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A personalized measure of thermal comfort for building controls

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ABSTRACT

A personalized measure for thermal comfort has been applied for use in combination with smart controls for building automation. Using data from a field study, we first show the superiority of personalized measures for thermal comfort compared to standard non-adaptive methods. Based on this knowledge we describe a methodology, using logistic regression techniques, to convert user votes to a probability of comfort. We also describe the interface used to collect the votes. We show that, for a given subject, our thermal profile converges against the probabilities found in the field study. As a case study we implemented the measure in a control algorithm to control the shading devices. The results clarify the mode of action and also show the effectiveness of the method.

1. Introduction

Energy-efficiency for buildings has always been a topic of interest, but with increasing energy costs the concern in this field is even growing. One of the main energy consumers in a building is the HVAC (heating ventilation and air conditioning) unit, which is supplying heat during wintertime, cold air during summer, and also regulating ventilation in the building. In Switzerland for example in 2006, 35.1% of the total energy consumption was used for heating and 1% for ventilation and air cooling [1]. In Northern Europe, most of the residential houses do not have air cooling units. Nevertheless, if no air cooling is available, a good control of shading devices is even more important to provide good thermal comfort and avoid overheating during summer time [2]. Since the control of these and other complex systems in a building are not trivial, automatic controllers for technical equipment are more and more used. In various publications is has been shown that energy reductions are possible through automatically controlled HVAC's. These units are controlled by a constant set-point, usually with a narrow bandwidth. Often, set-points are chosen according to general measures of thermal comfort, such as the BS EN ISO 7730 [3] and ANSI/ASHRAE 55-92 [4]. To find appropriate set-point temperatures with these standards, designer have to make assumptions about clothing and activity of occupants, which cannot be accurate at any time. It has also been shown that maybe other parameters such as outside temperature, suggested by Humphrey's [5], are important but neglected in the standards. To address these issues, newer standards such as the EN 15251 [6] or its North American counterpart, the ANSI/ASHRAE 55-2004 [7], incorporate an adaptive thermal comfort model to account for observed variations in comfort temperature of occupants. These are based on the hypothesis that thermal history modifies the occupants' thermal expectations and preferences. For example, De Dear et al. [8] showed that occupants in fully air-conditioned buildings are twice as sensitive to temperature changes than occupants in naturally ventilated buildings, which tend to be more active in adapting themselves to the indoor environment via window openings and clothing changes. Additionally, this shows also that each human being is different in the perception of thermal comfort.

1.1. Scope of research

For designing good controls the first step is always to define the controlled subject and the objective according to which it should be controlled. In the beginning, building controls have either been time dependent or have been based on a threshold value, for example inside temperature or solar radiation. Over the years more input variables have been added and the outcome was no longer linearly dependent upon input variables. Many controls use the PMV (Predicted Mean Vote) [9] as a measure for thermal comfort. For example, Dounis et al. [10] presented a living space thermal-comfort regulator based on fuzzy logic. A similar system was proposed by Calvino et al. [11] which tries to keep the PMV [9] at a given level by controlling the speed of the heating fan. This system is tested in a real room but only during winter time, where it performed well. The clothing insulation I_{cl} was chosen to be 1 clo

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