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Is your clock-face cozie? A methodology for the in-situ collection of occupant comfort data

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Abstract

A 2012 survey of 52'980 occupants in 251 office buildings found that 50% of all occupants were dissatisfied with their indoor environment [1]. This dissatisfaction can result in a reduction of work performance [2] and be a precursor for future health issues [3].

Significant progress has been made to improve occupant comfort. On one hand, there is the technological advancement of heating, ventilation and air conditioning systems (HVAC). On the other hand, there are advancements in human-building interaction which enables the local environment to adapt to the needs of the occupant [4]. These methods however have one fundamental limitation. They assume that all occupants within a building zone share the same comfort preference. In reality, variations in metabolic rates [5], light preferences [6], and noise tolerance [citation required] presents a challenge when attempting to condition a work-space to meet the requirements of all occupants [7].

Rather than tailoring the work-space to the preferences of the occupants, an alternative approach is to match the individual to a work-space. This requires an understanding of the individuals comfort preferences and a recommendation engine that can suggest a comfortable workspace in real time based on building environmental sensor data.

This paper focuses on the first of these challenges, namely comfort data collection. The state of the art in this field are comfort surveys. Although this works it has three main limitations

- The methodology cannot be scaled to large sample sets due to the administrative overhead in preparing these studies.
- The studies are often conducted outside of the test subjects natural working environment.
- Users suffer from survey fatigue [8] due to the number of data points required to conduct a thorough assessment, and even when willing to participate, they are concerned about how accurate they are responding to them [9]

This paper presents a novel form of occupant comfort data collection, using a wearable health tracker, in this case the Fitbit smartwatch, with 25 million active users [10]. The application is a simple clock-face where the user can state their comfort preference as a binary input "comfy" or "not comfy". The comfort preferences are mapped to a time series database and linked with sensors that were present in the location of the user at that time.

This proof of concept has been launched with a small sample set of 15 users. Each user has been equipped with a Fitbit, and a wearable environmental sensor from the National Singapore Science Experiment [11]. All data is collected in-situ in the user's natural work environment.

Next steps in this study involve the development of a work-space recommendation engine. This engine will process the data and give each user a unique comfort profile that can be used to recommend work-spaces in real time. This project, known as SpaceMatch will be launched in 2019 at the National University of Singapore.

The clock-face application is available for free download from the Fitbit store for future researchers to conduct their own crowd-sourced comfort studies.

Keywords: Comfort Feedback, Data Collection, Fitbit, Comfort Recommendation, Mood Logging

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1. Introduction

In the Maōri legends of old, there was a time when the sun would travel quickly across the sky, leaving people without sufficient light and warmth. Māui, a great hero of the time, observed this discomfort amongst the village and went on a quest to tame the sun. Armed with his magic jawbone of Murirangawhenua and a lot of flax rope, he succeeded in tying down the sun and beating it, until it slowed down to the speeds we have today. What Māui effectively did was categorise everyone in a one-size-fits-all model, and based on this assumption, took action to change the environment he lived in.

The way we control our buildings today, is similar to the way that Māui tamed the sun. We make an assumption of the general population based on a survey of a few people, and change the environment we live in based on these few data points. The issue here is that we assume that all occupants within a building zone share the same comfort preferences. In reality, variations in metabolic rates, light preferences, and noise tolerances presents a challenge when attempting to condition a work space to meet the requirements of all occupants.

From the times of Māui till now, a significant challenge is the aquisition of human comfort feedback data. The state of the art, in attaining human feedback are surveys, either as an online form, or paper based. While this in pricipal works, it presents three major challenges.

- The methodology cannot be scaled to large sample sets due to the administrative overhead in preparing these studies.
- The studies are often conducted outside of the test subjects natural working environment.

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- Users suffer from survey fatigue [8] due to the number of data points required to conduct a thorough assessment. Even when willing to participate, there is a concern about how accurately their responses are [9].

This paper presents cozie, a publically available clock-face designed for fitbit which can be used for tailored human comfort studies, and labeling of building management system data. In this paper, we will show how the watch-face can be easily deployed for a range of tailored scenarios, and be combined with building sensor data to create a high quality labeled data set that can be used to optimise the comfort of the user through spatial recommendation, and provide input training data for the comfort optimisation of the building management system.

The remainder of the paper is organised as follows. The next section outlines the cozie clock-face and how research teams can impliment it for a variety of human comfort related experiments. In Section 3 we detail a preliminary experiment conducted using the cozie clock-face for building comfort optimisation, Section 4 presents the preliminary results from this experiment, and Section 5 discusses our findings and next steps in this project. Finally, Section 6 concludes the paper.

2. The cozie watch-face

Cozie is built as a clock-face for fitbit, a wearable health tracker with 25 million active users [10]. The application is publicly available for download at the following link [insert link]

2.1. Overview

In this section we define "user" as the test participant who is wearing the fitbit, and "manager" as the person coordinating the experiment.

The default status of the clock-face is a simple binary question: "Comfy" or "Not Comfy", as seen in Figure 1. By simply clicking one of the icons, information about the users location (GPS), heart-rate, steps walked since last log, and the comfort data is anonymously sent to an Influx time series cloud database [Ref influx]. Data from this database can be simply queried with an API key that can be provided to the manager.

If the manager is interested as to why the user is feeling discomfort, then there is a range of additional questions that can be configured using the cellphone that the fitbit is paired with. The optional questions include:

- Thermal: Prefer Warmer - Prefer Cooler
- Light: Prefer brighter - Prefer Dimmer
- Noise: Prefer Louder - Prefer Quieter
- Mood: Happy - Neutral - Sad
- Location: Indoor - Outdoor

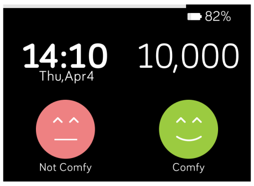

Figure 1: Homescreen

These responses will be bundled with the afore mentioned data, and stored in the Influx time series database. The manager is invited to contact the authors if they have further tailored questions that they would like to add.

A unique user-id for each user, and a unique experiment-id can be configured by the manager using the cellphone that the fitbit is paired with.

The watch-face also has the ability to prompt the user with a 3 second vibration, and force them to provide comfort feedback. This may be triggered using time intervals, certain hours of the day, random hours of the day, or at each 1000 steps walked.

2.2. Building Data Labeling

While the cozie watch-face can provide subjective in-situ human comfort feedback, the true value of the application arises when combined with building sensor data.

(Expand more here about the sensors used etc)

An example of this in practice will be introduced in the next section.

3. Methodology

An experient was conducted at the SDE4, a new built net-zero energy building, at the National Unviersity of Singapore. 20 participants who work in the co-working spaces of the level 6 design studio were recruited for the experiment and equiped with a fitbit watch. The watch settings were set to also request thermal preference (prefer warmer, prefer cooler, comfy), and the set to force request feedback every two hours between the hours of 9:00 to 17:00.

The watch was further complimented with IoT connected on-body and environmental sensors shown in Figure 2. The onbody sensor consists of a temperature and light sensor from mbientlabs, with bluetooth connectivity to raspberryPi gateways [ref]. The working space on level six is retrofitted with three WiFi connected environmental sensors from SenSING that measure temperature, humidity, light, noise, presence, CO_2, and VOC. All data is automatically synced to the Influx time series cloud database.

A simple application written in python merges the cozie time-series database, with the sensor data, thus creating a rich set of labeled data for the building. This data will be elborated on in the next section.

Figure 2: Strap-Pack

4. Results

4.1. Influence of Envelope Resistance

4.2. Influence of Infiltration

4.3. Influence of Thermal Mass

4.4. Archetype Evaluation of the ASF

5. Discussion and Conclusion

References

[1] M. Frontczak, S. Schiavon, J. Goins, E. Arens, H. Zhang, P. Wargocki, Quantitative relationships between occupant satisfaction and satisfaction aspects of indoor environmental quality and building design, Indoor air 22 (2) (2012) 119–131.

[2] P. Wargocki, D. P. Wyon, The effects of moderately raised classroom temperatures and classroom ventilation rate on the performance of schoolwork by children (rp-1257), Hvac&R Research 13 (2) (2007) 193–220.

[3] J. Jaakkola, O. Heinonen, O. Seppänen, Sick building syndrome, sensation of dryness and thermal comfort in relation to room temperature in an office building: need for individual control of temperature, Environment international 15 (1-6) (1989) 163–168.

[4] Y. Wang, J. Kuckelkorn, Y. Liu, A state of art review on methodologies for control strategies in low energy buildings in the period from 2006 to 2016, Energy and Buildings 147 (2017) 27–40.

[5] N. M. Byrne, A. P. Hills, G. R. Hunter, R. L. Weinsier, Y. Schutz, Metabolic equivalent: one size does not fit all, Journal of Applied physiology 99 (3) (2005) 1112–1119.

[6] A. D. Galasiu, 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) (2006) 728–742.

[7] B. Kingma, W. van Marken Lichtenbelt, Energy consumption in buildings and female thermal demand, Nature climate change 5 (12) (2015) 1054–1056.

[8] S. R. Porter, M. E. Whitcomb, W. H. Weitzer, Multiple surveys of students and survey fatigue, New Directions for Institutional Research 2004 (121) (2004) 63–73.

[9] A. K. Clear, S. Mitchell Finnigan, P. Olivier, R. Comber, ThermoKiosk: Investigating Roles for Digital Surveys of Thermal Experience in Workplace Comfort Management, Proc. of CHI (2018) 1–12doi:10.1145/3173574.3173956.

[10] Fitbit 2018 investor report (2018).
URL `https://investor.fitbit.com`

[11] E. Wilhelm, S. Siby, Y. Zhou, X. J. S. Ashok, M. Jayasuriya, S. Foong, J. Kee, K. L. Wood, N. O. Tippenhauer, Wearable environmental sensors and infrastructure for mobile large-scale urban deployment, IEEE Sensors Journal 16 (22) (2016) 8111–8123.