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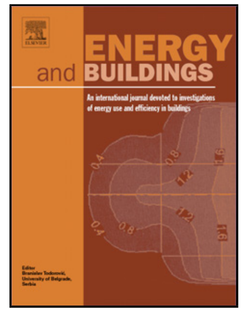

Title: Energy efficient thermal comfort in open-plan office buildings

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Energy efficient thermal comfort in open-plan office buildings

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Abstract

The effect of spatial variations in mean radiant temperature and occupancy on HVAC energy and occupant thermal comfort is studied in an open-plan office space with multiple AHUs. A predictive control method is proposed that arrives at optimum temperature set-point vector by solving an optimization problem, which minimizes HVAC energy consumption subject to acceptable thermal comfort and adequate outside air intake. The optimum temperature set-point vector is used in a PID controller that modulates the AHU fan speed. The proposed control is evaluated on occupancy traces observed in an open-plan space and compared with static set-points based PID control strategies. Normally PID control operates with a dead-band around the static set-point and the AHU fan speed is adjusted only when return air temperature is outside the dead-band. The proposed control has a dynamic set-point and hence the AHU speeds are adjusted at much finer time steps than the normal control. The occupancy traces are classified into densely and sparsely occupied days. Across all days, the proposed control achieves an average additional savings of 15% over a PID control that assumes uniform spatial occupancy distribution in AHU control and 12% over a PID based strategy that uses actual spatial occupancy information.

Keywords: Thermal comfort, HVAC energy, dynamic temperature set-point, model predictive control, mean radiant temperature, open-plan office

1. Introduction

It is well known that thermal radiation from the surrounding indoor surfaces can affect thermal comfort of the occupants [1–3]. The thermal radiation appears as mean radiant temperature (MRT) in the widely accepted Fanger's thermal comfort model [4], which is applicable to air-conditioned buildings. Two widely used metrics to quantify occupant comfort that stem from Fanger's model are: (1) the predicted mean vote (PMV), which is a function of four environment variables (namely the air temperature, humidity, local air velocity, and MRT) and two occupant related parameters (namely the clothing insulation and metabolism); and (2) the predicted percentage of dissatisfied (PPD), which is a function of PMV that expresses the quality of the thermal environment as percentage of occupant dissatisfied. It may be noted that to maintain the same PMV in Fanger's model, an increase in MRT would warrant a decrease in the air temperature with other parameters being constant, and vice versa. The value of MRT depends on the position and orientation of the occupant with

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