Abstract

In air-conditioned buildings, the problem of minimizing energy consumptions while maintaining occupants' comfort levels is of significant topical interest in reducing energy wastage. The solutions to the problem could benefit from the use of occupant sensing, which leverages sensors to obtain valuable and relevant occupant information. For example, the number of occupants and their behaviors can be recognized based on sensor data by using machine learning algorithms. In this dissertation, we studied the problem of occupant sensing by considering two important aspects: occupancy prediction and behavior recognition.

Existing methods for occupant sensing is to extract features that are fed into the classifiers training processes. In general, basic feature extraction methods are based on the simple statistics of the signals, both from time and frequency domains. However, the features that lead to satisfactory results require certain tricks or skills in designing them. Existing literature has emphasized on well-designed features to enhance the performance of the recognition system in distinguishing different classes from the varied occupants' information. But empirically extracted features normally rely too much on the expert knowledge. Consequently, there is a lack of guidelines in feature extraction and it is hard to ameliorate the classification performances to some extent.

In this thesis, we proposed four feature representation learning frameworks to solve the occupant sensing problem in terms of occupancy prediction and activity recognition. We studied the feature learning algorithms that allow them to find better representations automatically with minimal domain knowledge in occupant sensing area. For occupancy prediction perspective, we proposed a neural network framework with convolutional calculations on the environmental data, especially for CO2 information. Furthermore, when the time domain data is combined with frequency domain one, it can provide much valuable information in the feature extraction process to improve the classification performance. From the occupancy behavior recognition perspective, we proposed frameworks of deep learning approach, dictionary learning method, as well as feature learning with local receptive fields based on neural networks. We showed that unlabeled data combined with labeled data can indeed further enrich the feature learning in a semi-supervised scheme. We firstly proposed a temporal ensemble deep Bidirectional Long Short-Term Memory method for simple activity recognition based on Inertial Measurement Unit. The proposed approach could leverage unlabeled data to enhance the performance, thereby removing the burden of intensive labor in annotations. Besides, we also proposed a feature extraction framework using a dictionary learning method for the classification of occupants' activities. We also proposed a feature extraction framework for energy-related activities based on the audio information. With learning in the spectrogram using local receptive fields, the features learned from the neural networks are capable of capturing the scale invariance and local patterns in the sound signals.

The proposed frameworks have been evaluated in conducted real experiments. We expect that, through our results, the performances of occupancy behavior recognition system could be improved based on learned features when comparing to engineered features. Features are learned or extracted to offer solutions to the occupant sensing problem. While the results of the-state-of-art are satisfactory, our feature learning methods can further explore the distinguishable patterns automatically because they could learn the valuable information from historical data based on the statistics. The sensing solutions are

also non-intrusive to occupants while obtaining accurate active status of them. By accurately mining the information of occupants, ranging from general and coarse to individual and fine information, we can use this information to design proper control and strategy decisions to save building energy consumption while ensuring that the occupants indoor have a comfortable environment.