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Advocating the use of visual analytics in the context of BMS data

Julien Nembrini[a,c,*], Florian Évéquoz[a,b], Roman Baeriswyl[a], Denis Lalanne[a]

[a] *Human-IST, Université de Fribourg, Suisse,*
[b] *University of Applied Sciences, HES-SO Valais-Wallis, Sierre, Suisse*
[c] *Prona AG, Biel-Bienne, Suisse*

Abstract

A prototype of interactive data visualization is proposed for Building Management Systems (BMS). The aim is to enhance traditional data presentation format such as graphs and tables to support expert users in early open-ended exploration of building data. Based on data recorded over 3 years in a real office building in Switzerland, a case study is conducted involving 12 practicing expert users with engineering background. Both exploratory and qualitative in nature, this evaluation allows to : (1) show the ability of expert users to use advanced visualization tools to derive meaningful conclusions in limited time, (2) demonstrate the relevance of visual analytics results for the building physics field.

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1. Introduction

With the aim to simultaneously minimize energy consumption and maximise comfort, most buildings currently built in Europe rely on a certain level of automation. Standard examples include controlled ventilation, automatic window opening, daylight- or presence-sensitive lighting, sun triggered shading systems, etc., while more advanced "smart buildings" may even include weather or activity forecast based on learning algorithms [1]. This automation is achieved with Building Management Systems (BMS) which typically gather sensor data such as system operation, meteorological data, indoor temperatures, humidity levels or CO_2 concentrations. The sensed data triggers reactions that contribute to maintaining comfortable indoor conditions while saving energy. The effectiveness of this approach, together with corresponding law incentives in Europe resulted in a generalization of such systems, generating as a consequence significant amount of data.

However, many functioning buildings do not live up to expectations in terms of energy efficiency, a phenomenon know as Performance Gap [2]. Reasons are manifold, but include the fact that the optimization of the BMS to a specific building structure and usage is a complex task. Post-Occupancy Evaluations (POE) are standard procedures to assess

* Corresponding author. Tel.: +41-26-300-8474
E-mail address: julien.nembrini@unifr.ch

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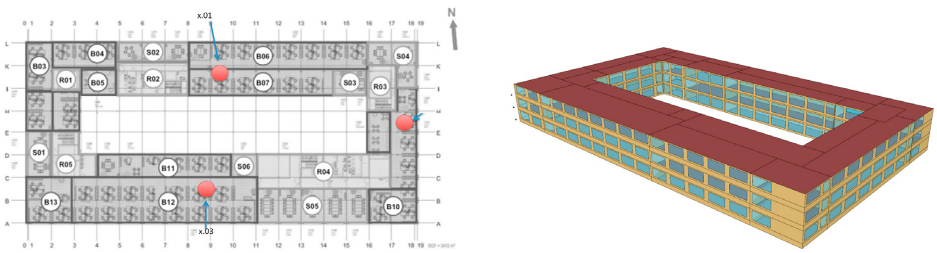

Fig. 1. Case study building: (left) floor plan including room temperature and humidity sensors position (red dots), (right) 3D building view

the BMS operation and to identify opportunities for optimization. In Switzerland, recent regulatory guidelines[1], request the use of BMS and regular POE for large buildings. In this context, the amount of sensor data generated and available represents an opportunity to be exploited: by correlating time series data, faulty system behaviour may be confirmed or ruled out [3]. Such data analysis may be conducted by various expert stakeholders including building engineers or facility operators in areas as various as maintenance, occupant comfort, energy and equipment monitoring, safety and security.

However, the complexity of the installed systems together with the specific dynamics of each building make such analysis an especially difficult task. Thus, the ability to process and represent large amounts of data in a meaningful way for analysis is highly relevant. This is precisely the domain of research in *visual analytics*. This field has reached a mature stage and provides a broad range of generic techniques that have been shown to provide a cognitive aid to analysts in their typical tasks. This body of research is starting to be applied in the building engineering field, with a trend to more interactive and sophisticated visualizations for building automation system. The purpose of this article is to discuss and illustrate with a qualitative experiment the potential contributions of this research field for building physics.

2. Visual Analytics and its application to building data

The discipline of information visualization has been defined by Card et al. [4] as *the use of computer-supported, interactive, visual representations of abstract data to amplify cognition* or by Keim et al. [5] as *the communication of abstract data through the use of interactive visual interfaces*. Its purpose is to transforms abstract data from its original raw state into a visual representation that leads to a gain of insight, rapid information assimilation and allows for the monitoring of large amounts of data [4]. In other terms, it leverages our natural ability to identify visual patterns in images in order to facilitate the cognitively-intensive process of sensemaking from number tables. Analytical needs may not be satisfied by visual representations only: addition of interaction techniques may support the dialogue between the analyst and the data, in a process called *visual data exploration* [5]. It allows the user to directly interact with data, understand trends and anomalies, isolate and reorganize information, and engage in the analytical reasoning process. An example of a generic tool for visualizing multi-dimensional datasets is the *parallel coordinates* [6], which represents an n-dimensional data point as a polyline connecting vertices on n parallel vertical axes, where each axis represents a dimension in the original dataset. The advantage is the transformation of high dimensional geometric properties into simple visual 2-dimensional patterns.

A further development of information visualization is visual analytics [7] that aims to "combine automated analysis techniques with interactive visualizations for an effective understanding, reasoning and decision making on the basis of very large and complex data sets". Typically, visual analytics include tools and techniques that provide data management for large quantities of data, a simplified access to statistical analysis and data mining capabilities, and more generally empowers analysts to help them make sense of massive and ambiguous data and take effective evidence-based decisions.

Buildings are closed dynamic ecosystems whose behaviour is influenced by and generates a vast amount of data. A large share of this data is generally collected by BMS. But the behaviour of occupants inside and around the building also generates large amounts of data, e.g. how they move or interact with appliances. This data can be typically tracked

[1] recent MuKEN/MoPEC, being currently enforced in the regional laws