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Improving Building Performance at Urban Scale with a Framework for Real-time Data Sharing

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Abstract

This paper describes work in progress toward an urban-scale system aiming to reduce energy use in neighboring buildings by providing three components: a database for accessing past and present weather data from high quality weather stations; a network for communicating energy-saving strategies between building owners; and a set of modeling tools for real-time building energy simulation.

1. INTRODUCTION

Many well-developed energy efficiency measures and emerging technologies to reduce energy use in buildings have been available for years. However, adoption of many of these technologies is slow. The reasons include unmotivated building owners, high implementation costs, and operation difficulties.

Due to the relatively low utility cost in the U.S., most building owners are not motivated to improve building energy efficiency as long as the comfort can be maintained. Based on the authors' experience, most of the energy efficiency projects are initiated by some sort of mechanical system failures or degradations in the buildings that cause comfort issues. There is a need for a marketing mechanism to inspire the building owners to go beyond energy and cost savings to implement energy efficiency.

When a building owner starts an energy efficiency project, the implementation can be costly, including the hardware upgrade and labor costs. Most of the measures and technologies require higher quality hardware than today's standard practice uses. For example, the standard sensors used in today's systems cannot provide the required accuracy and reliability of outdoor air temperature and humidity measurement for implementing an enthalpy economizer or an outdoor wet-bulb temperature based cooling tower control strategy. The high quality sensors costs much more than the standard sensors and require significant routine costs to maintain and calibrate. The implementation of an energy efficiency project is also labor intensive. An energy efficiency project typically has three phases: energy audit and planning, implementation, and Measurement and Verification (M&V). Each phase involves heavy labor investment from both the on-site staff and the service provider. There is a need to reduce the implementation cost to make the energy efficiency project more appealing to the building owners.

At the completion of the energy efficiency project, the facility management team takes over the building. However, they usually do not have the deep understanding on the energy efficiency measures and technologies implemented. They would turn some controls back to the original modes that they were familiar with if any comfort complaints arose. As a result, the energy savings diminish over time. There is a need for a tool to inform the facility management team about the degradation of the achieved energy savings and provide them the operational suggestions.

To address the three challenges described above, we suggest that the solution at the individual building level will be expensive and is not scalable. An effective way to scale up the energy efficiency is to promote it at the urban scale.

At the urban scale, buildings are close to each other and share many common features such as microclimates, building functions and occupancy patterns. Some energy efficiency measures for a single building will work for multiple buildings nearby. Weather measurements from one station with high accuracy well-maintained sensors can be shared, in contrast to today's systems where each building has its own poor quality weather measurements.

The potential to reduce energy consumption by the power of harnessing occupants' competitive spirits has been proved in the residential buildings and college dormitory (Behavioural Insights Team 2011; Petersen et al. 2007). The same strategy can be applied to the commercial sector to motivate the building owners. When building owners compare the energy performance of their buildings with the neighbors, a competition is naturally triggered, which can help accelerate the deployment of new advanced building technologies.

In this paper, we introduce a framework to promote the large scale energy efficiency by motivating building owners and reducing the implementation cost through data sharing, and improving the operation through the cloud-based real-time building energy simulation.

2. THE FRAMEWORK

Figure 1 shows the proposed framework. It consists of a server, a weather station network and the client software and the Energy Management and Control System (EMCS) at each individual building. The three components are connected through the internet.

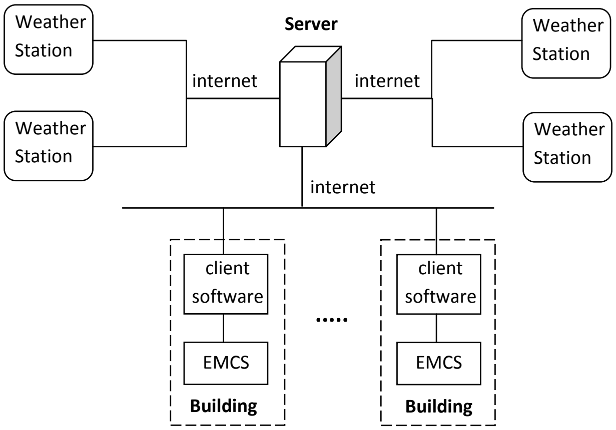

Figure 1 The proposed framework for urban scale energy efficiency

The high quality weather station network provides the measurement for a complete list of weather parameters that are needed for the energy efficiency measures and emerging low energy technologies. All the weather measurements are sent to the server through internet in real-time.

The server provides three main functions: 1) a database to collect and store data, including the weather measurements, the smart meter data from building owners or utility companies, and the building information provided by the owners; 2) a user interface to take the user inputs and view the data; 3) a computational engine to create building energy models, run the simulation in real time and provide the building operators with operational suggestions.

The client software installed in each building serves as a gateway between the EMCS and the server to allow the EMCS to access the data, e.g. the weather, the predicted building performance, the optimal operational suggestions, in the server in real-time.

2.1. Weather station network

The idea of integrating the real-time weather data into the EMCS through internet service is not new (Stunder et al. 2003; Kok 2007; Madsen 2009). However, the current solutions do not provide the measurement accuracy and reliability required by the building industry. Most importantly, none of the existing weather station networks provide all the necessary weather parameters. The emerging low-energy technologies and urban energy systems, such as radiant heating/cooling, demand response, district heating/cooling and renewable energy, require more weather measurements, e.g. global horizontal solar, direct and diffuse solar, wind speed and direction, to ensure their proper operations. In addition, the controls of the emerging technologies and the urban systems mentioned above also need predicted weather parameters to deliver optimal operation strategies. The existing weather forecast technology can predict the temperature, humidity, rain and snow very well, but the forecast model for the solar radiation, especially the direct and diffuse solar radiation, needs further development.

Therefore, the weather station network should not only be able to accurately measure outdoor air temperature, relative humidity, direct solar, diffuse solar, global horizontal solar, wind speed and direction, CO_2 concentration, and indication of rain and snow, but also predict these weather parameters for at least 24 hour ahead. So far there is no single product that can measure all the parameters mentioned above. LBNL had a proof-of-concept demonstration project for the Department of Defense (DOD). In that project, a weather station has been assembled to measure the parameters except the CO_2 and rain/snow (Pang et al. 2012). This prototype can be further improved to address the needs identified above.

Once we have the weather station, the remaining challenge is to determine how many weather stations are needed for a given city and where these weather stations should be installed.

2.2. Data sharing

The building owners log on the server and create the user profile by providing the detailed building characteristics, such as the year built, the location, the square footage, the building type, the occupancy density and schedule, the HVAC system type, low-energy technologies used, and energy efficiency measures. Once logged in, the building owners can generate a detailed whole building model by using the online wizard and download it to their local computers. This energy model is based on the user inputs that represent the design intent of the building.

The building owners can also view their neighbor's information and compare the energy consumption with their neighbors. Based upon the comparison, the building owners can refer to the energy efficiency measures or the low-energy technologies adopted by their neighbors whose energy consumptions are lower than that of their own buildings. The server also serves as a computational engine to provide real-time building energy simulation and optimal continuous operation improvement suggestions. The design intent model takes the weather data as real-time inputs and reports the predicted building performance which is used for the comparison with the actual building performance. Based on the comparison between the measured and predicted building performance, a whole building diagnostic algorithm will be used to provide continuous operation improvement suggestions.

2.3. Client software

Commercial solutions using internet have been developed to access the weather data in real time. One company has developed a communication driver, based on industry software standards (OPC Data Access), for the purpose of accessing weather station and forecasting data for use in the EMCS. Data is then available for use by any OPC Standard compliant EMCS software, such as Automated Logic, Honeywell, Invensys, Johnson Controls, and Siemens.

3. ENERGY MODELING AND REAL-TIME ENERGY SIMULATION

To address the operational challenges facing by the facility management team, LBNL have developed and demonstrated a technique that allows a comparison of building actual performance and expected performance in real time (Pang et al. 2012). When significant differences between the measured and predicted performance are observed, the system can inform the building operator about the presence and location of the degradation. The proposed framework leverages this effort to benchmark the buildings against the optimal performance and provide the operational suggestions.

The optimal building performance is typically represented by the design-intent or the state-of-the-art. In order to evaluate how the building performs as opposed to the optimal performance, a building energy model that represents the optimal performance is needed. There are two approaches for building energy modeling: forward model and data-driven model. The forward model approach utilizes the first principle such as conservation of mass, energy and momentum, while the data-driven model approach relies on experimental data or simulated data from a physical model to train an empirical or black-box model. For the purpose of whole building performance monitoring and optimization, the data needed for a data-driven model typically don't exist. Therefore, only the forward model approach or the data-driven model based on simulated data that generated by a forward model would work in this context.

Most current simulation programs, e.g. EnergyPlus, use the forward model approach. EnergyPlus is a detailed whole building energy simulation program that calculates the building heating and cooling loads, and disaggregates energy end use as well as many other simulation details that are necessary to verify that the simulation is performing as the actual building (Crawley et al. 2001). Because of its comprehensive features and extensive development and verification process, EnergyPlus is selected for the proposed framework.

The key effort of creating an EnergyPlus model is the generation of the geometry model and the building mechanical system model. The modeling process is typically time-consuming and it's unrealistic to build the energy model for each building in a city from scratch. A technique will be developed for rapid building energy modeling at the urban scale. The main idea behind this technique is to extract the common features from building blocks and develop the parameterized building models for different building types, such as large office buildings, shopping malls, small retails, hospitals, schools, and fast-service restaurants. With the development of templates based on the common features, the modeling process is reduced to modifying the free parameters according to the user's input, which is accomplished by an online wizard. Once the model is created, an automatic model validation process will be executed to make sure that the created model is within the allowed tolerance.

Once the reference model is established, it is used for the building continuous operation improvements. The real-time energy simulation technology developed at LBNL is used for this purpose. This technology is able to compare the predictions of a reference building model to the measured performance and analyze the difference to infer the potential operational degradations that cause the discrepancies (Pang et al. 2012). A middleware software acquires the relevant inputs from the server and passes them to EnergyPlus at each time step. The EnergyPlus model runs in real-time and reports the predicted building performance at each time step. Figure 2 shows the architecture of the technology.

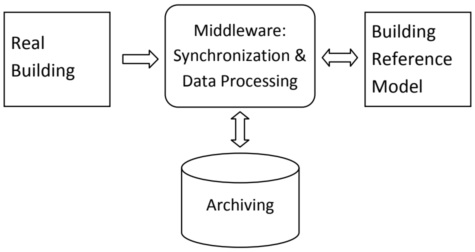

Figure 2 The architecture of real-time energy simulation

4. DISCUSSION

This paper presents a framework that can potentially improve building operations and thus reduce energy use at the urban scale. The keyword for this technology is "share". The building automation systems share the high-quality and well-maintained weather measurements. The building owners share the building information, such as energy use and efficiency measures employed in their buildings. It can be challenging to motivate building owners to share their building information, but recent development of regulations to encourage or require building owners to disclose energy use data would definitely help.

The success of the proposed system can lead to game changing effects in the building industry, not only to energy savings, but also to the infrastructure of building operations in general. It is an effective method that leads to energy savings in the national scale with minimal investment. The proposed system can: 1) improve energy performance of buildings; 2) promote low-energy buildings; 3) facilitate the national energy goal of achieving net-zero energy buildings.

References

PANG, X., WETTER, M., BHATTACHARYA, P AND HAVES, P. 2012. A framework for simulation-based real-time whole building performance assessment. Building and Environment 54. 100-108.

STUNDER, M., SEBASTIAN, P., CHUBE, B. AND KOONTZ, M. 2003. Integration of real-time data into building automation systems. Technical Report, Geomet Technologies, Inc, January 2003.

KOK, R. 2007. Weather on demand - a new way for building automation to leverage real-time weather information. http://www.automatedbuildings.com/news/sep07/articles/kepware/070827030303kepware.htm.

MADSEN, J.J. 2009. Integrate weather data into building automation. http://www.buildings.com/tabid/3334/ArticleID/6841/Default.aspx.

BEHAVIOURAL INSIGHTS TEAM. 2011. Behaviour change and energy use. Cabinet Office, London. http://www.cabinetoffice.gov.uk/resource-library/behaviour-change-and-energy-use

PETERSEN, J.E., SHUNTUROV, V., JANDA, K., PLATT, G. AND WEINBERGER, K. 2007. Dormitory residents reduce electricity consumption when exposed to real-time visual feedback and incentives. International Journal of Sustainability in Higher Education 8. 16-33.

CRAWLEY, D.B., LAWRIE, L.K., WINKELMANN, F.C., BUHL, W.F., HUANG, Y.J., PEDERSEN, C.O., STRAND, R.K., LIESEN, R.J., FISHER, D.E., WITTE, M.J. AND GLAZER, J. 2001. EnergyPlus: creating a new-generation building energy simulation program. Energy and Building 33. 319-331