Authors response to the Editor-in-Chief

Submission of the revised article auto-2024-0160
Application of stochastic model predictive control for building energy systems using latent force models

Dear Professor Ulrich Jumar,

please find attached the revised version of the article *Application of stochastic model predictive control for building energy systems using latent force models*. The answers to the individual comments and issues raised by the reviewers can be found in the enclosed response letter. The corresponding changes in the manuscript are highlighted in blue.

We hope that the revised version of the article accounts for the reviewers' comments in a satisfying manner.

Sincerely,

Thore Wietzke
Daniel Landgraf
Knut Graichen

Authors response to the reviewer comments

Authors response to Reviewer 1

	The paper is clear in its purpose and easy to understand. Performing whole-year simulations on two different building models gives the findings more statistical significance, compared to other studies that often rely on just a few days of data.

We thank the Reviewer for his overall positive feedback.

1.	*I have one major criticism of the paper's methodology, which is the use of a perfect white-box control model for the Renningen building. This is a rather unrealistic assumption that could easily be rectified by identifying a model from simulation data, similar to how the authors do it for the EnergyPlus building, and how it would most likely be done for a real building, in my experience.*

We updated the simulation for Renningen with an identified system model and correspondingly updated the evaluation of the results.

2.	*It is my understanding that this is the first publication using latent force models for MPC in buildings. If that is so, the authors should state it explicitly. If not, the pre-existing literature should be discussed.*

We share the reviewer's opinion regarding this point. The pre-existing literature is discussed inside the introduction, just before the structure of the paper. Here we also added the novelty of our paper.

3.	*A graphic for how the first-principles model and the GP model are merged would make this section easier to understand for a reader not familiar with LFMs.*

We thank the reviewer for this comment. We added a graphic which shows the control loop of the LFM-SMPC.

4.	*There should be more information on the use cases. What weather data is used? What is the construction style of the buildings? What type of HVAC system is installed?*

We have provided additional details about the weather data and HVAC equipment used in our study. Information about the construction style was not included, as our focus was on stochastic disturbance prediction applied to SMPC, and such details were not within the scope of our analysis.

5.	*In subsection (4.3), there should be a reference to an equation after the numerical values for alpha, beta and kappa are given.*

These parameters characterize the Unscented Transformation (UT), but we never stated the equations. We added the corresponding equations in section 2.2.

6.	*What does the zone temperature have to do with the building safety?*

In our understanding, if the zone temperature is too low during the night issues like condensation and therefore mold can occur.

7.	*Should the impact of disturbance modeling in zones 21 and 23 not be larger, instead of smaller, if they have a greater influence of solar radiation?*

We thank for this reminder and revised the explanation. The true cause for the lower impact were control limits of the ventilation.

8.	*Regarding the visualization of the results, I suggest the inclusion of at least one time-series plot.*

We added Figure 7 for one time series plot for Renningen to show the temperature trajectory and the corresponding control actions.

9.	*Fig. 5 is a bit tedious to read. I suggest the inclusion of a Pareto front plot, merging the values for the individual zones of each building into one cumulative value.*

We changed the bar plots to 2D plots with the energy consumption at x-axis and the discomfort at the y-axis. Now the results are far easier to read and much better comparable.

10.	*The labels at the bottom of Fig. 6 could be formatted better.*

The whole plot was restructured, which additionally leads to a better display of the results.

11.	*In Fig. 5 and 6, the performance of the rule-based controller should be added for comparison. Perhaps as a dashed line.*

We added a RB controller to the Renningen use-case since real world information about the controller was available. For the EnergyPlus building this is obviously not the case. Again, our main focus was to compare LFM-SMPC.

12.	*Going from results to conclusion, without a discussion section, is rather unusual.*

We appreciate the reviewer's suggestion. To address this, we have integrated the discussion within the evaluation section, ensuring a cohesive analysis of our findings. Consequently, we believe a separate discussion section is not necessary.

13.	*This section could be used to wrap up the many numerical results more concisely, as opposed to making purely qualitative statements.*

We value the reviewer's input. A quantitative summary has been included within the evaluation section to effectively consolidate the numerical results. Thus, we have focused on presenting the qualitative findings in the conclusion.

Authors response to Reviewer 2

	The study presents the application of stochastic MPC using latent force models (gaussian process regression) in combination with a physics-based model as process models for controlling two exemplary building energy systems. The study is well written and organized. I recommend publication of the paper if some minor remarks are adressed

We thank the reviewer for the overall positive assessment of the article and for the following remarks.

1.	*The authors should more strongly emphasise the novelties and contributions of the paper in contrast to the literature.*

Thanks for this remark. We included further implementation details for the state space representation and the evaluation. We additionally included a further evaluation of the occupancy prediction quality in Section 4.5.

2.	*At the beginning of section 3 the authors should rephrase: "The producers are Heating, Ventilation and Air Conditioning (HVAC) equipment which provide cold air and warm water." The HVAC equipment provides heat and cold independent of the medium.*
3.	*"Additional heat sources like solar radiation or the hot water flow in the radiator are omitted in the network for a better overview." the hot water flow is omitted is misleading, this should be clarified.*

We clarified both statements.

4.	*Usually, the massflow of air and water in building energy systems is neither measured nor controlled. The authors could add a short explanation how this methodology could be adapted to deal with real life control signals like valve positions or fan speeds.*

We appreciate the reviewer's suggestion. While the adaptation to real-life control signals such as valve positions or fan speeds is indeed an important aspect, we believe it is a straightforward extension of the methodology already presented. The approach can readily accommodate these signals as inputs without requiring significant modifications, which is why we have opted not to include a separate explanation in the manuscript.

5.	*The titles of section 4.1.1 and 4.1.2 could be more clear like "Exemplary EnergyPlus Model" and "Model of the Bosch Campus". The model type of the Bosch building is unknown, is it a EnergyPlus model, too?*

We have revised the title of Section 4.1.1 to "EnergyPlus Model" for improved clarity. Regarding the Renningen model, we prefer to retain the current title "Renningen Office Floor," as the Bosch Research

Campus comprises multiple buildings, and our current model represents only one floor of one building. Additionally, we have clarified that the model used is (14) based on identified parameters from real-world measurements.

6.	*What are the prediction horizons of the controllers? How are the prediction horizon, sample times and controller weights chosen?*

We appreciate the reviewer's insightful question. To address this, we have added Table 2, which directly presents the requested values.