Machine Learning Techniques to predict real time Thermal Comfort, Preference, Acceptability, and Sensation for automation of HVAC

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Cross-Disciplinary Research Area: Machine Learning

Introduction

- The primary importance of the HVAC system is to maintain indoor thermal comfort while ensuring energy efficiency.
- Individualized optimum comfort control – not possible today. How many times have you adjusted thermostat at work when you feel hot, and others feel comfortable?
- Knowing the number of people in a building or occupancy level alone does not depict comfortability and thus, not sufficient for HVAC control.
- There is therefore the need of expanded research to explore the thermal comfort, preference, acceptability, and sensation of occupants in a building for automation of the HVAC control.

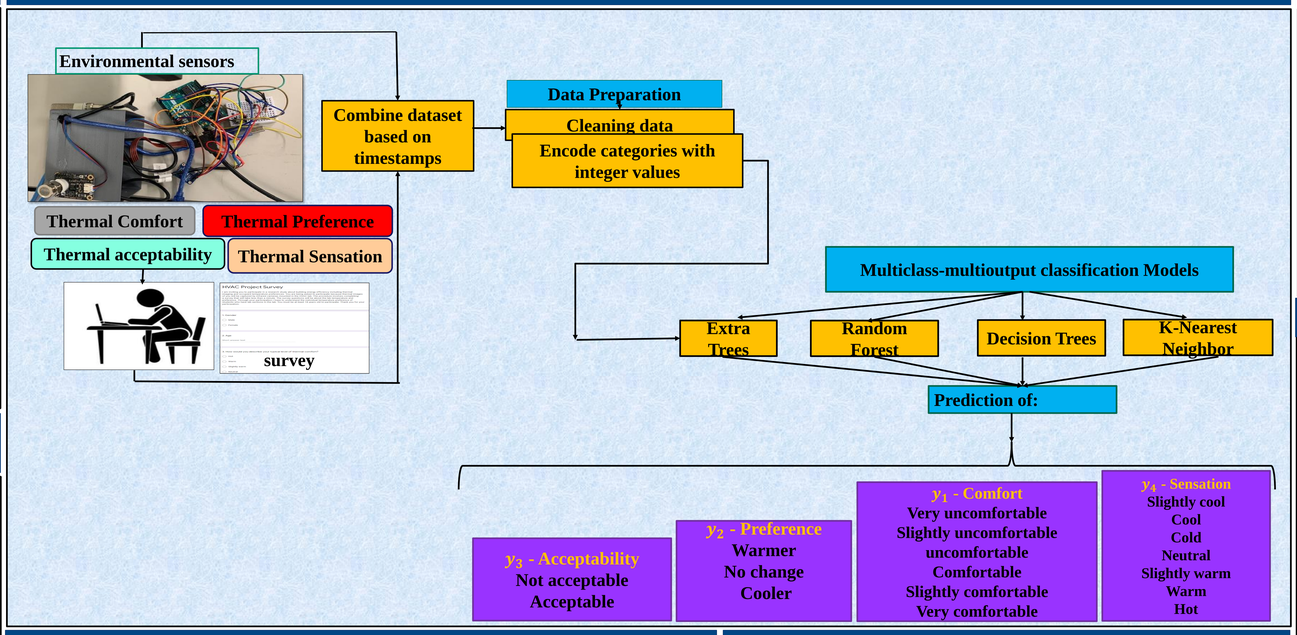
Objectives

- To collect real world accurate multi-sensor analog readings and subjective survey responds from subjects.
- To apply multiclass-multioutput classifiers for the determination of thermal comfort, sensation, acceptability, and preference for a holistic understanding of an individual's thermal comfort need.
- To evaluate the multiclass-multioutput classification models.

Problem Statement

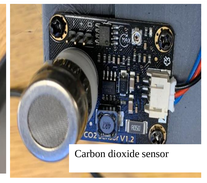
- Occupants in buildings still complain of high degree of dissatisfaction.
- A large-scale survey showed that only 38% of building occupants are satisfied with their thermal environments and only 11% of buildings meet the ASHRAE requirement of satisfying 80% or more occupants(Karmann et al., 2018).
- Most often, thermostats that control the HVAC system of buildings are placed in corridors or different rooms away from the areas being controlled. Regulation of temperatures in rooms are therefore based on the temperature around these thermostats placed in corridors and separate rooms.
- Energy is wasted through overheating and overcooling.
- Prediction of these thermal comfort metrics is necessary for HVAC control to improve thermal comfort and for energy efficiency.

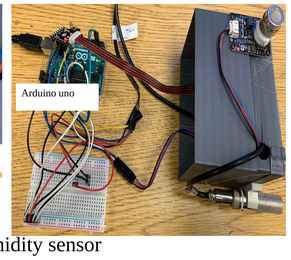
Materials and Methods



Environmental Sensors


Temperature and Humidity Sensor


Carbon dioxide sensor

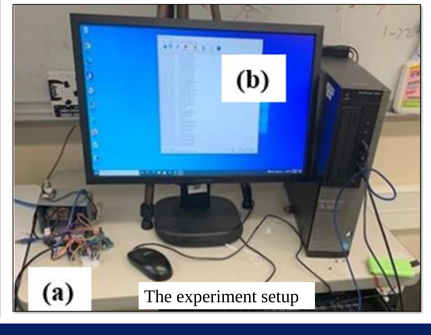

Arduino uno

❖ Specifications of the Temperature and Humidity sensor

Feature	Specification
Humidity Ranger	0-100%RH
Temperature ranger	-10-80°C
Humidity accuracy	:±5.0%RH
Temperature accuracy	±0.5°C
Size	49mm x 14mm (1.93" x 0.55")

Feature	Specification
Operating voltage	5V
Interface	Analog (Gravity Compatible)
Size	32x42mm (1.26x1.65")

Data Collection



The experiment setup

Results

❖ Performance evaluation for four Multiclass-Multioutput classifiers:

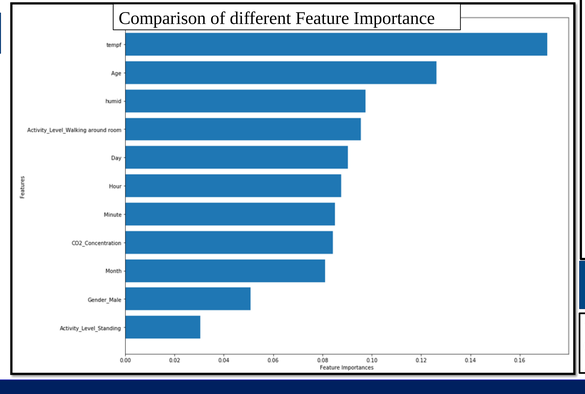
Multiclass-Multioutput Classifiers	Mean Accuracy (%)	Mean Squared Error
Extra Trees	68	2.15
Random Forest	58	2.79
Decision Trees	53	3.05
K-Nearest Neighbor	43	3.12

❖ Performance of the Hyperparameter tuned Extra Tree Multiclass-Multioutput Classification Model.

Multiclass-Multioutput Classifiers	Mean Accuracy (%)	Mean Squared Error
Extra Trees	69	1.49

❖ Hyperparameters of the proposed Extra Tree Multiclass-Multioutput Classification

Hyperparameter	
criterion	entropy
Max_features	5
n_estimators	10



Significance of the Approach

- Four classification problems are solved concurrently within the same model.
- When multiple models need to be trained using the same input data or features but with different output data, the training time is too high.
- Training a coherent multi-output classification model brings benefits in the form of increased predictive performance compared to training multiple disjoint models.

Conclusion

- Four new multiclass-multioutput classification models were trained and tested to predict the thermal comfort metrics of occupants in real time.
- The proposed Extra Tree multiclass-multioutput classification model achieved the best mean accuracy and mean squared error of **69%** and **1.49** respectively.
- The proposed model is expected to achieve automated control of built environments to improve human thermal comfort, health and for energy efficiency.

Future Work:

- **Future work will expand the dataset to improve the models' performance.**
- **Development of machine learning model to predict thermal preference of individuals (warmer, no change and cooler) based on thermal images and environmental parameters is will be explored.**

Related Work/References

- ANSI/ASHRAE Standard 55-2017, Thermal Environmental Conditions for Human Occupancy.
- ISO_7730, Ergonomics of the Thermal Environment - Analytical Determination.
- Luo, M., Xie, J., Yan, Y., Ke, Z., Yu, P., Wang, Z., Zhang, J.: Comparing ma-chine learning algorithms in predicting thermal sensation using ASHRAE com-fort database II. Energy and Buildings, 210 (2020).
- Y, Acquaah, B. Gokaraju, R. Tesiero, and K. Roy "**Machine Learning Techniques to predict real time Thermal Comfort, Preference, Acceptability, and sensation**," 35th International Conference on Industrial, Engineering & Other Applications of Applied Intelligent Systems, Springer Publications, 2022. Japan. Accepted.

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