Journal of Computer and System Sciences 81 (2015) 958–965

Contents lists available at ScienceDirect

Journal of Computer and System Sciences

www.elsevier.com/locate/jcss

Multi-agent system for energy consumption optimisation in higher education institutions

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ARTICLE INFO

Article history:
Received 14 February 2014
Received in revised form 11 April 2014
Accepted 14 April 2014
Available online 29 December 2014

Keywords:
Energy management
Energy optimisation
Energy conservation
Sensor network
HVAC control
Energy efficiency

ABSTRACT

Global warming is one of the most serious issues faced by today's world. The increase in world population and adoption of modern lifestyle have dramatically increased the demand for energy. Over the last decade Higher Educational Institution (HEI) buildings have seen massive increase in energy consumption due to increased use of IT equipments, longer occupancy and increased use of Heating Ventilation and Air Conditioning (HVAC) systems. Current Building Management Systems (BMS) fail to optimize energy consumption of HVAC systems in commercial and educational buildings. In this paper we present an intelligent agent based system to optimize energy consumption of HVAC system in HEI buildings. The system employs artificial intelligence techniques to predict the demand of the system and optimize energy consumption of the HVAC system. The experimental results have shown that the deployment of the system has resulted in 3% reduction in energy consumption of HVAC.

1. Introduction

Global warming is one of the main contributing factors to climate change [1]. Global warming has been linked to emission of CO_2 generated by burning of fossil fuel. A Well maintained and properly working HVAC contributes towards a large portion of energy consumption in educational buildings. Making things worse, an HVAC system that is not working optimally results in waste of energy by too much heating or cooling and may start heating or cooling earlier than required [2].

It is important to investigate the means of optimising energy consumption of HVAC in order to reduce overall energy consumption in these buildings. Educational buildings present extra challenge in modelling their environment due to high degree of variation in their occupancy model [14].

Smart buildings require indoor environment control system to optimize energy consumption while maintaining the thermal comfort level of their occupants [3]. Often improved thermal comfort of the building requires increased energy consumption. It becomes crucial for energy efficient buildings to maintain balance between thermal comfort and energy consumption. Various approaches have been applied to learn occupant's behaviour and model it for efficient energy consumption [4,5]. Occupancy models are important for energy efficient buildings. The simplest occupancy model in HEI buildings is based on the assumption that all staff offices are occupied during office hours and classrooms and labs are occupied for specified period of time during term time. Most HVAC systems base their control on this simplistic occupancy

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http://dx.doi.org/10.1016/j.jcss.2014.12.010
0022-0000/

model and this kind of control leads to suboptimal energy consumption. It is essential to have an adaptive control system to be able to deal with complex occupancy model of educational buildings.

Although there has been research in smart buildings technology and adaptive BMS, but there has not been much research on BMSs that adapt to external environmental conditions [6]. Our proposed adaptive agents system incorporates real time data of external environmental conditions to manage optimal energy consumption. Adaptive agents adapt to their environment and have potential to reduce energy consumption by producing suggestions for adjusting HVAC systems to respond to environmental conditions and occupants' ever changing requirements. The system ensures that rooms are cold or warm enough to desired level of comfort just before occupants' arrival and switch off heating or cooling soon these rooms get vacant.

The main objective of this research is to apply information and communication technologies (ICT) to optimise energy consumption in HEI buildings while maintaining occupants' comfort level. Our proposed system optimises energy consumption by constantly monitoring energy consumption of HVAC and occupancy level, and by predicting and taking energy aware actions.

This paper proposes a new approach based on adaptive intelligent agents and fuzzy logic to manage energy consumption in HEI buildings. The control of the system is expected to emerge from collaboration and cooperation of the agents in the system. The proposed system consists of sensing agents, control agents, data processing agent and prediction agent. Sensor agents have access to occupancy, temperature, humidity and real time weather conditions data. Prediction agent manages coordination between various control agents in order to maintain comfort and temperature in the building. The system exploits real-time weather data and university's event management system in order to adapt and timely respond to changing conditions while maintaining comfort and energy consumption efficiency.

Sensor agents read environmental parameters, every 10 s from their underlying sensors and store them in a central data server. Prediction agent predicts occupancy window and uses its prediction result to adjust heating or cooling accordingly to a desired temperature. The Prediction agent also exploits university's event management systems and Google's online weather services to achieve maximum accuracy in prediction process. The accuracy of the prediction helps to adjust start-up time required for cooling or heating classrooms, labs and offices to a desired temperature.

The system is deployed in labs and staff offices in the King Saud University KSA as a part of university's energy efficiency program. The occupants consist of academic staff with permanent offices and students as temporary occupants of classrooms and labs. Another kind of occupancy involves meeting rooms used by staff and students.

This paper is organised as follows: Section 2 describes the related work. Section 3 presents the system architecture. Section 4 describes the sensor network and provides brief description of various sensors. Section 5 provides description of experimental results and finally Section 6 concludes the paper.

2. Related work

Occupants' behaviour and preferences play a pivotal role in building energy management system [7]. Energy consumption is highly dependent on residents' activities in a built environment [8]. Recent research efforts have been focused on applying machine learning techniques to model occupants' behaviour in a built environment. Yu et al. applied Genetic Programming approach to model occupant behaviour [9] by taking into account variation in occupancy timing.

It is imperative to a system to model occupants' behaviour accurately in order to take optimal actions of adjusting HVAC temperature without scarifying occupants' comfort. There are various factors and interplay between them that need to be considered for optimal energy consumption in HVAC systems. Optimal energy consumption requires timely coordination between various components of the HVAC system.

Traditional building control systems employ centralised control to environmental comfort and they usually do not fully address differences in comfort requirements in different parts of the building. Recently these systems have adopted bi-lateral control to allow both occupants and operators to control local environment settings [10]. These bi-lateral control approaches may allow occupant to control local environment parameters but they may result into conflict with operator settings of optimal energy consumption. Agent based framework provides a decentralised control where local controls are influenced by overall system goal [11,12]. Agent technology provides essential coordination and communication mechanism where a large number of actors are involved in performing cooperative activities in order to satisfy local and global constrains [13]. There have been recent efforts in agent research community to develop agent-based energy management systems for commercial and domestic building domains [14,15].

Bourgeois et al. proposed occupancy based control model employing occupants behavioural model to simulate energy consumption by lighting system. Their simulation results have shown that the occupants who actively seek daylight can reduce 40% of energy consumption in the building lighting systems [16]. The main focus of this research effort is on lighting rather than HVAC. A multi-agent based control system is proposed by Zhu et al. which considers both the energy efficiency and occupants' comfort [17]. The system also takes into account occupants' preference and uses renewable energy sources as a backup source. The system assumes static nature of occupancy and uses simple occupancy model rather than dynamic occupancy model.

Artificial intelligence techniques have been proposed to manage energy consumption in buildings. Sierra et al. proposed fuzzy controller which attempts to minimise energy consumption by the use of a suitable cost function for the whole system [18]. They have modelled overall control system including the cost function, and tested it by using the software