A Bayesian Approach for Learning and Predicting Personal Thermal Preference

Seungjae Lee, Ilias Bilionis,
Panagiota Karava, Athanasios Tzempelikos

July 11 -14, 2016
OUTLINE

- INTRODUCTION
- METHODOLOGY
- RESULTS
- DISCUSSION AND CONCLUSIONS
INTRODUCTION

- Field studies show typical thermal control systems cannot achieve high levels of occupant satisfaction and productivity since individual occupants prefer different thermal conditions.

- Studies have recognized that the problems can be resolved by
  - Incorporating building occupants in sensing and control frameworks
  - Tuning systems based on individual preferences to achieve personalized indoor environments.
INTRODUCTION

- Learning occupant preference is an essential part of this innovative concept

- Two significant problems associated with learning occupant in real buildings
  » learning requires a long-term data collection, since the rate of data collection is limited by the fact that occupants should not be exposed to potentially uncomfortable conditions for long time
  » in order to avoid overfitting, the limited data availability imposes model structures that may be too simple to describe the human preference
In this study, a new method has been designed for learning and predicting individual occupant’s thermal preference based on a Bayesian approach.
1. Model Structure

- Develop a generalized thermal preference model based on a large dataset collected from various people.

- In the model, explicitly encode our key assumption: “Different people prefer different thermal condition.”

- Use the general model for learning and predicting an individual occupant’s preference.
1. Model Structure

- A graph representing connections between occupant’s thermal preference and related factors
1. Model Structure

- Estimate parameters with MCMC (Markov Chain Monte Carlo)
METHODOLOGY

2. How Can We Learn and Predict Individual’s Thermal Preference

\[
p(y_{\text{inference}} = j | x_{\text{inference}}, x_{1:D}, y_{1:D}, x_{\text{new}}, y_{\text{new}}, w, \theta, \xi) \\
= \sum_{k=1}^{K} p(y_{\text{inference}} = j | x_{\text{inference}}, x_{1:D}, y_{1:D}, x_{\text{new}}, y_{\text{new}}, w, \theta, \xi, z_{\text{new}} = k) P(z_{\text{new}} = k | x_{1:D}, y_{1:D}, x_{\text{new}}, y_{\text{new}}), \quad j = 0, \ldots, 2
\]
3. Data Set

- Subset of ASHRAE RP-884 database
- HVAC conditioned office buildings in North America
1. Single Cluster Model

- Re-calibrated parameters in PMV equations
1. Single Cluster Model

- Predicted probability of an occupant being in each preference class w.r.t. air temperature change

Other Conditions
MRT = Air temp.
Air vel. = 0.1 m/s
RH = 50%
Met = 1.2
clo = 0.65
1. Single Cluster Model

- Predicted probability of an occupant being in each preference class w.r.t. air temperature change

\[
\begin{align*}
\text{MRT} & = \text{Air temp.} \\
\text{Air vel.} & = 0.2 \text{ m/s} \\
\text{RH} & = 50\% \\
\text{met} & = 1.2 \\
\text{clo} & = 0.65
\end{align*}
\]

\[
\begin{align*}
\text{MRT} & = \text{Air temp.} \\
\text{Air vel.} & = 0.1 \text{ m/s} \\
\text{RH} & = 50\% \\
\text{met} & = 1.2 \\
\text{clo} & = 1.0
\end{align*}
\]
2. Two Clusters Model

- Sub-models for
  - a cluster of people preferring cooler condition
  - another cluster preferring warmer condition

Figures will be updated
2. Two Clusters Model

- Different set of parameters for each cluster
  - Blue and Green dots are clearly distinguished

Figures will be updated
2. Two Clusters Model

- Probability of the occupant being in cluster 1 or 2

\[ P(z_d = k \mid x_{1:D}, y_{1:D}), \; k = 1 \text{or} 2 \]

- Occupants on the left side are highly probable to be in the cluster 1
- Occupants on the opposite side are highly probable to be in the cluster 2
- Occupants in the middle may be between the two clusters or there are not enough observations to decide in which cluster the occupants belong too
DISCUSSION AND CONCLUSIONS

- There is a high probability of classifying two or more clusters of people with respect to thermal preference characteristic.
- As a result, the multi-cluster model is more promising considering our modeling purpose, i.e. learning and predicting individual occupant’s thermal preference.
- The models should be also evaluated and compared in an objective and quantitative way.
- The optimal number of clusters will be identified.
DISCUSSION AND CONCLUSIONS

- The method will be tested if it can infer the hidden cluster value of a new occupant with a new dataset.
- Since the authors believe that occupant’s thermal preference is affected by other factors, additional relationships and variables will be introduced in the general model and tested.
- Carefully designed experiments will be conducted in the future to enrich the dataset for this specific purpose.
Thank you

Q & A