Abstract

Occupants’ behavior could bring significant impact on the performance of built environment. Methods of analyzing people’s behavior have not been adequately developed. The traditional methods such as survey or interview are not efficient. This study proposed a data-driven method to analyze the occupants’ behavior, supported by a specific case of analyzing people’s adjustment to ventilation system in a Dutch community. In the individual level, to analyze the motivation of a single person, a logistic regression based approach was proposed to classify occupants’ behavior of increasing/decreasing the ventilation flow rate and then reveal the motivations behind. In the community level, the behavior motivations derived from different occupants were compared. Three motivational behavior patterns, namely the environment-driven type, the time-driven type and the mixed-type were summarized. The proposed mining method is useful to discover and develop occupant behavior models.

1. Introduction

The energy consumption of buildings depends not only on the deterministic aspects such as building physics and design of HVAC systems, but also on the stochastic aspects such as occupants' behavior. However, so far the occupant behaviors have not been adequately modeled. Consequently, field test studies have shown discrepancies between real and simulated performance of building [1,2]. In the frontier of intelligent building research, one of the...
most important features that could indicate a building to be ‘intelligent’ is effective interaction with its occupants [3]. With a better understanding of people’s behavioral pattern, the building control system could generate tailored strategies for its occupants. Therefore, it is critical to understand occupants’ behavior and their motivation from real records.

De Kroeven in Roosendaal is a housing stock built around 1964. Between April 2010 and April 2011, it was completely renovated on the basis of passive house principles. As a result, the energy consumption should decrease 60%-70% compared with before [4]. After the renovation, to test whether the presumed performance has been reached, a monitoring program was launched. Between the year 2013 and 2015, sensors were installed in 10 experimental houses to record various of information including the domestic energy consumption, indoor environment as well as people’s operation on light/ventilation etc. A part of this database, introduced in Table 1, is used to conduct the study introduced in this article.

Table 1. Specifications of the De Kroeven monitoring program database

<table>
<thead>
<tr>
<th>Category</th>
<th>Items</th>
<th>Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather Condition</td>
<td>Average Temperature [°C]</td>
<td>1 hour</td>
</tr>
<tr>
<td></td>
<td>Average Relative humidity [%]</td>
<td>1 hour</td>
</tr>
<tr>
<td></td>
<td>Average Irradiation [W/m²]</td>
<td>1 hour</td>
</tr>
<tr>
<td></td>
<td>Average Wind speed [m/s]</td>
<td>1 hour</td>
</tr>
<tr>
<td>Indoor Environment</td>
<td>Indoor Temperature [°C]</td>
<td>3 min</td>
</tr>
<tr>
<td></td>
<td>Relative humidity [%]</td>
<td>3 min</td>
</tr>
<tr>
<td></td>
<td>Concentration [ppm]</td>
<td>3 min</td>
</tr>
<tr>
<td></td>
<td>Ventilation System Supply Air Temperature [°C]</td>
<td>3 min</td>
</tr>
<tr>
<td>Occupant Behavior</td>
<td>Increase/decrease ventilation flow on control panel</td>
<td>/</td>
</tr>
</tbody>
</table>

The occupants’ interaction with the ventilation control panel is chosen for the case study. The following two research questions listed would be answered.

- **Question 1** What is the motivation for an occupant to increase/decrease ventilation flowrate?
- **Question 2** For different occupants, whether do they behave in the same way?

2. Methods

Fig. 1 shows the schematic diagram of the data mining-based method. It describes generally how will the data stream ‘flow’ throughout the whole process and defines the basic blocks and their own functionalities.

Firstly, the related dataset stated in Table 1 was extracted from the monitoring program database, including weather data, indoor environment data and occupant behavior records. After essential data cleaning and mapping, the logistic regression model was then trained to find the motivation combination. Finally, the motivation sets from different people were compared and grouped into several occupant profiles.

To find the reason why people adjust the ventilation could be seen as a feature selection question in the perspective of data mining. Mathematically, it’s possible to build a model to predict people’s behavior under a certain circumstance and then quantitatively evaluate the importance of each feature. L1-regularized logistic regression is a robust solution to this purpose by practice.

Up to the community level, comparing different samples and grouping ones with similarities is called clustering in the data mining domain. This kind of algorithms, such as widely-used K-means, could group different samples into several clusters with the best optimized in-cluster similarity and inter-cluster difference.

In the following of this section the technique mentioned will be briefly introduced. Logistic regression [5], despite its name, is a linear model for classification rather than regression. It is also known in the literature as logit regression, maximum-entropy classification (MaxEnt) or the log-linear classifier. This is a standard linear regression formula

$$ h_\theta(x) = \theta^T x $$  \hspace{1cm} (1)

where x is a series of features, it is a vector containing coefficients for each feature and represents the regression
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