Dear Editor,

Enclosed please find our submission to the TODAES. The submission is titled "Thermal-Sensor-Based Occupancy Detection for Smart Buildings Using Machine Learning Methods." Some preliminary results of this article appeared in IEEE International Symposium on Circuits and Systems (ISCAS 2016). In this journal submission, we have made significant changes over the conference version. We believe the difference is more than 40% over the conference version of this work. The details of changes are summarized below:

First, we added another learning-based technique, support vector regression (SVR) for thermal-sensor-based occupancy detection in smart buildings. This addition itself can account about 30% changes to the original conference submission.

Detail concepts of EnergyPlus and machine-learning based methods for occupancy detection have been added in Sections 2 and 3 so that the main content and the contribution of the new work can be better appreciated. Also, the details of feature selection and data configuration used in the two machine learning methods for occupancy detection have been added in Section 4.

Experiment results of SVR based occupancy detection have been given in Section 5. We added the discussion and comparison between the SVR and RNN methods in the experimental section.

We completely rewrote the abstract, introduction, problem sections to reflect the new scope of the article. The content of the article, including the notations and figures, have been substantially revised to improve the presentation.

Thank you,

Hai-Bao Chen

**ABSTRACT**

In this article, we propose a novel approach to detect the occupancy behavior of a building through the temperature and/or possible heat source information, which can be used for energy reduction and security monitoring for emerging smart buildings. Our work is based on a realistic building simulation program, EnergyPlus, which can model the various time-series inputs to a building such as ambient temperature, heating, ventilation, and air-conditioning (HVAC) inputs. Two machine learning based approaches for detecting human occupancy of a smart building are applied herein, namely: support vector regression (SVR) method and recurrent neural network (RNN) method. Experimental results with SVR method show that 4-feature model provides accurate detection rate giving a 0.638 average error and 0.0532 error ratio, and 5-feature model gives a 0.317 average error and 0.0264 error ratio. This indicates that SVR is a viable option for occupancy detection. In RNN method, Elman's RNN (ELNN) can estimate occupancy information of each room of a building with high accuracy. The error level, in terms of number of people can be as low as 0.0056 on average and 0.288 at maximum considering ambient, room temperatures and HVAC powers as detectable information. Our study further shows both methods can deliver similar accuracy in the occupancy detection. But that SVR model is more stable for changing features of the system, while the RNN method can deliver more accuracy when the features used in the model do not change a lot.

Experimental results with SVR method show that 4-feature model provides accurate detection rate giving a 0.638 average error and 0.0532 error ratio, and 5-feature model gives a 0.317 average error and 0.0264 error ratio. The error level with RNN can be as low as 0.0056 on average and 0.288 at maximum considering ambient, room temperatures and HVAC powers as detectable information.