An urban tropical thermal comfort dataset for smart buildings

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Poster abstract: An Urban Tropical Thermal Comfort Dataset for Smart Buildings

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ABSTRACT

Occupant thermal comfort is a pillar of smart buildings. However, the research community lacks a sufficient updated dataset and often has to apply the obsolete ones with inaccurate comfort modeling performance. In this paper, we present our latest urban tropical dataset for thermal comfort research. We follow a non-intrusive approach by using the emerging wearables to collect the data about the occupant profile, vital signs, thermal sensation, and ambient environment. In total, we obtain a unique dataset with 8,972 data items in two years. Our dataset will be publicly available and owns the high potential to propel the smart building researches like thermal comfort modeling and energy management.

CCS CONCEPTS

• **Hardware** → **Sensor applications and deployments**; • **Computer systems organization** → *Sensor networks*; • **Human-centered computing**;

KEYWORDS

Dataset, thermal comfort, smart buildings.

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1 INTRODUCTION

Building's ultimate function is to serve people. The indoor environment shall be comfortable enough for people's working and daily life. While a comfortable building environment promotes people's well-being and happiness, a poorly maintained environment can deteriorate cognitive performance, working efficiency, and even health. It is thus important to fully understand the thermal sensation of building occupants under

different conditions. The understanding enables the building managers and operators to optimize the building control towards satisfied comfort as well as the other expectations like energy efficiency. Generally, such an understanding process is called thermal comfort modeling.

The modeling methodologies can be diverse and both statistics and machine learning have been applied to model thermal comfort for the past decades. Interestingly, the methodology diversity does not lead to the diversified prerequisite, and almost all the methodologies start from the same point, *data*. Predicted mean vote (PMV) [1] is possibly the most classic and widely used thermal comfort model based on six features. The model is derived based on the ASHRAE RP-884 dataset half-century ago with the data samples non-uniformly and insufficiently distributed across different regions. Despite the fast progress of the smart building research, the data sources remain limited and stagnant, and many research works have to adopt the obsolete datasets.

We argue that issues do exist for using the old dataset. For example, occupant thermal sensation is subjective. It can vary in different generations, regions, and societies. Also, the old dataset mainly comes from the chamber-based study, where the occupant feedback can be biased compared to the normal working and life environments. Besides, the data is limited or even missing for certain features like skin temperature and some typical settings like urban tropical areas. As a result, PMV based on the old dataset suffers from significant inaccuracy for many scenarios [2]. Thereby, we address the data obsolescence and scarcity based on the Internet-of-things (IoT) technology. We collect a unique thermal comfort dataset to capture the urban tropical regions in the new millennium with a diverse range of features.

In the following parts, we describe some details about the data collection procedure and dataset. Then, we introduce some potential applications driven by our dataset. Due to the space limit, we will defer the full details and specifications of our dataset in the extended version of this paper.

2 THE DATASET DESCRIPTION

We recruited 461 participants from our university and conducted the data collection for two years (2018 and 2019). Most of the participants are students, so the age distribution is concentrated within 20–25 as shown in Fig. 1(a). The gender distribution is very balanced, and we have 50.8% male and 49.2% female participants.

The collected features are listed in Table 1. Altogether, we have 12 features from diverse categories. Each data item starts

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Figure 1: Dataset age and thermal sensation distribution.

Table 1: Dataset Features

#	Feature	Code	Data Source
F_1	hour	hour	mobile App
F_2	age	age	
F_3	weight	weight	profile
F_4	height	height	
F_5	clothing level	c1	
F_6	gender	gender	BiB set
F_7	air temperature	at	
F_8	relative humidity	rh	
F_9	metabolic rate	met	wearable device
F_{10}	heart rate	hr	
F_{11}	skin temperature	st	
F_{12}	actual thermal index	ati	participants

from time and here we record hour to reflect the comfort level change throughout a day. We also extract the user profile in terms of age, weight, height, cloth insulation, and gender to offer the possibility to study personalized thermal comfort modelling. The ambient environment is monitored with a BiB set developed by SinBerBEST. We also follow a non-intrusive data collection scheme by utilizing wearables with the minimized impact of psychological fluctuation and biased subjective feedback. From the wearables, i.e., Microsoft Band 2, we are able to track the occupant’s metabolic rate, heart rate, and skin temperature. Finally, we record the corresponding thermal sensation feedback submitted by the participants. Here, we follow the ASHRAE standard by quantizing the thermal comfort into seven levels (e.g., -3 for cold, -2 for cool, -1 for slightly cool, 0 for perfectly comfortable, 1 for slightly warm, etc.). We compare the PMV-modelled comfort and our actual obtained feedback as shown in Fig. 1(b). Interesting to see that PMV tends to underestimate occupant’s thermal discomfort, i.e., PMV indicates slightly cool or warm even the actual feedback is significantly cold and hot. This may shed light on future comfort modeling research about the high necessity of having a latest and specialized dataset.

The data collection is conducted in sessions, each lasts for 3.5 hours. The first half-hour is for preparation tasks, i.e.,

participants signing the consent forms and getting familiarized with our experimental devices. Data is only collected in the rest of 3 hours and we remind the participants to submit the thermal sensation feedback every ten minutes. After each session, we reset the experimental devices to wipe out the bio-data to ensure accuracy of some parameter such as metabolic rate.

In total, we successfully collected a unique urban tropical thermal comfort dataset with 8,972 data items. The dataset captures the thermal sensation of 461 participants and the wide ranges of temperature and humidity from 19°C to 31°C and from 37% to 84%, respectively.

3 POTENTIAL APPLICATION SCENARIOS

Our dataset enables a wide spectrum of applications for smart building research. One of the most direct applications is to model the thermal comfort accurately for the occupants in urban tropical environments with unique insights. Different algorithms can be explored, i.e., the latest deep learning algorithms. Also, transfer learning can be a choice to fully utilize both the existing thermal comfort model and the newly available dataset. Given the derived model which might be close to the ground truth, we can update and fine-tune the building settings like set-point temperature and humidity to create a comfortable indoor environment for occupants.

Indeed, the building system is complex where thermal comfort is not the only consideration. As such, the new data-driven comfort models can also be incorporated with the other building modular like air conditioning and energy management. Together, the whole building system can be configured and optimized for improved comfort, energy efficiency, and so on. Intelligent and automatic smart building control can also be derived based on emerging technologies like reinforcement learning. Guided by the accurate comfort models, the achieved energy reduction will be the key enabler towards energy sustainability and carbon neutral.

4 CONCLUSION

In this paper, we present a unique thermal comfort dataset for urban tropical regions. We specifically introduce the data collection procedure, dataset description, and potential applications. In the future, we plan to re-investigate our collected dataset and initiate further data collections to augment our dataset. Besides, we would like to extend our user-centric research by collecting user behavior data with different thermal conditions and incentive schemes. Finally, the synergy between thermal comfort and energy efficiency would be an interesting research topic with a huge practical impact.

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