Desktop polling station for real-time building occupant feedback

STINE PEDERSEN
M.Sc.
Civil and Architectural Engineering
stinemlp@gmail.com

STEFFEN PETERSEN
Associate Professor
Department of Engineering,
Aarhus University, Denmark
stp@eng.au.dk

In general people spend up to 90% of their daily life indoor and therefore a good indoor climate is important. Building designers therefore use quantitative models to foresee the expected quality of the indoor climate when designing buildings. These models are established based on relations between measured (quantitative) data and subjective (qualitative) data. A newly developed Desktop Polling Station (DPS) for fast collection of vast amounts of subjective and objective data in real building environments helps developing more accurate indoor climate prediction models.

Motivation and theory

The concept of a Predicted Mean Vote (PMV) as a design criterion for thermal comfort (Fanger 1970) is carefully developed and validated in a scientific manner under controlled conditions in laboratories. These criteria are widely accepted and used for design goals in building design projects. However, a number of experiments (de Dear *et al.* 1998, Humphreys and Nicol 2002, Olesen and Parsons 2002) show that there seems to be a deviation between the "theoretical" thermal comfort and the "actual" thermal comfort in real buildings.

Reasons for this deviation are by some ascribed to be the occupant *expectations* to the indoor climate and the possibilities of occupants to adapt themselves or their environment to maintain thermal comfort. The so-called adaptive comfort models (de Dear *et al.* 1998, Humphreys and Nicol 2007) rely on the recognition of these behavioural and psychological factors. Even the heat balance-based PMV has been suggested to be expanded with an *expectation factor* so the index becomes PMV_e (Fanger and Toftum 2002).

The prevailing adaptive models and the PMV_e model result in different temperature ranges of thermal comfort. This is because the data for the models are obtained in different climates. This goes to show that *expectations* to the indoor climate can be different in different climates and cultures. More studies are needed to understand the expectation factor in relation to thermal comfort in real buildings. The challenge of research in this area is the scale and frequency of the data needed. Typically web-based indoor environment surveys only sample each participant once (Konis 2012). This can be problematic because the indoor environment is not homogeneous but dynamic: the indoor conditions change throughout the day. Furthermore, the participants are likely to forget to answer the survey due to their work tasks (Konis 2012). Therefore new efficient methods to collect vast amounts subjective and objective data simultaneously in a fast and reliable manner are desired.

Desktop polling station

A desktop polling station (DPS) for fast and reliable collection of vast amounts of data has been developed. The DPS is a small box with an interface where building occupants can be asked for their subjective assessment of the indoor climate while sensors continuously are logging objective measures like air temperature, relative humidity, CO_2 concentration, and illuminance level. The subjective assessment is based on a questionnaire containing questions about clothing level, thermal sensation, thermal preference, air quality, air velocity and lighting level. The questionnaire takes 1-2 minutes to answer. The questionnaire uses the 7-point ASHRAE-scale (ISO 7730 2005) to assess the subjective thermal sensation. The other questions were adopted into this form but only with a 5-point scale to shorten the survey time. The DPS can be seen in **Figure 1** (top).

The desktop polling station was designed and built to be located at each participant's workstation making the interaction easier. This allows the occupants to participate in studies without them having to change location, time schedule or environment. Interactions with the DPS are encouraged trough prompts for regular subjective feedback by blinking diodes in the buttons. The conceptual design of how the DPS collects fast data can be seen in the **Figure 1** (bottom).

Pilot field study

A pilot field study was conducted on the lower floor (2^{nd}) of a 5-story open plan air-conditioned office in Aarhus, Denmark. The purpose was 1) to test the robustness of the DPS for data collection, 2) testing the rate of user interaction and experience, and 3) to gather data for the development of a conceptual analysis method to identify the expectation factor based on DPS data. Data was collected at the workspaces of 10 participants with a distribution of gender at 40% female and 60% male. All participants had similar work task that involved computer work for the majority of their work hours.

The potential for data collection

Despite of some minor technical issues, a total of 371 subjective assessments of the indoor environment were collected from 9 participants on the course of 10 workdays. This is a relatively vast amount of assessments within the few days considering that 4 655 observations were collected in a time period of three years in the research project SCATs (Nicol *et al.* 2007) which is the basis for the adaptive comfort criteria in the European

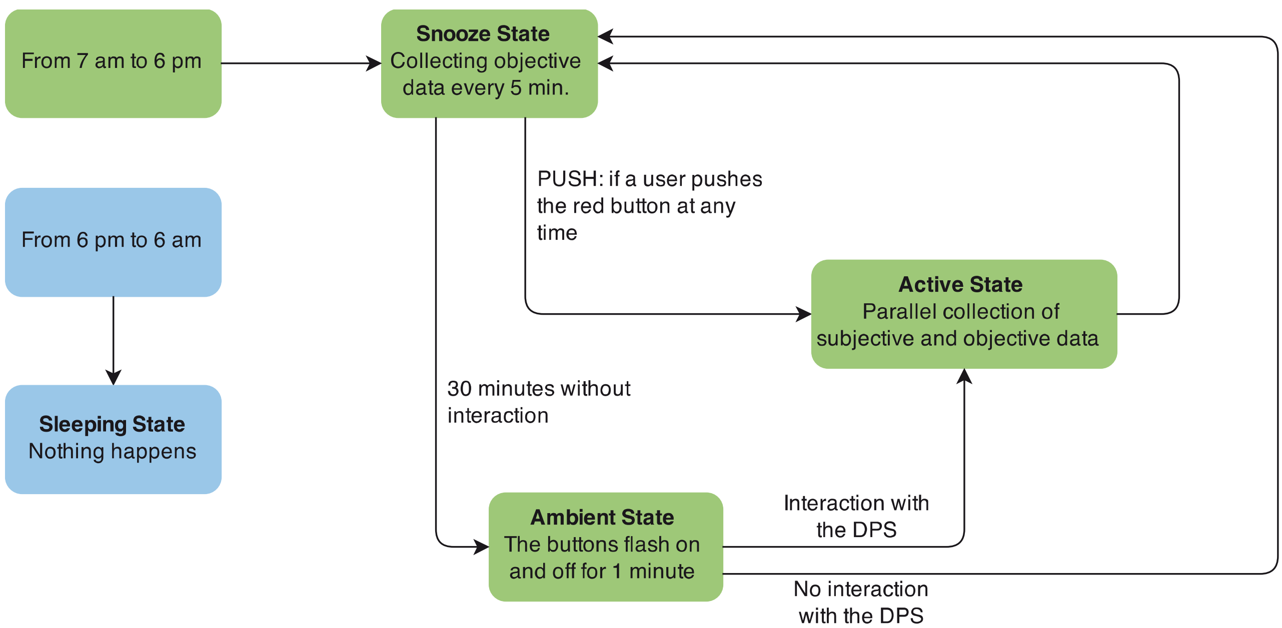

Figure 1. Top: The Desktop Polling Station. Bottom: Flow diagram of the user interactions.

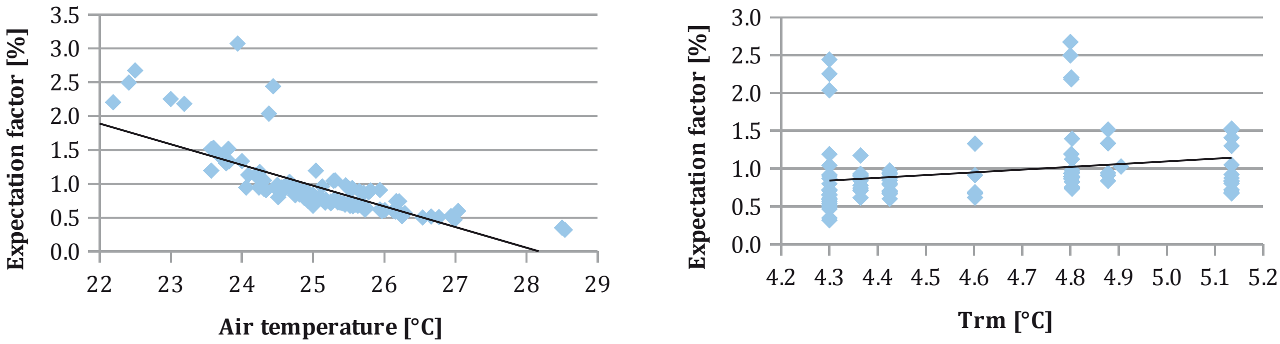

Figure 2. The expectation factor in relation to the air temperature and the running mean outdoor temperature.

standard EN 15251. In average each DPS collected 4.7 participant responses per day but the most active participants had 8–12 assessments per day. The DPS technology therefore has a high potential for gathering large amounts of subjective votes and objective data.

The expectation factor

A difference between PMV and Actual Mean Vote (AMV) was observed. A theory is that difference between PMV and AMV is due to an expectation factor since no other adaptive behaviour was observed in the pilot field study case. The preliminary findings showed a tendency for a relationship between the derived expectation factor and air indoor temperature (**Figure 2**, left) and a relatively weaker relation between the expectation factor and running mean outdoor temperature (**Figure 2**, right). It is important to note that the pilot study was very small in number of participants and limited to a very short period to make any sound conclusions for development of indoor climate models. However, the pilot study has illustrated that the DPS technology has the potential to collect vast amount of data – data which is valuable for various purposes in indoor climate research and development of more user-driven control of indoor climate systems. We welcome any ideas for future collaborations in this field. ■

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