Poster Abstract: Learning Individual Preferences for Energy-Efficiency and Comfortable Living

Chayan Sarkar, Akshay Uttama Nambi S.N., R. Venkatesha Prasad
Delft University of Technology, The Netherlands
{c.sarkar,akshay.narashiman,r.r.venkateshaprasad}@tudelft.nl

ABSTRACT

Automatic control of HVAC and artificial lights has been one of the popular methods for achieving energy-efficient buildings. The operating set-points are decided based on predefined values to ensure comfort level to most of the occupants based on prior studies. However, a person can feel comfortable beyond the traditional set-point ranges used in the energy management systems of buildings. In this work, we develop a smartphone application that learns individual preferences about thermal and visual comfort with minimal user intervention. These functions provide the flexibility to operate the controllers in an aggressively lower energy consuming state while maintaining the comfort level of the occupants. Using a HVAC energy consumption model, we show that individual comfort preference based set-point can attain lesser energy consumption as compared to fixed set-point.

1. INTRODUCTION

Many studies have shown that suitable lighting and thermal comfort in an indoor environment plays a significant role in the well-being and productivity of human beings. Typically, building energy management systems (BEMS) are installed to lower the energy cost by automatically controlling the HVAC and lighting systems based on some fixed set of operating points. These set-points are decided based on a pre-defined comfort range. When climate control over the whole building is implemented, the operating set-points of the controllers need to be decided in such a way that maximum occupants feel comfortable [5]. This leaves a narrow range of choices for the set-points. However, a particular person can feel comfortable beyond these pre-defined set-points. Thus understanding the individual preference provides a larger range to decide the operating set-point [1] leading to higher energy-efficiency.

In this work, we propose a mechanism that learns comfort ranges of a user comprehensively, using a smartphone with minimal user intervention. The comfort functions are stored in the smartphone itself. Thus, the person can carry his/her own preferences for comfortable climate settings. A room level controller after detecting the presence of a person, fetches the comfort preferences from the person and decides the set-points (Fig. 1). The room level controller can be developed by following a scalable and distributed systems as described in [3].

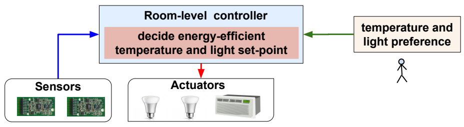


Figure 1: A room-level the controller sets an energy optimal operating point based on the preferences of the occupant.

2. FUNCTION FOR COMFORT PREFERENCES

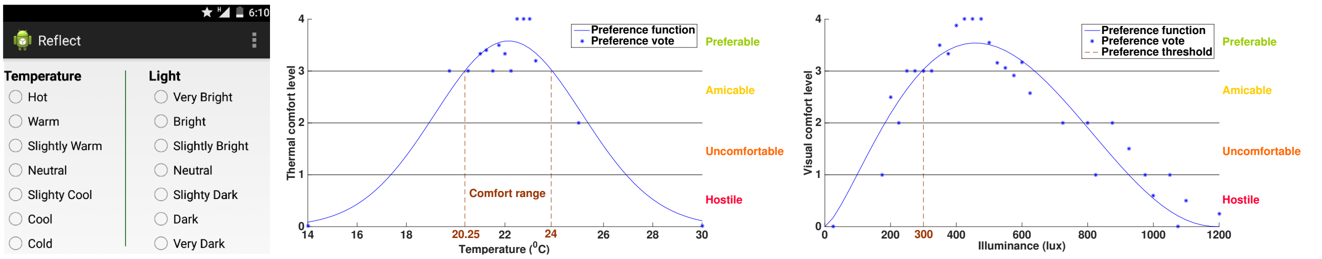
For a person, maximum thermal comfort is not a single temperature value but a range of temperature values that can be thermally desirable, and it can also vary significantly from person to person. Thus to provide a thermally comfortable indoor environment, the room temperature should be maintained within the thermal comfort range of each occupant as much as possible. Moreover, if the maximum comfort range for a person is known, the HVAC set-point can be adjusted in such a way so that the person feels comfortable and at the same time the energy consumption can also be kept minimal. Similarly, lighting comfort can also be achieved.

2.1 Collection of user preference data

Most users cannot easily correlate their comfort levels with temperature or light intensity values. Even if they do, there is a chance of significant deviations. Precise measurement of temperature and light value can be obtained using a corresponding sensor. Thus, we used a smartphone *App* to register comfort levels based on user perception and we related them with the corresponding sensor data. A screenshot of the App is shown in Fig. 2a. To indicate comfort a seven-point scale is used as suggested by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), where 'neutral' indicates maximum comfort level, and 'cold' and 'hot' are considered the lowest comfort level (equally bad). We used a similar scale to indicate the lighting comfort.

During the experiments, we placed a Tmote-sky based sensor platform to collect temperature and light data. The

BuildSys'15, November 04-05, 2015, Seoul, Republic of Korea
ACM 978-1-4503-3981-0/15/11.
DOI: http://dx.doi.org/10.1145/2821650.2830306.



(a) Application screenshot (b) Thermal comfort function of a person (c) Visual comfort function of a person

Figure 2: Thermal and visual comfort function of individuals are created using simultaneously collected preference votes through a smartphone *App* and the temperature and light values through a sensor device.

sensor node measured and reported the data periodically every 5 s. However, the user registered the comfort feeling whenever they wished. When the user indicated the comfort level, it was correlated with the sensor data at the same (nearest) time instance.

2.2 Building preference function

Though Pan *et al.* [2] also proposed a smartphone based approach to learn thermal preference of a person, our goal is to create comprehensive comfort mapping functions that can indicate the comfort levels of the person for any given temperature or light intensity. To build such a function, ideally, we should have comfort level indicator for each possible value, which is not a feasible option. Thus we collect a few comfort indicators and then we try to model them.

During function creation, we cluster these comfort indicators in multiple but equal sized bins. For temperature, it starts from 14°C until 30°C with a bin size of 0.25°C, that means any comfort label indicator for the range 18°C to 18.25°C is mapped to 18°C. For the light values, a bin size of 25 lux is used over a range of 0 to 1200 lux. After studying data from multiple users, we notice that thermal comfort function can be represented using a Gaussian function, whereas the light preference function can be represented using a Beta function.

For every user, the parameters of these functions differ. Based on the comfort indicators, we derive the individual function parameters using the least square curve fitting. To derive a reflective function from the limited samples, we assume that any temperature beyond 14°C and 30°C will be uncomfortable for any person. Thus, with the existing comfort indicator data set, we added two additional data points of these two extreme temperatures with lowest comfort value before using the least square method. Similarly, for light these two extreme values are 0 and 1200 lux. Fig. 2b shows the clustered voting data and the thermal comfort function for a user. Similarly, the clustered lighting comfort indicators and the curve-fit for comfort function for a user is shown in Fig. 2c.

2.3 Energy savings comparison

Based on the energy consumption model by the HVAC as described in [4], we compare yearly energy consumption when the fixed set-point range is used and in case the set-point is decided based on an individual's thermal preference. From Fig. 3, it is evident that individual preference based room level controlling is more energy-efficient.

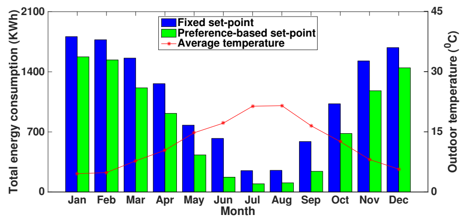


Figure 3: Based on the temperature data in Delft, comparison of energy consumption by the HVAC for fixed set-point technique and individual preference function.

3. CONCLUSIONS AND FUTURE WORK

We developed comprehensive thermal and visual comfort functions that can map any temperature and light value to the comfort level for each individual. This provides a wide range of set-point choices to decide the operating levels of the devices in order to maintain comfortable environment. The potential room level controlling based on the comfort preferences of the occupant provide a larger scope of energy saving. To learn user comfort preference, we collected only a few data points about comfort indicator in a human perceptible rating (comfort indicator). Now we are planning to extend this work to build a complete system where automated room level controlling is done based on individual comfort preferences. If a room is occupied with multiple people, a challenging task would be to decide a set-point which consumes minimal possible energy while ensuring comfortable environment for every occupant.

4. REFERENCES

[1] A. D. Galasiu and J. A. Veitch. Occupant preferences and satisfaction with the luminous environment and control systems in daylit offices: a literature review. *Energy and Buildings*, 38(7):728–742, 2006.

[2] D. Pan, A. H.-y. Lam, and D. Wang. Carrying my environment with me in iot-enhanced smart buildings. In *MobiSys*, pages 521–522. ACM, 2013.

[3] C. Sarkar, A. Nambi, R. Prasad, A. Rahim, R. Neisse, and G. Baldini. Diat: A scalable distributed architecture for iot. *Internet of Things Journal, IEEE*, 2(3):230–239, June 2015.

[4] Y. Yuan, D. Pan, D. Wang, X. Xu, Y. Peng, X. Peng, and P.-J. Wan. A study towards applying thermal inertia for energy conservation in rooms. *TOSN*, 10(1), 2013.

[5] L. Zhang, A. H.-y. Lam, and D. Wang. Strategy-proof thermal comfort voting in buildings. In *BuildSys*, pages 160–163. ACM, 2014.