Optimisation of Energy Consumption in Buildings through User-Identification




OSMAN AKYILDIZ
University of Stuttgart,
Institute for Building Energetics,
Stuttgart Germany
osman.akyildiz@ige.uni-stuttgart.de

ANDERS BERG
University of Stuttgart,
Institute for Building Energetics,
Stuttgart Germany
anders.berg@ige.uni-stuttgart.de

TOBIAS HENZLER
University of Stuttgart,
Institute for Building Energetics,
Stuttgart Germany
tobias.henzler@ige.uni-stuttgart.de

KONSTANTINOS STERGIAROPOULOS
University of Stuttgart,
Institute for Building Energetics,
Stuttgart Germany
konstantinos.stergiaropoulos@ige.uni-stuttgart.de

The occupancy of buildings constantly changes. Typically, occupancy profiles from standards or known data are used when determining the energy demands of a building. This often results in a discrepancy between the actual occupancy of rooms and the occupancy used to determine the energy demands of the building. Consequently, the energy usage in buildings can differ significantly from the energy needed to maintain thermal comfort within buildings.

The increased use of mobile electronic devices makes it possible to determine the occupancy in individual zones. This data can improve the energy-analysis of individual zones of the building. With the help of occupancy data, the planning of a building's energy demand, as well as the buildings energy consumption during operation can improve.

In the research project „Building optimisation through user-identification" funded by the German Federal Ministry for Economics and Technology (BMWi, FKZ: 03ET1428A), an application is being developed that determines the occupancy of individual zones. The application will be tested in an office building and the influence of occupancy on energy demand will be determined by building simulation. Additionally, different approaches to building optimisation will be researched – intelligent building control should be able to learn and predict the occupancy profiles in zones. Once the occupancy of the building is learnt, the operation of the building can be adjusted accordingly.

Occupancy of Buildings

The occupancy of zones depends on a variety of factors – within a company, different branches and departments may vary significantly in their building usage. The level of employment (full-time, part-time), the number of days absent from the work-place (holidays, business trips, sick leave) and the type of office (single office, group office, open-plan office) are just some examples of the factors influencing occupancy.

Within office and residential buildings, the distribution and number of hours of daily occupancy, as well as the heat gains from people and devices varies. In **Figure 1**, the cumulative number of occupancy hours (people present multiplied by hours present) is shown. In **Figure 2**, the cumulative heat gains through people and devices are shown for a work day in a single office.

Depending on the chosen standard, the calculated energy demands of the building can vary significantly (**Figure 1** and **Figure 2**). In **Figure 3**, the average level of occupancy of a typical single office on a work day is shown and compared to the norms. The occupancy profile is taken quarter-hourly during a working week (Monday to Friday) and averaged to get the level of occupancy during a week.

User-Identification

The user-identification application is being developed in collaboration with the company Indoo.rs GmbH. The occupancy identification application for the mobile phone, works with Bluetooth. Divers Bluetooth transmitters, also named beacons, are positioned in zones. These beacons are net transmitters. Since there are several beacons in each zone, any chosen reference point has a characteristic Bluetooth signal. It is therefore possible to calculate the position of a mobile phone or user in a room. This is done with the help of a positioning map, generated by an algorithm of the company "indoors". On the positioning map, each reference point corresponds to the characteristic Bluetooth signal of that point. The positioning map is transferred to the application and used to determine the occupancy of the room online.

Data Protection

With the help of the Institute for Business Rights at the University of Kassel, a data-protection plan is being developed, that fulfils data-protection requirements. Currently, the German "Federal Data Protection Act" and other data-protection rules are in place and will be adhered to. As of the 25-05-2016, the European "General Data Protection Regulation" is in place, and is effective as of the 25-05-2018. The aim of the General Data Protection Regulation is to have a consistent data-protection level within the EU. One important legal requirement – the anonymity of the data processed – will be possible with the application for user-identification.

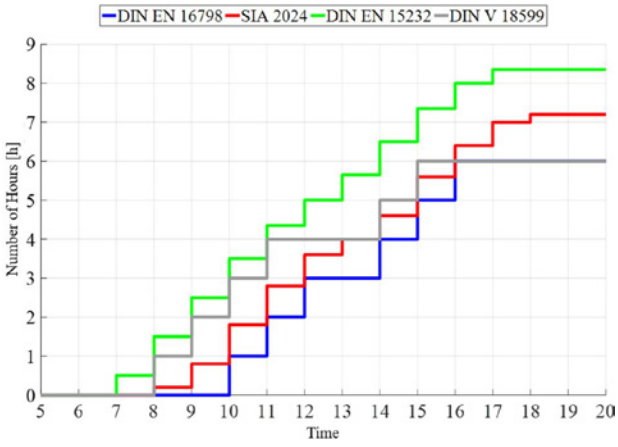

Figure 1. Cumulative Number of Occupancy Hours for a Single Office.

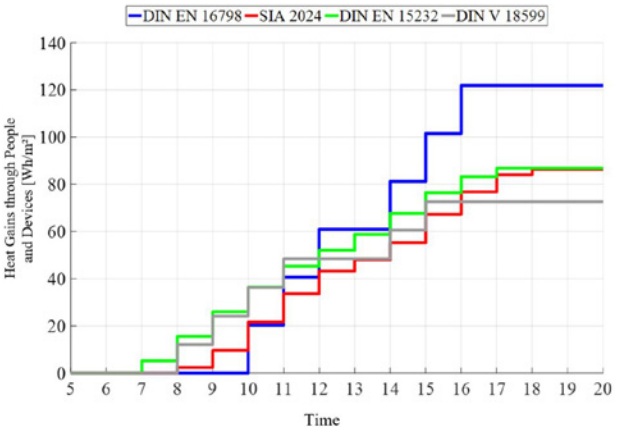

Figure 2. Heat Gains through Devices and People for a Single Office.

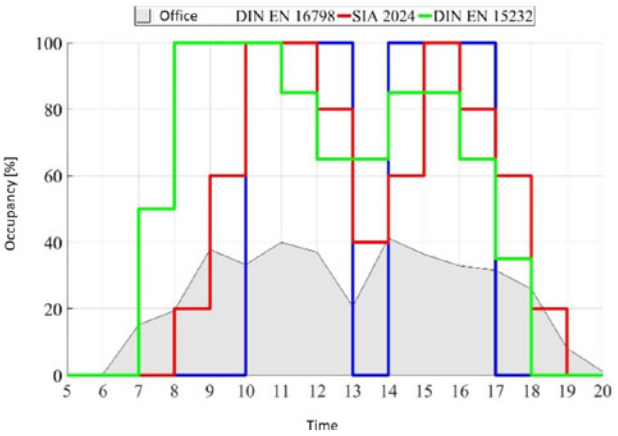

Figure 3. Comparison between a Single Office Occupancy and Occupancy from Standards.

Technical Implementation

The application will be used and tested with mobile devices in office buildings of the Ed. Züblin AG in Stuttgart. The commissioning will start at the beginning of 2018. The recorded occupancy profiles will be compared with the data from existing occupancy detectors and the occupancy profiles from norms. This information will be used to determine the influence of occupancy on energy usage. The recorded occupancy profiles make it possible to better understand the usage of buildings and the user requirements within buildings.

Predictive Systems

Energy-savings can be achieved by adapting the climate control in rooms to suit the occupancy patterns. For example, it is possible to control the climate in meeting rooms when they are in use. Offices should be pre-heated/pre-cooled before the workers are expected to arrive. An array of optimisation possibilities is imaginable. The learning and prediction of occupancy is essential for the implementation of these strategies. The occupancy profiles make it possible to determine the time-frames in which the climate control should be active. The important question of when and how to best pre-condition buildings so that the prescribed room temperatures are met when the building is occupied while minimising energy consumption remains. Given the discussed information, static user-profiles are not the optimal solution. Furthermore, the ambient temperature and solar radiation (the main factors contributing to heat transmission through the building) change daily and throughout any given day. As a result, the buildings and its climate control facilities will have different pre-conditioning times.

To design a robust application which caters for a wide range of scenarios, predictive-control will be used. The main advantage of this approach is that the system can learn continuously during operation. Correlations between input and output data are learned, which allows the system to predict the thermal behaviour of the building. A data set from a simulated building was learnt by such a system. If the control of the room temperature is learnt according to outside temperature and solar radiation, the inside temperature is correctly predicted to an error of max. ± 1K -see **Figure 4**. The building is heated by a heat-pump and an under-floor heating system with their own control systems. It has been demonstrated that such a system is able to deal with multiple links between complex inputs, and accurately learns the thermal behaviour of the building. The influence of occupancy has yet to be learnt by such a system.

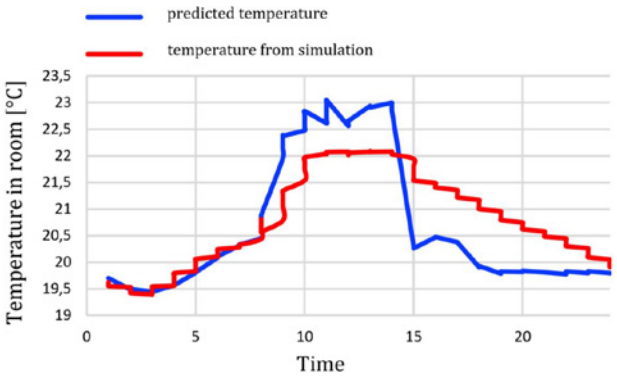

Figure 4. Temperature profile of Room Temperature - Comparison between Simulation and Predictive-Control Model.

Outlook

The field test of the user-identification application starts at the beginning of the 2018. Various configurations of the application will be examined. Parameters such as the time interval for the occupancy checks will be varied to find out how often the occupancy must be recorded to maintain accurate occupancy profiles. One important aspect for the application is to avoid fast battery discharge of the mobile device.

In future, the predictive-control approach should learn the influence of the user on energy usage. The data from the field test should supply a suitable base to this end. The findings of will derive possible application scenarios for user-identification. ■

References

[1] DIN EN 16798 - energy performance of buildings, draft standard, German edition, July 2015.

[2] EN 15232:2012 - Energy performance of buildings - Impact of Building Automation, Controls and Building Management; German version.

[3] SIA 2014 - room operation data for energy and building technologies, swiss norm.

[4] DIN V 18599:2016 - Energy efficiency of buildings - Calculation of the net, final and primary energy demand for heating, cooling, ventilation, domestic hot water and lighting.