Available online at www.sciencedirect.com
ScienceDirect
Building and Environment 42 (2007) 4022–4027
BUILDING AND ENVIRONMENT
www.elsevier.com/locate/buildenv

Field experiments on energy consumption and thermal comfort in the office environment controlled by occupants' requirements from PC terminal

Yoshifumi Murakami[a,*], Masaaki Terano[a], Kana Mizutani[b], Masayuki Harada[b], Satoru Kuno[b]

[a]*Installed Equipment Network System Development Department, Matsushita Electric Works, Ltd., Kadoma, Japan*
[b]*Department of Environmental Engineering and Architecture, Nagoya University, Nagoya, Japan*

Received 4 January 2006; accepted 2 May 2006

Abstract

The thermal environment in an office is not always optimal from the viewpoint of energy-conservation and occupants' comfort. The main reason is that air-conditioning systems are controlled without taking the occupants' needs into account. In this study, we would like to propose a new system to control air-conditioning systems, lighting systems, etc. via occupants' requests. This system collects occupants' requests from their own personal computers and controls the air-conditioning system with logic that balances the needs of occupants and energy consumption. The control logic is referred to as "Logic for Building a Consensus" and can be adjusted according to operating strategies such as energy-saving or occupants' satisfaction with their environment. Moreover, the variety of feedback motivates occupants to cooperate with energy-saving efforts.

An interactive system to use occupants' requests for controlling the air-conditioning system and providing a variety of feedback was developed. A series of cooling experiments were conducted in an open-plan office where about 50 people worked. The results show that this interactive system could save 20% more energy compared with controlling an air-conditioning system at a constant 26 °C.

Keywords: Air-conditioning system; Occupants' requests; Energy-saving; Thermal environment; Interactivity

1. Introduction

The thermal environment in an office is not always optimal from an energy saving and occupant satisfaction perspective. For example, we often observe that some occupants feel too cold in an air-conditioned office while an air temperature is controlled to a set temperature based on thermal comfort standards such as PMV [1] and ISO 7730 [2]. The main reason of this issue is that air-conditioning systems are controlled without taking the occupants' needs into account. This was so pointed out by field surveys such as Bordass and Leaman [3]. In this study, we would like to propose the use of several occupants' requests to control the air-conditioning system, lighting system and so on.

An interactive control system that can control an air-conditioning system based on occupants' requests and provide a variety of feedback was developed and applied experimentally in an open-plan office where about 50 people worked. The main purpose of this paper is to confirm the effects of this system on energy saving and improvement of thermal comfort. The design of the proposed system was described in the other report [4].

2. Methods

2.1. Overview of interactive system

The structure of this interactive system is shown in Fig. 1. The system is composed of occupants' personal

*Corresponding author. Tel.: +81 6 6906 3397; fax: +81 6 6907 8146.
E-mail address: y_murakami@mail.mew.co.jp (Y. Murakami).

0360-1323/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.buildenv.2006.05.012

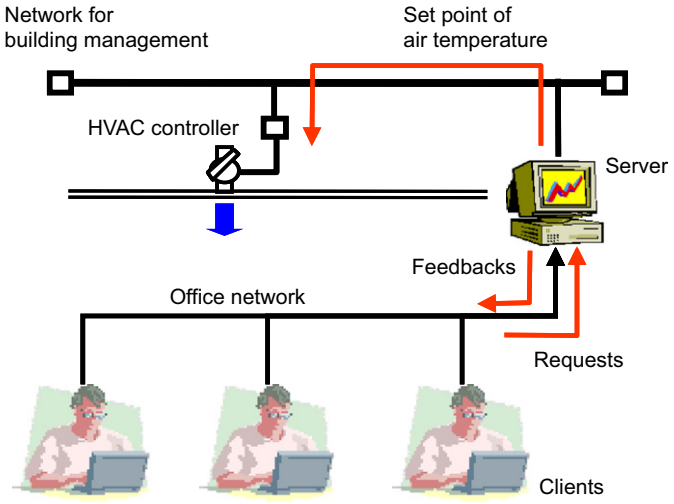

Fig. 1. Structure of the interactive system: occupants' personal computers and a server, which can communicate with both the Client and HVAC controllers over the Internet.

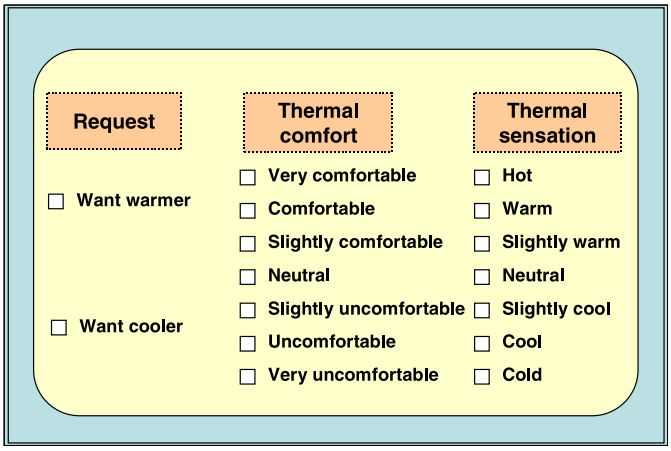

Fig. 2. User input screen for voting: via this input screen, occupants can send their requests and desired thermal sensation as they want.

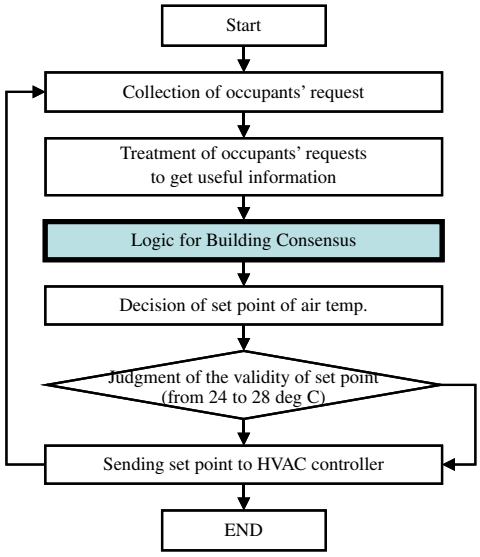

Fig. 3. Algorithm for Building a Consensus: this figure shows program flows from collection of occupants' request to sending set point to HVAC controller decided by logic for Building a Consensus.

computers (Client) and a server (Server), which can communicate with both the Client and HVAC controllers over the Internet. The server gathers requests from occupants' personal computers and determines set temperatures according to the logic for Building a Consensus (LBC), and sends commands to the HVAC controllers every minute. Clients serve as terminals to send occupants' requests for the air-conditioning system and at the same time, they can obtain a variety of information related to energy consumption conditions and static information of occupants from the server. Therefore, the system works very interactively.

A user input screen for voting is shown in Fig. 2. The options "Want warmer" or "Want cooler" are used to determine occupants' preferences about how they would like to change the thermal environment [5]. The options "Very hot," "Hot," "Slightly hot," "Neutral," "Slightly cold," "Cold" and "Very cold" constitute the thermal sensation scale in Japan [6]. Via this input screen, occupants can send their requests and desired thermal sensation to the server.

2.2. Algorithm and LBC

The algorithm for Building a Consensus of the occupants regarding the air-conditioning system is shown in Fig. 3. This system collects occupants' requests and uses this information to control the environment on a minute per minute basis. The set temperature is determined by the LBC which maintains a balance between occupants' needs and energy consumption.

LBC can be described by a two-dimensional chart. The X-axis represents the percentage of occupants who want the room to be cooler, whereas the Y-axis represents the percentage of occupants who want it to be warmer. We can choose a basic strategy among the two; one is prior to 'occupants' satisfaction' or 'energy saving'. In this study, we refer to the former as "LBC for thermal comfort (LBC-TC)" (Fig. 4) and the latter as "LBC for energy saving (LBC-ES)" (Fig. 5). In summary, the purpose of LBC-TC is to maximize the occupants' satisfaction level and determine the set temperature by a majority vote. On the other hand, the purpose of LBC-ES is to save energy for cooling and gradually raise the set temperature to a level where most of the occupants do not feel displeasure. Figs. 4 and 5 show the rule whether set temperatures are raised, remained, or set down. We can decide set temperatures by the percentage of occupants who want thermal environment to be warmer or cooler. When each percentage of occupants who want thermal environment to be warmer and cooler is below 10%, set temperatures are remained in LBC-TC, because most of the occupants are considered to be satisfied with their environment.