FM TOOLS TO ENSURE HEALTHY PERFORMANCE BASED BUILDINGS

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ABSTRACT

The paper is aimed at presenting the needs to monitor building performance and a description of tools for the purpose. The need arises mainly from the necessity to observe compliance, and the need to provide consistent performance to the clients of the spaces. As various user groups are utilizing the same performance data to ensure optimal and healthy conditions, the integration of performance data to deliver meaningful and exploitable results for each user needs (1) collection of the relevant data, (2) compilation of data into information, and (3) delivery of user specific information to the correct instance. For this need, a performance sensing system with data management was developed into facility management tool. The paper discusses it's usefulness for coping with performance based healthy facilities. Such tools are becoming necessity for facility management because of the profession is turning increasingly into the provider of performance to meet the user requirements.

KEYWORDS: performance based buildings, healthy buildings, sensing, data management

INTRODUCTION

The necessity for improved performance and condition monitoring in structures arises from the recent performance-based building methodologies. Performance based building (PBB) has come to the fore over the last ten years, when changes in the client – provider relationship were mandated by the World Trade Organization (WTO, 1997) with the 1997 Agreement on Tariffs and Trade - "Whenever appropriate, Members shall specify technical regulations based on product requirements in terms of performance rather than design or descriptive characteristics." The U.S. government has made performance-based contracting mandatory (The USA Federal Acquisition Regulations, 2000). In Europe, there are many initiatives, both at the national and at the Union level, such as the Construction Product Directive, to promote the same end. This necessitates a standardization effort to describe the target performance rather than the structural solution, and has led to developments such as the CIB Proactive Programme for Performance Based Building Codes and Standards (Foliente et al., 1998).

Whether the PBB approach is used explicitly or not, a required performance is always embedded in the building process. It is important for the project delivery team to be able to predict not only the performance of the parts, but also how the whole will perform when all the parts are synthesized (Szigeti and Davis, 2001). During operation, both performance and condition must be monitored with sensors. The statements of user requirements (i.e. according to definitions by ISO, 1984) provide the reference point of a facility or constructed asset, as a complete product. PBB changes the time scale of the contracting process. Traditionally the contractor produces a structure to some stated specifications as to materials, assembly method, finish, etc. mandated by the architect/engineer. Once the building is accepted by the owner, the design/build team no longer plays a role. In the PBB environment the design/build team must warrantee and maintain structural performance to the level stated in the contract, for the extended duration of the contract. This requires measurement, hence sensors.

The two key parameters selected here for the observation of the performance of a building are humidity and temperature. In terms of healthy indoors conditions, hygrothermal performance is essential; it plays a major role in follow-up of the healthiness of a facility. For facility management, optimisation of temperature has also significance for economic aspects, and in a wider context, for the sustainability at large as an energy use issue.

HUMIDITY AND HEALTHY PERFORMANCE

Known critical items for condition and healthiness related performance monitoring are the aspects of humidity and temperature. Hygrothermal analyses have become more important in building design as moisture damages have become one of the main causes of building envelope deterioration. Water and moisture can cause structural damage, reduce the thermal resistance of building materials, change the physical properties of materials, and deform materials. Not surprisingly, moisture problems are the main cause of building damage. It is estimated (Ronald 1994, Bomberg and Brown 1993) that 75-80 % of all the problems with building envelopes, to a certain extent, are caused by moisture. Haverinen (2002) has classified moisture damages. In her cross sectional analyses of moisture findings in the Finnish housing stock she has reported that some 38 % of the detached houses and 26 % of the apartments have notable or significant moisture problems. Similar results are found in other Nordic countries. The presence of home dampness and/or moulds (that is damp spots, visible mould or mildew, water damage, and flooding) was reported by 38 %in Canadian study (Dales et al. 1991). These estimates show that moisture problems are a serious issue and have a strong economic effect. In fact, repair of extensive problems is very expensive. According to estimates by Pirinen et al. (2005), expenses to repair microbiological damages causing health effects, are in the magnitude of 10000-40000 € per case. But even worse are the excessive moisture related health effects on the occupants. The evidence of a causal association between dampness and health effects is strong. However, the mechanisms are unknown, as shown in comprehensive reviews by Bornehag et al. (2001 and 2004). Common symptoms associated with moisture problems are respiratory symptoms, sensitization to house dust mites, asthmatic symptoms or emergency room visits due to asthma as well as tiredness and headaches. Causal association between dampness and health effects shows that avoidance and control of moisture problems should be an essential concern in public health issues.

Hygrothermal analyses are needed to demonstrate the acceptable performance of structures and to construct healthy buildings with good indoor air quality. Hygrothermal models are useful tools in assessing the heat and moisture performance of building envelope systems and optimizing these systems for maximum hygrothermal performance and longer service life, but they also need correct climatic data for boundary conditions. Moisture conditions in building envelopes depend strongly on indoor and outdoor climatic conditions. Standardized methodology for dynamic moisture design and hygrothermal loads does not exist yet (Kalamees, Vinha and Kurnitski, 2006). Therefore sensing offers a way to both observe the actual hygrothermal performance and monitor safety both in structural and occupational sense.

As the excessive humidity is a known degradation factor, and in particular a major contributor to the adverse heath effects both in residential and other indoors spaces, its monitoring and resulting control are a major technical performance factors.

ENERGY AND ECONOMIC PERFORMANCE

A key economic performance indicator of a building is energy consumption. According to the common European energy policy Green Paper, the major guidelines of the energy policy are sustainable development, competitiveness, and security of supply (European Commission, 2006). To achieve that goal, the consumers need to be motivated and able to make choices. A large fraction of the potential savings from rational use of energy can be attained if governments give the responsibility for implementation to the proper actor. A proper actor is one who does not suffer a financial loss due to implementation. To be able to act rationally, the actual energy consumption and costs needs to be known to the decision makers. If the provision of the needed information comes with ease and at minimal cost, the demand-side management decisions can be guided to actual energy savings.

For electricity, production and consumption is simultaneous – it is not readily storable. In the Nordic countries, the peak consumption of electricity is reached only on a few winter days of the year, namely the coldest morning and afternoon hours. In many industrialized countries with warm climate, the peak consumption occurs on the hottest summer days as a consequence of cooling systems operating during times of high consumption of electricity for other purposes. There are obvious reasons – high peak demand requires commissioning expensive power plants to be used only for peak periods. (There are also elaborate pump-storage and compressed air schemes, but they also are enormously expensive.)

In California, peak load is strongly dominated by air conditioning, followed by commercial lighting and miscellaneous. Residential air conditioning alone accounts for nearly as large a portion of peak load as the entire industrial sector (Brown and Koomey, 2003). Although high rates remain a focus for the state, the challenge of ensuring adequate electricity supplies, especially during high-demand peak periods, has emerged as the critical issue. The 2004 Energy Report Update expressed serious concern over dangerously low reserve margins, especially in light of the expected retirement of aging power plants.

Demand rates are usually cheapest during the hours between 10 PM to 7 AM, when grid demand is lowest. In Finland are also specific winter rates valid from the beginning of November until the end of March. The intention is to cut peak consumption rates, in particular during the coldest periods, with the incentive of cheaper night time rates. Preferably, domestic heating will be mostly during the night, with massive structures and hot water containers to store the heat.

The use of locally measured data has the potential to spur a reduction in electricity consumption during the peak hours. In Finland this means reduction of heating and unessential electronic equipments during the coldest times. In California this would cause lower consumption of domestic electricity during the hottest hours. To truly motivate the users, there needs to be clear real time indication of both the consumption and its cost.

A TOOL TO MANAGE THE PERFORMNCE OF A FACILITY

A facility manager is a professional decision-maker. Informed decisions rely on originally correct data reduced into valid information. This encompasses a process of data collection, reduction of data into relevant concise information, and presenting the information in a user friendly manner. Notably the same data can be processed for various needs and displayed according to the specific interests of a particular user. A powerful facility management tool needs to be able to handle collection of massive amount of data and communicating it as information to the facility manager (and other actors of the facility use and maintenance).

Sensor data collection

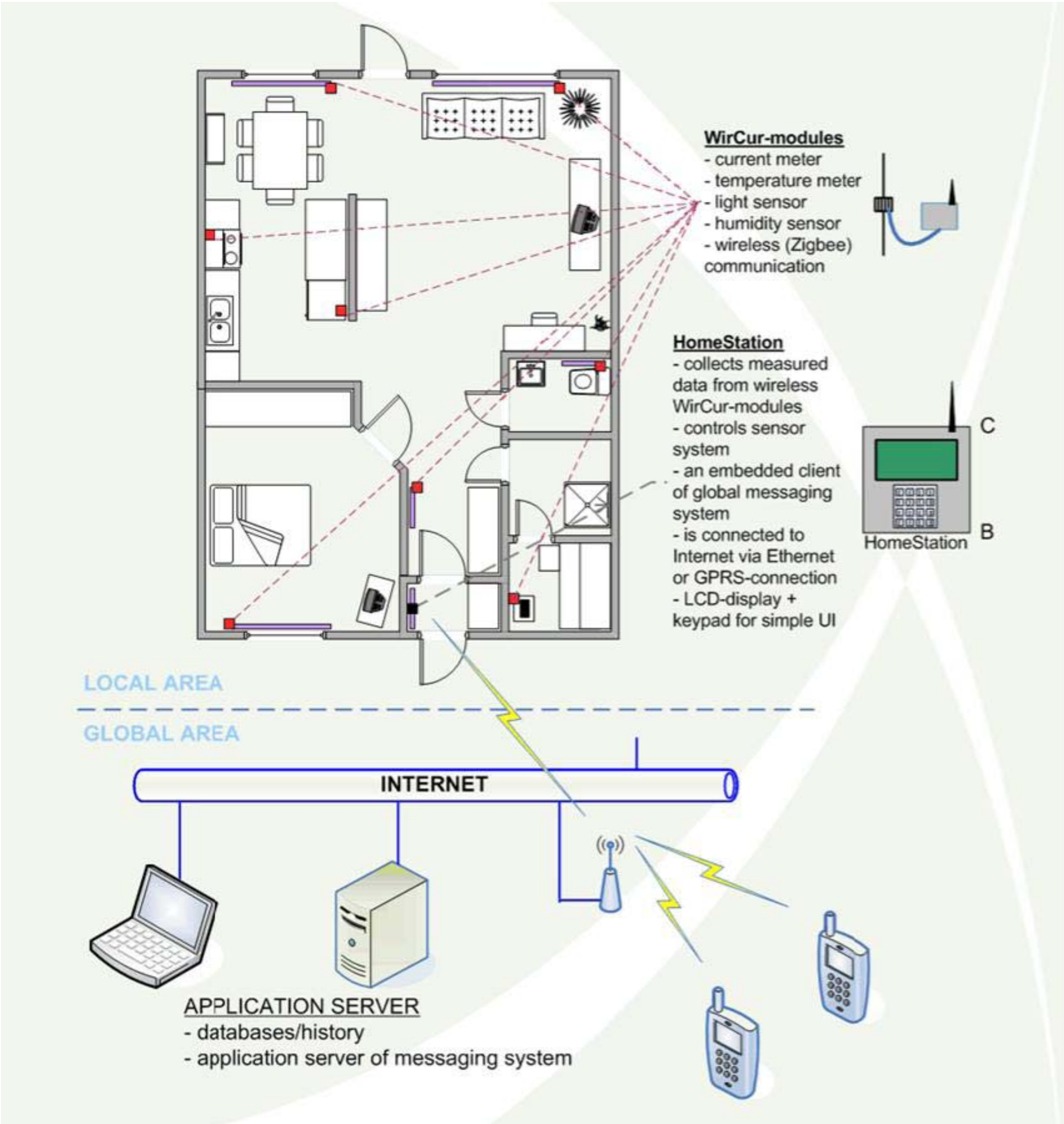
Dense sensing offers a powerful mechanism to observe the actual hygrothermal performance, building safety in the structural and occupational sense, and power consumption. In order to monitor hygrothermal conditions in real time and with fine granularity, VTT (Technical Research Centre of Finland) commissioned a Mote called WirCur. This is a multi-sensor Mote, including electric current flow, temperature, humidity, and illumination transducers, and data transmission via Zigbee wireless. This device can be manufactures for a reasonable cost since MEMS (Micro-Electro-Mechanical Systems) technology makes available inexpensive and accurate transducers to measure all these variables. For instance, hygrothermal data is extremely simple to measure with current sensors, such at the Sensirion SHT15 (CMOSens®) relative humidity sensor (range 0 - 100% rH, accuracy ±2%) which also measures temperature measurement with an accuracy of ±0.3°C, linearizes and temperature compensates the data, and digitizes it, at a cost of $12. Illumination sensor is commercial Osram SFH2400FA photodiode connected to 10-bit AD-converter of multisensor node. The described WirCur Mote can be utilized for several needs. It is a tool for observation of performance compliance enabling proactive condition control for several environmental variable, and serves as a source of data for optimizing energy consumption. The same data can be refined into relevant information for various user groups, with user interfaces essential to enable genuine decision support.

Utilization of the data for facility management

The data is accordingly to the set of sensors. In this case, sources of data are (1) multisensor nodes (WirCur, including electric current and temperature meters, humidity and illumination sensors, a electric current meter, and wireless Zigbee communication) which measure environment conditions and transmit measurements to a building terminal over wireless or wired communication or (2) individual sensors (selected upon special needs) which are connected directly to the building terminal.

The data flow from the sensors occurs as wireless short range radio communication between the multisensor nodes and the house terminal, where the data can be stored. (The multisensor nodes may be connected to the terminal either via wireless or wired media, and individual sensors can be directly connected to the terminal.) The terminal collects and saves the measured data from multisensor nodes (or individual sensors) and transmits data to the server (figure 1). The communication with the server is either via Ethernet or GPRS (General Packet Radio Service) connection using standard XMPP (Extensible Messaging and Presence Protocol) instant messaging protocol. The server saves the measured data to a database. The data management (command and control messaging) is using standard hybrid person-to-person messaging protocol XMPP.

Figure 1. Data collection with sensors and utilization with different applications i.e. through PC or mobile phones.



Different terminals or equipment are same level peers of the system as the data storing terminal, also one or more software agents for autonomic computing and data saving to database are same level peers of the system. WWW (World Wide Web) command and control UI (user interface) is provided using software agent as a gateway. Communication between peers is routed confidentially and securely. Dynamical WWW pages offer different instances of the saved data (i.e. through PC, pocket PC, mobile phone), as e.g. graphs of room temperature during the past three months

The use of sensor output data has i.e. the potential to reduce electricity consumption during the peak hours. User interface with display to see the consumption and the cost of the consumption may direct the user decisions towards allowing deviation from the optimal comfort zone. In Finland this would mean reduction on heating and reduction of redundant use of electronic equipments during the coldest winter period. In California this would cause lesser domestic electricity use for hottest time. To truly motivate the users, there needs to be clear real time indication of both the consumption and its cost.

The WirCur Mote is not unique in the sense that a similar operating sensor system has been developed and utilized at the University of California, Berkeley (Wright, 2006). Simultaneous to the development of WirCur, Wright spearheaded a CITRIS project for the California Energy Commission to optimize domestic energy use. The balancing of occupant comfort versus energy price has been made simple with user-friendly displays and a preference slider for adjustments of conditions. Within each house, the electricity meters are capable of receiving real-time electricity tariffs and automatically initiating responses that reduce overall energy cost, while being responsive to occupants' preferences. The meters also act as a platform to support other sensors and actuators, with a good portion of the development effort spent on providing a user interface that is clear and intuitive to typical residential users (Arens et al., 2005). The system will be rolled out state-wide beginning in 2008.

CONCLUSIONS

PBB evaluations can and should be performed in a routine manner. In practice, evaluations are often made only as part of commissioning or shortly thereafter, or when there is a problem. In order for any measurement and evaluation to be truly meaningful, they should refer to explicit requirement levels against which they can be judged. The performance of a building has some physical factors that serve as principle indicators. For condition monitoring, temperature and humidity are key indicators, which are also major factors for performance evaluation. In the use phase, maintenance and energy consumption are the main cost components, and directly relate to user comfort and services. All these items can be objectively evaluated by sensor data. In all, the only way to quantify performance is to measure performance indicators. This requires proper sensors and measurement techniques. The wider the variety of performance metrics that need to be determined, the more sensors are needed. This requires small, inexpensive sensors placed in dense arrays, with simple communications (Glaser et al., 2005).

Sensing is becoming an essential element in facility management, from procurement to operation. Its importance is obvious for validating of the outcomes in performance based commissioning and construction, which is being pushed by US and EU. Sensing provides a tool to observe the output of the whole system in actual operation, which is the actual target of commissioning and continuous commissioning. In case of disputes, all parties benefit from sensor data.

The future scenario for the construction industry is that increasingly more the clients will purchase the performance of the structures in stead of the physical means for providing it.

The decision making of the operation phase then becomes an integrated part of the initial design and construction. When operation period is taken under consideration, changing on circumstances became more critical. Sensor data is becoming essential for professional operation of built environment. The tools to deliver the sensor data refined into user specific information will be an element of facility management.

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