available. Two approaches are suggested to treat this problem:
    - Incorporation of prior information about the system to be modeled, e.g. static gain or non-existence of the system matrix D, however this solution is not valid universally.
    - Combined approach using computer aided simulation tools (e.g. TRNSYS) to generate rich identification data, and statistical identification.
- A new approach of systematic selecting the system disturbance inputs and states is proposed, which leads to a model of much lower order with almost the same quality.

Building modeling approaches and techniques have thoroughly been studied through both theoretical work and case studies. With respect to the theoretical work, the main achievements are:

- Incorporation of prior information into the subspace algorithm;

- Use of detailed building simulation models to generate identification data of high quality to be used in statistically-based identification approaches;
- Utilization of the multi-step ahead prediction framework;
- Proposal of controller model selection and validation methodology.

The proposed algorithms and techniques have been demonstrated on several case studies (CTU building, building in Munich, 2-zone office building in TRNSYS used as benchmark.

To what extent the work is important for the further development of science

This work is very important for further development in science. The first translation, extension and refinement of system identification methods originating from system and control engineering to the HVAC in buildings field is a very important step forward. It gives insight in the data needed for building model identification. Detailed building simulation models are helpful but not always available, measurement data are more and more available, however quality should be improved. These are crucial observations. The next challenge is how to implement building model identification in practice on a large scale for different buildings without a high additional cost for an identification expert.

Whether the thesis satisfies conditions of a creative scientific work

This work is very multidisciplinary, integrating the disciplines of system and control engineering, thermal systems and building physics. This integration is on itself a great contribution and adds a significant step forward to the current knowledge. Translation of system and control theory to the application of HVAC in buildings is not that straightforward. The number of possible approaches is very large and not all of them are suitable for this type of applications. Therefore, a careful and scientifically sound selection is crucial, being aware of the benefits and drawbacks of each method applied, and if needed, some modifications should be made to cope with the specific requirements (e.g. high quality data for the use of statistically-based identification approaches to treat MIMO systems). The candidate has performed this integration and translation in a solid way, leading to innovative and creative work. The combination of thorough theoretical work and application to cases is an additional strength of this research work.

My conclusion:

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 PhD.