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Building energy data analysis by clustering measured daily profiles

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Abstract

Nowadays, new methods for the determination of energy efficiency in buildings can be applied since highly-resolved monitoring data of HVAC (heating, ventilation and air conditioning) systems are available. The presented method aims to aggregate similar daily profiles of HVAC-variables into behavior patterns. For the method`s validation, one-year monitoring data from a renovated single-family house have been analyzed. The results show that the daily profiles of different HVAC variables are usually aggregated into 4 to 8 groups of typical and untypical behavior patterns. Obtained behavior patterns were examined more closely and pointed out a performance gap for several systems.

Keywords: building energy efficiency; data analysis; performance gap; clustering; daily profiles

1. Introduction

Since approximately half the primary energy consumption in Switzerland occurs in buildings [1], improving the energy efficiency of buildings is essential in order to reach the goals of the Swiss Energy Strategy 2050 [2], which aims to avoid energy waste and slow down climate change. Around 60 % of the energy used in buildings is needed for heating. The rest relates to lighting, home automation, ventilation and climate systems etc. Decreasing losses (both on the electrical and thermal sides) will obviously increase the efficiency of a building. Thermal losses of the building can be decreased by improvements of the insulation, airtightness, installation of mechanical ventilation systems with heat recovery etc. To decrease electricity consumption, the energy efficiency of operating equipment and lighting systems may be increased or their working time can be optimized. The increase of the building energy performance can also be achieved by improving energy-related occupant's behaviour.

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In order to find ways to increase building energy efficiency, on-site measured data is needed. With the rapid improvement of IT-technologies and increased measurement capabilities, it is now possible to capture and store large quantities of data with a high resolution (time steps of minutes or below) for long periods of time (years and decades) [3]. A range of statistical methods were developed and successfully applied for the analysis of monthly or daily energy values [4]. However, analyses of monthly or daily aggregated electricity or heat consumption do not provide much information about users' behaviour efficiency (for instance, manual control of the lightning system) or about the efficiency of the separate systems [4]. In this case, the values only reflect the sum of the influence of the user behaviour and the efficiencies of the building's components. With high-resolution data, distinctions can be made more clearly. The authors of the present research suggest that processing of the energy-related large amounts of data should focus on the definition of the different behaviour time patterns - sets of similar daily measured profiles of the system variable. Example of such behaviour patterns can be electricity load profiles of the office rooms during standard working day or weekend. Post-analysis of each obtained pattern with additional information can show, whether the system is optimized in terms of energy use or not, and therefore, answer the question about building performance.

Nomenclature

ANN	Artificial neural network
SOM	Self-organized map

2. Aim of the present study

The aim of the present study was to develop a practical, semi-automated methodology to extract behavior time patterns of different building systems from large quantities of consumption data.

After reviewing the relevant literature in Chapter 3, the methodology description is presented in Chapter 4. In Chapter 5 the results of the case study are presented. A summary is given in Chapter 6.

3. Literature overview

The methodology proposed in this paper relies on well-known statistical approaches such as clustering. Clustering methods aim at forming groups of similar scalar or vector units, i.e. of measured load profiles. Clustering methods can be divided, in general terms, into hierarchical, nonhierarchical, geometric, and others [5]. Clustering methods based on artificial neural networks (ANN-clustering) [6] form a separate class, since for nonhierarchical method – except ANN methods – the final number of behavior patterns must be known beforehand. However, even with ANN, the *maximal* possible number of clusters should be set beforehand.

According to [5] the first model of the artificial neural networks (ANN) dated from the 1940s [7], which was explored by [8], who proposed a model based on the adjustment of weights in inputs neurons. However, only in the 1980s the ANN started being more used.

According to [6, 9], today clustering methods are available in software functions that are well developed and robust, if the input data is clear enough (distinct difference between patterns) to lead to the same clustering results with different initial conditions.

In one approach, the electrical load profiles of different buildings have been compared to each other, in order to group them continuously and coherently in a way that the profiles in one group are similar and distinct to the profiles of other groups [10]. In this case, hierarchical clustering of measured electrical daily profiles of different buildings was used. This algorithm was tested on 120 measured load profiles of tariff customers and 18 groups were determined by the clustering. Most profiles (about 70%) could be classified into four representative groups: administration (schools, banks, insurance companies); two-shift workday; commerce and production; casinos and cinemas.