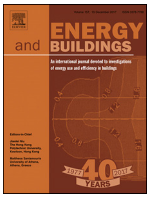
Energy & Buildings 166 (2018) 210–219

Contents lists available at ScienceDirect

Energy & Buildings

journal homepage: www.elsevier.com/locate/enbuild



Determination of thermal preferences based on event analysis

Andrzej Szczurek[a], Monika Maciejewska[a,*], Mariusz Uchroński[b]

[a] Wroclaw University of Science and Technology, Faculty of Environmental Engineering, Wybrzeże Wyspiańskiego 27, Wrocław 50-370, Poland
[b] Wroclaw Centre for Networking and Supercomputing, Wybrzeże Wyspiańskiego 27, Wrocław 50-370, Poland

ARTICLE INFO

Article history:
Received 31 August 2017
Revised 31 January 2018
Accepted 1 February 2018
Available online 14 February 2018

Keywords:
Indoor air
Thermal preferences
Measurement
Event detection
DFT

ABSTRACT

Real thermal preferences of occupants are rarely considered by the automatic control of HVAC systems. It is due to difficulties in describing satisfactory thermal conditions, especially when opinion of many people has to be taken into account. This work presents a method which allows to determine the preferred temperature and the associated relative humidity for a group of occupants in the room equipped with a manually controlled local cooling/heating system. It was assumed that thermal preferences of the group are reflected in the way they operate such system. The method is based on the continuous monitoring of air temperature and relative humidity and the detection of events. An event is defined by the time period between succeeding adjustments of the heating/cooling device. During events, temperature and relative humidity behave in a characteristic manner. Patterns of their periodic variation were determined using Discrete Fourier Transform and used for the detection of events. The preferred temperature can be derived from the descriptive statistics of temperature during detected events. The method was developed and calibrated for an air conditioned office. The relevant data was collected during summer period. The analysis showed that the method is successful in retrieving the preferred temperature and it is less effective in reproducing the preferred temperature range. Events were more accurately detected when using patterns of temperature variation (false negative detection rate was 14.00% and false positive detection rate was 4.44%) compared with patterns of variation of relative humidity. The approach is computationally efficient and after calibration, it may be directly applied to evaluate local thermal preferences.

© 2018 Elsevier B.V. All rights reserved.

List of symbols and abbreviations

A	DFT spectrum amplitude
AC	Air Conditioning
$A_T(f)$	amplitude of DFT spectrum for temperature data
$A_{RH}(f)$	amplitude of DFT spectrum for relative humidity data
DFT	Discrete Fourier Transform
E_A	false negative events detection rate
E_B	false positive events detection rate
f	DFT spectrum frequency
(f_{1T}, f_{2T})	low amplitude range of spectrum, in T variation pattern
(f_{3T}, f_{4T})	range of spectrum with maximum amplitude, in T variation pattern
(f_{1RH}, f_{2RH})	low amplitude range of spectrum, in the RH variation pattern
(f_{3RH}, f_{4RH})	range of spectrum with maximum amplitude, in RH variation pattern
FFT	Fast Fourier Transform
HVAC	Heating, Ventilation and Air Conditioning
N_{RH}	T data segment length which is best for events detection
N_T	RH data segment length which is best for events detection
n	total number of time points in the data used for calibration of event detection method
n_A	number of time points (amongst n) when events were correctly detected
n_B	number of time points (amongst n) when the lack of event was correctly detected
n_1	number of time points (amongst n) when events occurred
n_2	number of time points (amongst n) when events did not occur
N	length of data segment
PDF	probability density function
RH	relative humidity [% RH]
T	temperature [°C]
T/RH	temperature or relative humidity
$\{x_n\}$	data segment of variable x
$\{X_k\}$	DFT transform of data segment of variable x

---

* Corresponding author.
E-mail address: monika.maciejewska@pwr.edu.pl (M. Maciejewska).

https://doi.org/10.1016/j.enbuild.2018.02.014
0378-7788/© 2018 Elsevier B.V. All rights reserved.

1. Introduction

The service sector is now the largest and fastest-growing branch of the economy. The rapid expansion of this segment is visible in both employment levels and the dynamic development of office buildings which are intensively localized in big cities and urban areas. Buildings of service sector represent high energy consumption compared to other economic branches. Therefore, energy use reduction initiatives are today a prime objective for environmental policy. Modern office buildings have high energy savings potential [1]. A careful supervision of energy management can significantly reduce consumption of heat and electricity. In order to perform this task, the analysis of energy demand and consumption is required. This is a complex problem due to a wide variety of uses and services. In offices, most of the energy is consumed for the operation of various types of electrical equipment and appliances (e.g. electric heaters, computing equipment and lighting). Practically, the energy consumption in a modern office building is a very complex organizational issue involving four important elements: energy management policies/regulations made by the energy management division of an organization, energy management technologies installed in the office building (e.g. metering, monitoring, automation of switch-on/off technologies), types and numbers of the electrical equipment and appliances in the office building (e.g. lights, computers and heaters), and more importantly staff's behaviour regarding use of electric equipment and appliances in the office building [2].

The growth of energy consumption relates particularly to heating, ventilation and air-conditioning (HVAC) system which dominates the total energy consumption in buildings. This part of a building has two fundamental functions. On one hand, HVAC system has to control indoor temperature and moisture levels in air, in order to meet the needs of occupants and maintain typical thermal comfort standards and indoor air quality in offices. On the other hand, its management algorithms should reduce the energy consumption to fulfil organizational regulations and requirements. Recently, occupants' individual preferences have received growing interest in order to not only save energy but also to satisfy user thermal comfort [3,4].

Thermal comfort is defined as conditions in which occupants express satisfaction with the thermal environment [5]. It is a key component regarding the quality of indoor environments. Its importance cannot be underestimated. Occupant thermal comfort pays a dominant role in influencing building operations and it is a major criterion to evaluate the performance of building systems. Thermal discomfort in offices can create dissatisfaction of occupants and it is likely to reduce their productivity and performance [6,7]. The vast majority of complaints about indoor microclimate regards this issue. Despite high rate of energy use for indoor environment conditioning, a significant portion of occupants (i.e., 35% of building occupants) are still unsatisfied with the code-defined indoor thermal conditions in commercial buildings [6,8]. Dissatisfaction with indoor thermal conditions may lead to the use of local heating and cooling sources, such as electrical heaters or fans. Hence, it is important to overcome the state of discomfort with minimum energy utilization.

Improving thermal conditions inside buildings is impossible without proper information, which is the key to make management and investment decisions. In practice, it can be obtained using different strategies, e.g. it can be obtained by calculating the predicted mean vote (PMV) index. The predicted percentage dissatisfied (PPD) index, obtained from the PMV index, provides information on thermal discomfort (thermal dissatisfaction) by predicting the percentage of people likely to feel too hot or too cold in the given thermal environment. Predictive-based approaches mainly rely on predictable occupancy and the historical data from human activities that are obtained from various sensors, equipment data and activity schedules. They very often use advanced artificial intelligence to predict people's needs. Predictable occupancy and activity schedules are especially useful for spaces with significant thermal mass, because it can take a long time for temperatures to rise or fall. Most building management systems (BMS) are based on standards using the predicted mean vote (PMV) as a thermal comfort index, to ensure and assess satisfactory environmental conditions during occupancy. However, studies have shown weak and context-dependent correlations between standard-defined comfort ranges and occupant-reported comfort ranges [9–11]. Often, occupant comfort ranges are found to be larger than the predicted ranges implying a potential for reduced energy consumption by allowing more flexible and adaptive control of system set points [12,13].

Since many environmental and occupant associated variables are difficult to predict for a building population, field studies are commonly applied for assessing the quality of indoor environment and occupant comfort. Field studies generally involve one-time or periodic occupant surveys, which either ask participants to remember their comfort and summarize their experience over different seasons and times of day or ask participants to report only their current level of comfort, requiring multiple responses from each participant over a period of time [14,15]. In comparison to the code-defined standards, field studies can often predict ambient comfort for a given population more accurately as they make no prior assumptions and take into account all contextual influences including climate, building characteristics, and culture. Yet, these field studies also have limitations as they do not reflect real-time or context dependent comfort of occupants. There is no feedback about occupants' comfort levels on an ongoing basis. Without any direct feedback, other than infrequent complaints, building managers are forced to play it safe, resulting in suboptimal operations. The building energy research community increasingly acknowledges the importance of human-related information, including human presence, activities, behaviour, and attitudes in building energy management [16–21].

When occupants preferences are less predictable, sensors of environmental parameters can be used to characterize thermal comfort. Relative humidity and air temperature are the most critical factors for maintaining satisfactory thermal conditions. Unfortunately, human perception of thermal conditions is subjective. Hence, preferences vary greatly among individuals and there is no single value of these parameters that can satisfy everyone.

2. Assumptions

Recently, it is quite popular to provide workplaces, in particular offices, with automatic heating/cooling devices, which are manually controlled. Thanks to them, humans can regulate indoor temperature and less frequently, also relative humidity. Usually, only persons working in the room have access to the controller of the heating/cooling device and can change system settings. It is also reasonable to assume that occupants do not provide false feedback votes and their action is aimed at improving conditions in the workplace. As a result of multiple actions of individual people, their preferences are averaged and the conditions maintained in the room reflect the group opinion about thermal comfort.

In this work there was proposed a method which allows to determine thermal preferences in rooms, where expectations of many occupants regarding indoor climate have to be taken into account, e.g. in offices. The proposition was based on several assumptions.

1. Room occupants express their thermal preferences by changing settings of local automatic heating and cooling systems.

Download English Version:

https://daneshyari.com/en/article/6728481

Download Persian Version:

https://daneshyari.com/article/6728481

Daneshyari.com