Available online at www.sciencedirect.com

ScienceDirect

Procedia Environmental Sciences 34 (2016) 80 – 93

Procedia Environmental Sciences

Improving Sustainability Concept in Developing Countries

Cognitive Simulation Driven Domestic Heating Energy Management

Dilhan J. Thilakarathne, Jan Treur*

Agent Systems Research Group, VU University Amsterdam, The Netherlands

Abstract

Energy management for domestic heating is a non trivial research challenge, especially given the dynamics associated to indoor and outdoor air temperatures, required comfortable temperature set points over time, parameters of the heating source and system, and energy loss rate and capacity of a house. In addition to all these factors, human influence or interaction is also a key aspect in this complex system. It is difficult and very costly to conduct experiments of this nature to scrutinize the dynamics and optimal efficiency of the system under all circumstances and constraints. This paper focuses on a domestic heating energy management system using an air to water heat pump and uses a pre-developed mathematical model for its performance. This mathematical model is integrated within a computational dynamic cognitive model which was developed based on neurocognitive evidence. An approach like this can be used as an experimental workbench for complex scenarios.
© 2016 Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of IEREK, International experts for Research Enrichment and Knowledge Exchange

Keywords: Heating energy management; Cognitive modeling; Mathematical model; Heat pump; Short term and long term goals

1. Introduction

Energy is an important ingredient for the development of a country and adequate energy management is a vital aspect for a sustainable development. In many countries most of the energy usage goes to domestic heating and cooling [1, 2]. The amount of energy that can be saved by properly managing the energy usage of a house may not be felt as very significant, but in a global context it surely may provide a significant contribution to a better environment in the future. It has been observed that a major portion of energy used for domestic heating and cooling

* Corresponding author. Tel.: +3-120-598-7763; fax: +3-120-598-7653.
E-mail address: jtreur@vu.nl

1878-0296 © 2016 Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of IEREK, International experts for Research Enrichment and Knowledge Exchange
doi:10.1016/j.proenv.2016.04.009

is needlessly wasted [2]. Therefore, many researchers focus on how to reduce domestic energy usage, specifically for heating related energy usage. The research reported here addresses different aspects of energy saving, among others making use of predicting variations in outside temperature, characteristics of a house, user preferences, improved devices, and usage of renewable energy sources. This paper mainly focuses on domestic heating management through an air to water heat pump together with relevant human cognition. For performance of an air to water heat pump a mathematical model was already developed [3]. This model describes the performance of an air to water heat pump, over time, in relation to variation both for indoor and outdoor temperatures and characteristics of a house. This model has been validated with realistic simulations and partly with empirical data [3,4].

Due to the developments in brain imaging and recording techniques, the insight in human brain processes is growing rapidly. This contributes to an improved quality of relevant data and knowledge, and to the development of new methods to explore this most complex system within human anatomy through different dimensions. Based on findings from Cognitive Neuroscience, a dynamic computational model was developed for action selection taking into account situation awareness [5]. This model includes a number of relevant cognitive states: performative desires, subjective desires, feeling, action preparation, ownership, attention, intention, and awareness. It models the interplay between conscious and unconscious processes. Behavior of inhabitants in a house has a strong impact on the energy consumption and it is an important factor for energy waste reduction, especially in a dynamic context [6].

This paper combines the mathematical model that was developed for analysis of smart daily energy management for an air to water heat pump with the cognitive model for situation awareness. It is a common problem in energy related research that practical experiments cost a lot in effort and money. Furthermore, when it is required to integrate human cognition also into the experiment it is much harder. Having this type of research contributes to facilitate a sophisticated working environment to simulate complex situations including behaviour of both technical systems and humans. This paper focuses on a single house with a human's desires and intentions for selecting night indoor temperature. An inhabitant has desires on a comfort level required at night, strong desires to save money, and has to balance between comfort level and money (or energy) saving.

2. A mathematical model for heating by a heat pump and a cognitive model for action selection

This paper integrates two models that have been developed earlier. The first explains a mathematical model for the domestic energy usage by using an air-to-water heat pump. Due to space limitations only a brief description of this model will be presented in the current paper; more details can be found in [3]. The model calculates the energy used to heat a house over time according to a particular heating program. The second model covers cognitive processes behind action selection taking into account situation awareness; it has been applied to analyse the role of situation awareness in the aviation domain in [5]. This model addresses the interplay of a bottom-up and a top-down process and in particular how they interact with each other in order to cognitively drive a given situation to an adequate action.

2.1. Mathematical model for the domestic energy usage by an air-to-water heat pump

For a mathematical model of domestic energy usage by an air to water heat pump there are various dynamic factors to be considered. Among them one is the dynamics of outdoor air temperature. This also further can be divided into two parts daytime and nighttime outdoor air temperature. The outdoor air temperature typically shows a 24h periodic behavior (e.g., [7, 8]) and therefore also the energy usage to maintain a constant indoor temperature will vary over the time of a day. Sine-exponential and sinusoidal models are the most common analytical models used for this purpose. They calculate the pattern of outdoor temperatures over a day (and night) based on four parameters: sunrise time ($t_{sunrise}$) and sunset time (t_{sunset}), and maximum (T_{max}) and minimum (T_{min}) temperature values over the day [7]. Note that these are parameters for one given day, but they themselves are in fact variables at a time scale over a year, as they differ from day to day.

Equation (1) below presents the daytime outdoor temperature variation *dot(t)* and equation (2) presents the nighttime variation *not(t)*. The values for the time parameters and variables are relative to midnight. Here in the evening (before midnight) T_{min} refers to the minimum temperature ahead in time and in the early morning (after midnight) it is of the day itself; similarly in the early morning (after midnight) T_{sunset} refers to the temperature at

Download English Version:

https://daneshyari.com/en/article/4401459

Download Persian Version:

https://daneshyari.com/article/4401459

Daneshyari.com