Poster Abstract: Evaluation of Machine Learning Methods for Thermal Sensation and Comfort Predictions in Microenvironments Created by Personal Conditioning Devices

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ABSTRACT

Multiple thermal comfort models were developed for occupants in spaces with centralized HVAC systems. However, the thermal comfort modeling in microenvironments created by the personal conditioning device (PCD) is different because of the local non-uniform thermal stimuli on occupant bodies. This study compares the thermal sensation and comfort predictive performances of multiple machine learning models developed based on the wrist temperature and heart rate variability (HRV) collected in human subject experiments. In our results, the k nearest neighbors (KNN) outperforms the other machine learning methods, with the F1 score higher than 0.9 for both thermal sensation and comfort category classification, which indicates its suitability for comfort modeling for the PCD.

CCS CONCEPTS

• **Applied computing → Health informatics**.

KEYWORDS

Personal Conditioning Devise (PCD), Thermal Comfort, Heart Rate Variability (HRV), Machine Learning

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1 INTRODUCTION

Modeling of thermal sensation and comfort is critical to the design, evaluation, and control of the indoor environment. With the centralized HVAC system, personal thermal comfort models become a trending topic because they can predict thermal comfort requirements of individual occupant more accurately than aggregate models. However, in recent years, personalized air conditioning has been proposed to regulate the microenvironment in the proximity of an occupant in accordance with his/her thermal preferences [2]. Comparing to centralized HVAC, the PCD aims to provide the local thermal stimuli to only condition a relatively small volume around the user, which developing non-uniform thermal conditions. In this case, the personal thermal comfort models based on uniform environmental conditions created by the centralized HVAC may not be applicable [4]. New thermal comfort modeling methods are needed for the PCD. In addition, the comfort models for uniform environments rely on physiological variables, such as skin temperature, which represent the outcomes, but not the drivers of the thermoregulatory process specifically controlled by the autonomic nervous system. The heart rate variability (HRV) can be a potential physiological variable for thermal comfort modeling, because it assesses the balance between the parasympathetic nervous system (PNS) and sympathetic nervous system (SNS), which drives the human thermoregulation. Overall, this study uses machine learning methods to develop thermal sensation and comfort models for the PCD based on HRV indices and wrist temperatures. The performances of eight machine learning methods are compared to find a feasible solution for the actual thermal sensation and comfort modeling for occupants immersed in non-uniform microenvironments created by the PCD.

2 METHODOLOGY

This study conducted experiments with 14 human subject to collect thermal sensation/comfort surveys and physiological data in an environmental chamber. The physiological data, wrist temperatures and HRV indices, were collected by a bracelet sensor developed by ourselves. Figure 1 shows the setup of the human subject experiment. In each experiment, the human subjects first stayed in the anteroom to acclimatize to a neutral thermal condition. Then human subjects were introduced into the environmental chamber. Air temperature in the chamber was maintained at 28 ± 0.5 °C during the first 50 minutes, then increased and maintained at 30 ± 0.5 °C during the latter 50 minutes of the experiment. To simulate an actual office environment, throughout the 100-minute measurement, each human subject was asked to perform office type activities, such as reading, writing, and typing. Each human subject had a PCD located at approximately 1 ± 0.1 m away at his/her side, and provided the option to use the PCD at any point in time upon request. When in use, the PCD supplied cooled air of 5 °C lower than the room air, towards the torso. The human subjects continuously reported their thermal sensation and thermal comfort levels every 10 minutes. The thermal sensation levels were based on a -3 to 3 scale [1] . The thermal comfort levels were based on a 5-points scale used in the relevant studies [3]. The HRV indices considered in this study include SDNN, SDSD, RMSSD, pNN20, pNN50, LF/HF. The machine learning classification methods used in this study include linear classifier (LC), k nearest neighbor (KNN), linear support vector machine (L_SVM), support vector machine with RBF kernel (RBF_SVM), decision tree (DT), random forest (RF), AdaBoost, Naïve Bayes (NB). Because the class imbalance was found in the collected data, we report the macro averaged F1 score to represent the performance of models.

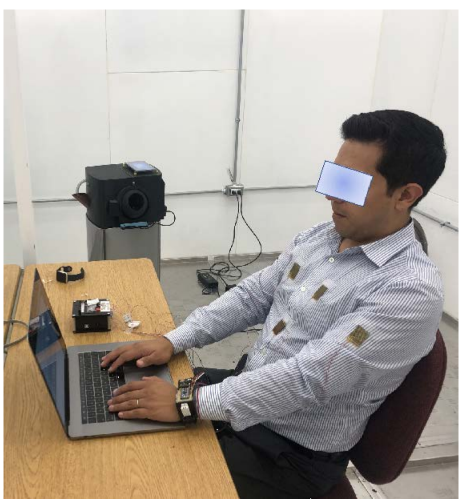

Figure 1: Setup of the human subject experiment.

3 RESULTS

Figure 2 shows the F1 scores of the classification models. It indicates that, among all the machine learning methods, the KNN outperform the others. The F1 score of the KNN is about 0.94 for thermal sensation and 0.93 for thermal comfort. These high F1 scores shows that the KNN can better capture the nonlinearity of the thermal sensation and thermal comfort with respect to the physiological variables than the other models, making it suitable for actual thermal sensation and thermal comfort modeling for the PCD. Because the thermal sensation has more categories than the thermal comfort, the F1 scores of the thermal sensation is generally lower than those of the thermal comfort. No big variances were found between training and testing scores of all considered machine learning methods, which shows no overfits.

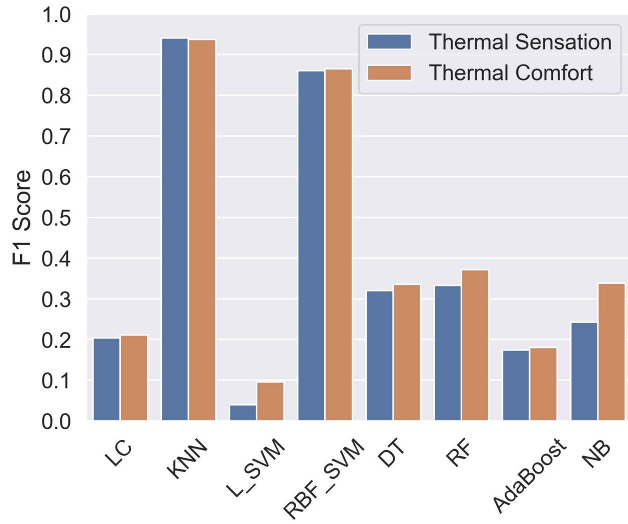

Figure 2: F1 scores of machine learning models.

4 CONCLUSIONS

This study compared performances of eight machine learning methods to predict thermal sensation and comfort in non-uniform microenvironments created by the personal conditioning device (PCD). The models were developed based on the wrist temperature and HRV indices collected in the human subject experiments. The KNN provided F1 scores higher than 0.9 for both thermal sensation and comfort category classification, which indicates its suitability in thermal sensation and comfort modeling for the PCD.

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