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Abstract Buildings are big consumers of power, as they tend to group many people in one location. Because of this, they require large amounts of power for heating, cooling, ventilation and for powering electric devices such as lights, kettles etc. The optimisation of this usage could bring large energy savings. The management systems that deal with different infrastructural aspects of the buildings face the problem of varied and random behaviour of people, problems with prediction and problems with unclear conditions to define the comfort of occupants. This article presents the state of the art in simulating presence of occupants in the building and suggests usage of the developed algorithm for energy consumption simulation as a possible approach to the problem.

1 Introduction

The energy usage growth is one of the main problems of current times [20]; the energy consumption is growing even faster than the worldwide population. This causes the increase of greenhouse gas emissions, which is the main contributor to climatic change. The heat from the houses, transportation and general human activity creates a specific micro-climate around the cities [23]. There is a lot of discussion on how to limit the pollution and the most current research shows that it has to be a global, complex and multidimensional effort in order to change the world view on production, consumption and saving of energy. Energy here is understood in the broad sense, encompassing heat, cold and electricity.

The general actions taken to reduce the pollution are: developing renewable energy sources, developing technologies to filter the greenhouse gases, forcing investments into clearer coal and gas power plants and, last but not least, reducing

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the power usage. The latter is extremely problematic as it is very difficult to pinpoint where energy is really wasted and where the energy usage could be limited by just investing in newer technology. It is also a sensitive social issue as the access to electric energy and heating is not equal among the population and the financial incentives may cause a serious inequality problems [14]. The available data often provide information on how much and when power is used, but much less is known regarding the questions why the energy is needed and why it is needed at a certain time of the day. Such knowledge might open the door to mechanisms to motivate people more to participate in demand site management (DSM). DSM [2] is an attempt to include users in the saving of the energy, not only by imposing regulations and forcing financial incentives, but also by education and awareness.

The overall usage of power is usually categorised in the following groups: industrial usage, transport and *other* [20]. The *Other* group contains the usage connected to buildings: households and offices. The overall portion of power usage for office buildings is difficult to estimate, but literature suggests it ranges from 20 to 40% of the power usage in this category. Better management of power in office buildings would contribute to overall energy saving. The power usage of buildings is growing due to development of HVAC[1] systems which are now considered a standard: HVAC systems are the responsible for 50% of power consumption in the non-domestic buildings.

The key to optimising the power is knowledge regarding the presence of the people in the building. The problem of people's presence and behaviour is so important that on the 74th Executive Committee Meeting of the IEA Energy in Buildings and Communities Programme, held on 14th November 2013 in Dublin, Ireland the project Energy in Buildings and Communities Programme Annex 66 was approved [1]. It aims to support the development of an occupant behaviour definition platform, the development of simulation methodologies and the research in the influence of people on building energy use.

The structure of this report is as following: next section presents the context of energy management in modern smart buildings. Section 3 presents the state of the art in occupancy modelling. Following section presents the simulator for power consumption that can be used for occupancy modelling. The final section concludes the report.

2 Smart buildings

The human presence detection became the important information for the smart systems in the buildings (energy, HVAC systems). These smart systems aim to control the power usage and environmental settings in a way that the users have certain degree of comfort and systems are using energy (both heat and electricity) in a possibly optimal way. Unfortunately, as presented in [8] many of the intelligent systems

[1] Heating - Ventilation - Air Conditioning systems

are not adequately detecting human presence which causes the system e.g. not to turn down heating or switch off the lights, leading to minimal or even no saving on maintenance cost and energy. This illustrates the need for careful monitoring of the systems and for properly analysing the real behaviour of occupants.

A smart building is a building in which the systems are controlled and configured via a computer system that has ability to adjust settings of the buildings' systems. The systems under control are: lights, HVAC and electric power access (some sockets or devices might be not powered for part of the day).

Currently smart buildings use such elements as:

- sensors of temperature, humidity, air quality,
- detectors of movement,
- counters of people entering (two way infrared sensors) [18],
- access cards used to open doors,
- detection of cell phones [30],
- feedback from users via various interfaces,
- location monitoring devices worn by people.

Not all smart buildings use all of the above mentioned techniques, as in some cases they interfere with the privacy issues, are difficult to use for some people or are not applicable in some situations (e.g. a shop with large numbers of clients). The methods of detecting and checking behaviour should not disturb the people and at the same time it would be beneficial if they would use as little equipment, sensors and systems as possible to reduce the cost of building operation.

Although there are many research and pilot installations [7], the majority of power managing systems today are realised using few simple techniques:

- working based on fixed daily profiles,
- setting statically parameters, e.g. one temperature as comfort temperature, not considering different factors,
- working based on expected occupants activities rather than real activities,
- working reactively not proactively – not using the predictions (weather and other).

As described in [17], using general profiles is a simplification that leads to a very averaged behaviour that does not model changeability and unexpected changes in daily routine.

In modern buildings setting the parameters optimally, even when considering systems that use only fixed daily profiles, is not easy and usually requires some time and adjustment. The biggest issue is that users might have different expectations and that those expectations change over time, which is especially difficult in the context of HVAC systems. It is not a simple problem of maintaining constant conditions in time, but to adjust to continuously changing user's requirements. In [5] the problems with users perception of comfort are described, the main problems are: it is changeable, not always well defined (people do not sense absolute temperature) and the group of people in the same room or space can have different expectations.

As presented in [23] thermal sensation and satisfaction are not well described by standard steady state thermal comfort models (ISO 7730).

The standard approaches are considered by many as sufficient, but from the building administrator's point of view the systems should be more self-adjusting and reactive. An additional problem is setting the right parameters when they are so interconnected: humidity influences the sensation of temperature, as well as intensity of light. From the point of view of the building administrator, the systems should detect the presence of people and their actions and consequently set the parameters accordingly.

3 State of art

The most efficient way of saving energy used for HVAC systems of a building is improving the building design (by e.g. renovating) [8]. Elements as isolation, windows and the ventilation systems make a big difference in energy usage [11]. In [19] the change of power usage depending on the building construction (glazing of the windows) is analysed. The considered factors were heating, cooling and light. However, such renovations in some cases might be impossible or too expensive.

The simulation of people in the buildings became a hot topic for research regarding the optimisation of HVAC systems and energy systems. Prior to simulation, knowledge on the behaviour is necessary. This resulted in very advanced projects using a combination of different devices as sensors, Kinect, etc. to first learn the behaviour of people and then set the HVAC systems: [6, 25]. Those systems assume the people's presence in the building, which is a research field in itself. The modelling and simulation of presence and behaviour of the occupants are in reality a set of problems that have a bit different scope. There is the problem of localisation of people, which means perfect tracking of their route, and there is the problem of obtaining general information when people enter and leave some area, but without interfering with their privacy.

The problem of indoor localisation of people is widely researched [31, 7] for the purpose of telemedicine and for supporting the elderly people [4]. GPS systems, although very accurate and widely used in open spaces, tend not to work well in buildings due to too much interference of the signal. Different methods were developed, based on different techniques: infrared sensors [26], radio [10], ultrasound [12], etc. Although such detailed monitoring of people in an office building might be considered in some limited scope, as there might be some situations where such functionality is desired, e.g. in hospitals.

The subject of modelling human behaviour belongs more to the field of sociology. In literature, it is often modelled using techniques from artificial intelligence, e.g. neural networks [3, 13].

People enter and leave buildings in a stochastic way; of course they are bounded by typical working hours, breaks and scheduled meetings, but also they get sick, go on holidays and a lot of unexpected events happen. People change the climate of the environment just by their presence (body heat) and additionally they perform different actions that are also changing the ambient environment, like opening windows, switching on/off devices etc. [23].

Humans have their comfort levels but also a large inertia in taking actions, especially if they require some effort. In [23] the distinction is made between offices with one occupant and many occupants. In the second case the decision upon changing environment (opening window, increasing heating) is done in a democratic way – someone asks for the approval of the action he/she wants to perform and then other people verify their thermal comfort and express their opinion.

In [16] the general state of the art of the modelling of human presence in the building is presented. The article shows the pros and cons of using general profiles, statistical models (discussing the model in [28]) and show their model based on Markov chains. J. Page is an author of a thesis [15] on stochastic models of occupants simulation. The presented papers use data from real offices and buildings.

There are not many works that consider the simulation of movement of people between zones (rooms, areas of the buildings), one of work that analyses this is [27]. In [24], apart from measurements taken by sensors, the Time Use Surveys (TUS) are used. TUS are fairly simple surveys filled out by the occupants of the building, gathering detailed information about what people did. They are in the form of diagrams where users mark which activities were performed where and when, or they may also be a set of questions about the frequency of performing some actions. The paper presents that this is very good source of data about people using the equipment and gives insight about the reasons of people behaviour.

There exists a number of publications that use the multi-agent models of occupation in the buildings. They are very suitable for simulation of social behaviours. In the agent paradigm, agents are entities that work autonomously in their environment [29]. The multi-agent models for occupancy simulation are very advanced, using a stochastic approach to model people's behaviour. The most advanced work is performed by the teams of Robinson [24] and Liao [9].

4 Simulation of occupancy in office buildings using profiles

The author of this report was working in development of multi-agent system for power balancing [22] which required simulators for energy production and consumption. The methods used for simulating power consumption indirectly simulated human actions in the modelled building. That method could be adjusted to be used as an occupancy simulator in the office building.

To simulate the operation of electric equipment in a work place, a profile model was developed [21]. The method divides devices into four different categories, which are used to determine profiles that match different usage patterns. These approaches model not only how frequently a device is switched on or off, but also when and how it uses power. The four profiles are:

- Daily Profiles – approximates the function of energy usage of the device during its operation. They are obtained from real measurements and are applicable for devices (or group of devices) that have stable and well-defined work cycles. Daily profiles define the average, typical behaviour and are not suitable to describe events that happen not regularly or that happen randomly. They are useful for devices that are scheduled automatically or happen at regular times.
- Probability of activation – incorporates the probability of activation to generate the load profiles: in this case the approach is not using the total power consumption at certain time of the day, but considers the probability of switching the device on and off at a given time. The list of time periods with the associated probability is called here the probability list. For each case, at least two probability lists are needed: one to model the probability for switching on the device and one to model the probability for switching it off.
- Rule driven – rules describe the statistical properties of activation of the device (its duration, probable time of activation, maximum power and variance). The simulator interprets the description of the rule and uses a pseudo random Gaussian number generator to generate the load profile of a single device. This type of description might yield a large variability in consumption generation, but this is the expected behaviour.
- Combined rules with single activation – the combination of rules with single activation approach allows for modelling devices that are switched on at some point in time (defined by the rules), but then show a more complex load profile (defined by the single activation profile).

This approach can be used to simulate the occupancy of the people. Depending on the real data the probability of activation profiles seem to be the most promising in efficiently simulating the arriving and leaving people to and from the building. The base for simulator data has to be the measured times of arrival and leaving of people from zone (zone can be a building, a room, etc.), based on gathered data a statistical distribution can be calculated for few types of people. Such distribution can be used to create the probability of activation profiles and rules. The profiles for people with regular working hours and rules for short-time visits in the building. That can give a occupancy generator that would reflect the statistical behaviour of people .The profiles should be dependent on the day of the week – presence of people on Monday might be different than Tuesday and it is almost certain that the behaviour changes in the weekends. Such simulator will not properly reflect the long-time absence, like holidays, sick leaves, etc.

5 Conclusions

The research regarding the simulation of occupant presence is very advanced. As presented in previous sections the base for all simulation models are real data that were gathered for the space that will be used for simulation. Without the real data it is not possible to adequately choose the probabilities for stochastic models or create profiles. On the other hand, having sufficient profiles can be the base for testing and setting parameters of HVAC systems without the need to create the simulator. The method applied should be adequate to the problem it should solve, in many cases simpler methods can give good enough solution to verify the system.

In this work the use of simulation method for energy consumption as a occupancy simulator was considered. It can work well providing the real measurements are the source of probability profiles and rules. The method requires creating separate profiles for weekdays and weekends and will not represent the periods of long absence. It is possible to extend method as in [16] to treat the long holidays as a special case scenario.

The occupancy simulators are in the majority still limited to a number of zones and are usually not considering the problem of property and control [24] – the systems are not reflecting that only a limited number of people use a machine or are entitled to change environmental parameters in the office. There are also projects to use the data gathered from personal sensors in a way not to disturb the privacy of the people, which might be the future main source of data for HVAC systems.

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