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High-order Boltzmann machines to quantify the building energy variability

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Introduction
The interconnection between the Smart Grid and Building Energy Management Systems involves complex interactions. The quantification of the building energy variability requires more powerful learning methods in the context of more and more data available, paving the way for a new optimized behaviour from the demand side.

Methods
In this context, firstly we extend and explore the state-of-the-art learning methods by using high-order Restricted Boltzmann Machines (RBMs). Their mathematical derivation requires a tensor factorization procedure which is applied to the high-order connections between their various layers [1]. Secondly, for the unsupervised prediction problem we propose two new methods based on the reinforcement and transfer learning approaches, which are able to learn from experience by exploring their environment and by using a deep belief network to automatically estimate the continuous states [2]. The RBM model is then combined with data mining techniques in order to solve the energy disaggregation problem, and to provide real-time building flexibility detection [3]. Finally, two four-order RBMs and their factored counterparts are proposed to simultaneously perform building flexibility detection and prediction [4].

Numerical Results
The proposed detection and prediction methods are validated on different real-world data and compared with standard methods. Overall, the results show a good level of accuracy (see Fig. 1).

Conclusions
Our proposed methods are able to quantify the variability at the building level by performing successfully supervised and unsupervised energy prediction. Furthermore, the dynamic learning concept is considerate by using different high-order RBMs for building flexibility detection and prediction.

Figure 1: Energy prediction in a price responsiveness context: data, methods and MAPE results [1].

References