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OPEN UP THE BUILDING

Architectural relevance of building-users and their participations

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Abstract. As buildings have become more advanced and complex, our ability to understand how they are operated and managed has diminished. Modern technologies have given us systems to look after us but it appears to have taken away our say in how we like our environment to be managed. The aim of this paper is to discuss our research concerning spaces that are sensitive to changing needs and allow building-users to have a certain level of freedom to understand and control their environment. We discuss why, what we call the Active Layer, is needed in modern buildings; how building inhabitants are to interact with it; and the development of interface prototypes to test consequences of having the Active Layer in our environment.

Keywords. Active layer; participation; sensors; interface; BIM; BMS.

1. Introduction

Architects generally design spaces for people to live and work in. Some spaces are designed for specific and well-defined needs while other spaces are more open and designed to cater to unknown needs or for not well-defined groups of people that may change routinely or periodically over time. The aim of this paper is to discuss our research concerning spaces that are sensitive to changing needs and that allow building-users to learn and take control of their own environments.

Lynch (1958) discussed that environments could be designed to 1) offer wide range of choice, 2) be plastic, or 3) be adaptive to provide flexibility for future change. While his main interest was to discuss benefits of environments that can continue to adapt as requirement changes over time, our key interest is to investigate how an environment can be plastic in a relatively short period of time. To be more specific, our interest is in how building-users can actively participate in customising and fine-tuning their environments to their liking in a fluid and

interactive manner. This paper addresses three key issues that prevent building-users from becoming active participants of their environment.

The *first* issue is that the building information which modern buildings hold is largely inaccessible and invisible to their occupants. Although many of them are monitored by an array of sensors, the information generated by them is typically kept for the facilities management (FM) experts. Either the building information model (BIM) and/or building management systems (BMS) hold all necessary data but there is, typically, no interface that allows the occupants to access and decipher the information held. An explanation of BIM, its history and development is given by Eastman et al. (2011). There are various types of information that can benefit and educate occupants to use their environment more effectively and comfortably but our study identified that there is little research conducted to investigate how it can be opened up for the benefit of them. BMS is not open to building occupants because they are not designed to be handled by building-users but we speculate both managers and occupants will greatly benefit from a certain level of open access if it were available in the right way.

The *second* issue is that information held by BIM or BMS does not necessarily bring much benefit to building occupants if the means for them to access the information were not designed specifically for them. The building information available for experts is not necessarily useful for untrained users. Understanding the information about their building and responding appropriately and effectively without causing problems is very likely to be a challenge for most of them. As identified by Brown and Cole (2009), modern and so-called green buildings offer higher availability of personal controls but often, users are not capable of understanding or are not informed of the state of their building or how it works despite their interest to operate their building. We propose this issue can be addressed by providing appropriate user-interfaces for the systems as well as a layer of additional infrastructure. Our current research focuses mainly on how information could be open to users, how they could recognise useful information about their environments in real-time and how they could respond or take action to fine-tune the environment or to plan future changes.

The *third* issue is that the action taken by building-users could conflict with the FM strategies. Building-users should, therefore, be given tools and systems developed specifically for them to take action if they were to be given the access and control of their building information and systems. We propose the Active Layer would be needed to allow building-users and FM to coexist and collaborate effectively to achieve the maximum building performance and satisfaction for both parties.

The following sections provide the background of the relationship of building-users and their building; how they could be accessing data and making decisions

in response to the information that interfaces could provide; the prototype we developed to test the principle of the Active Layer; followed by discussion and conclusion.

2. Background

2.1. PERSONAL CONTROL AND PERCEIVED WELL-BEING

A colleague mentioned that when she was a child living in an older Queenslander house of vernacular tradition, they understood that when it rained heavily they had to close the wooden shutters to prevent the rain from coming into the house. But it would get quite hot and stuffy so they would be aware that immediately after the storm had passed, they would quickly open the windows to allow the cooler air in to make the indoor spaces more tolerable.

We are no longer required to listen for the rain to stop so we can open the windows to adjust our personal environment for thermal comfort. In fact, many of us do not know when the rain stops outside our office space or how to adjust our personal space or if there are devices in place for us to activate that. Having devices that inform us of our surroundings could raise our awareness of how our actions could increase or decrease energy or water usage and in turn affect our planet. We may not need to open windows but we can have open systems that enable us to engage with our environment.

For the past decade, researchers of thermal comfort in building environments have demonstrated in several experiments that users of spaces want to be able to manipulate their environment to suit their personal preferences. The occupants' desire for local control of their immediate surroundings has been exemplified in what has been termed the need for an "operable window". Bordass (1990, p.1) quotes observations by psychologists that the operable window "is disproportionately significant to perceived well-being" and confirms that "people are more forgiving of discomfort if they have some effective means of control over alleviating it" (Leaman and Bordass, 1999, p. 22).

2.2. PERSONAL VS. CENTRAL CONTROL

However, conflicts arise when users want to modify their personal space in a building that is designed to give indoor environment controls to FM. FM needs to run a building efficiently and the BMS controls they are given are usually designed to suit a centrally run system. Even if users were given some say in controlling their particular environment, the BMS information is too complex to be manipulated by untrained users. But having control also means allowing "systems

to operate efficiently according to need" (Bordass and Adrian, 1997, p.7) and this can also mean allowing systems to be more open which may be a key to better building performance and occupant satisfaction.

2.3. FEEDBACK LOOPS AND ACTIVE PARTICIPANTS

From their experiments, Brager claims that "it is critical that buildings be designed so that occupants can be active participants in the indoor climate feedback loop, not simply passive recipients of whatever thermal conditions the BMS delivers" (Brager et al., 2004, p. 32)

One of the necessary steps for better interaction between building-users and building systems is to provide a means for the building information to be easily interpreted by the users. Users could be more knowledgeable building-users if they were given means to understand:

- how the building information given is affecting them personally and
- how their personal adjustment of the BMS will affect others around them (community of users) and also
- how they can affect the overall building conditions (bigger climate change picture).

One of the recommendations from a pilot project done at Queensland University of Technology on thermostat settings and institutional offices is to enable better communication between end users of the building and the building systems themselves. The study found "end-users who have a better understanding of how thermal comfort can be achieved in their space i.e. via timers or individual expectations/adjustments can attain greater satisfaction and productivity with the work space" (Kennedy et al., 2007, p. 65).

Feedback loops enable systems to become more transparent. They open up our understanding and enable us to actively participate in the making of the space to suit our needs. However, in order for this system to work and not just be another non-actionable digital readout, the "feedback on the consequences of exerting environmental control should be directly observable, inherently legible, and deal explicitly with the inhabitants' experience" and not "through add-ons such as orientation sessions, signage, lobby displays etc. which may not be adequate or effective" (Brown and Cole, 2009, p. 244).

2.4. NEED INTERPRETATION AND ACTION - NOT JUST INFORMATION TO ACT

Communication from building systems is still not of great use unless the users understand how to interpret and act on it. When users are given this "interactive

adaptivity" (Cole et al., 2008, p. 333) between themselves and a complex building system that is dynamic and responsive to their participation, then we have opened up the building system. We think that an open system occurs when users understand the information given to them and can easily associate their actions to a desired outcome and also can understand the consequences of their adjustments affecting others around. With our interactions, then we are no longer a passive object of the environment but can be a knowledgeable subject able to manipulate our spaces to suit our requirements quickly and easily.

3. Participatory Building Management

3.1. OPENING UP BUILDING INFORMATION

Making building information simply available does not allow building-users to make informed decisions. This is especially true if the only information available is a set of (raw) data that could only be read or analysed with interfaces designed for experts such as designers, engineers and facility managers. In order for the data to become meaningful and useful for building-users, a set of user interfaces developed specifically for non-experts is essential so that they could more effectively and easily fine-tune their environment for their own benefit. We developed a set of input and output interface ideas and ad-hoc network infrastructure to be retrofitted to our existing environment. We call this the Active Layer.

To investigate these issues in tangible manners, we constructed sensor modules to monitor our environment; software that uploads data to a free online database called Cosm (www.cosm.com); software that downloads the data and overlays the data to BIM; and BIM viewer that provides high-fidelity information for general users to study and learn about their environment. We also constructed a range of ambient displays and feedback systems that respond to user interactions and/or environmental conditions according to certain (predefined) parameters. Further information of this could be found in our recent paper (Santo, 2012).

3.2. AMBIENT BUILDING INFORMATION

Just as people look through a window to stay informed about their local climate information in real time, we aim to provide the ambient information that keeps building-users informed about their local environment and the building performance. As McCullough (2004) argues that digital computing tends to augment architecture, rather than replace it, the Active Layer is to augment existing or newly designed environments to allow building-users to take active roles in managing their spaces.

Wigley (2007, p. 52) claimed "the architectural responsibility to house humanity became a responsibility to shape flows of information". We are critical about how modern buildings no longer allow us to stay in touch with flows of information. Our aim, therefore, is to reintroduce the level of understanding and control we used to have with simple buildings in the past. With this in mind, we first chose to investigate how ambient information could be introduced to our spaces to keep us informed about the flow of information. The provision of ambient information to our environment through (tangible) interfaces is nothing new as research has been conducted since the 90's (see Ishii and Ullmer, 1997). Fair amount of research has been conducted on the benefit of ambient information to positively influence user behaviours in their environment. This was best demonstrated by Pousman and Stasko (2006). Our contribution is that we are aiming to construct a layer that consists of network infrastructure and various devices that are integrated into BMS through BIM.

Our current interests are in the thermal, luminous and visual comfort of building-users, the consequent energy savings and the level of user engagement and satisfaction that our interface prototypes can monitor and communicate. The ambient interfaces that constitute a part of the Active Layer is for engaging building-users to be positively critical about their environment and for them to respond actively to fix it. Figure 1 shows some of the available ambient interfaces that we have constructed (see Loh and Santo, 2010, and Santo, 2012, for further descriptions) that can be used to show certain aspects of the building's environment. The majority of users do not need to accurately interpret detailed information before they can understand the need or method to effect a change in their environment. They need only be provided with a level of information sufficient for them to

Figure 1. Ambient interface prototypes networked as devices for Active Layer.

sense this requirement and this can be communicated through ambient interfaces. Thus, complex building information can be distilled and visualised understood by the user through moving objects and changing intensity and/or colour of lights (typically LEDs).

3.3. HIGH-FIDELITY BULDING INFORMATION

While ambient information can keep building-users informed about their otherwise invisible environment, further resolution of information is often needed to take informed actions. This is especially true for building-users who are keen to participate and contribute to the extent that they would take an active part in maintaining and improving their own environment.

Typically, building-users in most office buildings need to come into contact with FM when they want to or are interested to:

- alter the indoor climate (the temperature, humidity, lighting levels),
- alter or determine the use of spaces (space allocation, event planning, etc.),
- report building problems (plumbing, electrical lighting, etc.),
- provide feedback for development and renovations.

Each of these actions can benefit from having intuitive and informative interfaces that allow users to determine the use and condition of their environment by themselves. The interfaces implemented utilise BIM, by targeting objects within the model and associating the data streaming from these 'real' sensors to the 'virtual' objects held in BIM.

BIM virtually always holds a geometric representation as well as attributes and meta-data of objects and the project. With the level of information BIM is designed to hold, it is an ideal platform to visualise easily graspable yet detailed information of the building for its users if a BIM viewer is designed specifically for them. To develop a means to obtain finer and localised environmental information, we constructed a sensor module that monitors light, temperature, humidity and sound of its immediate environment (Figure 2a). Figure 2b shows a possible appearance of the sensor module that can be moved around by the users. As the Internet access became ubiquitous for many, providing platforms to visualise BIM tailored specifically for building-users, as shown in Figure 2c and 2d, has become trivial.

In our preliminary experiments, we implemented an interface to allow building-users (primarily ourselves) to visualise environmental data as it was streamed to the online server. While ambient interfaces allows us to visually perceive current conditions, observe changes that are normally invisible, and gain certain level of awareness; these computer user interfaces built around BIM could offer high-

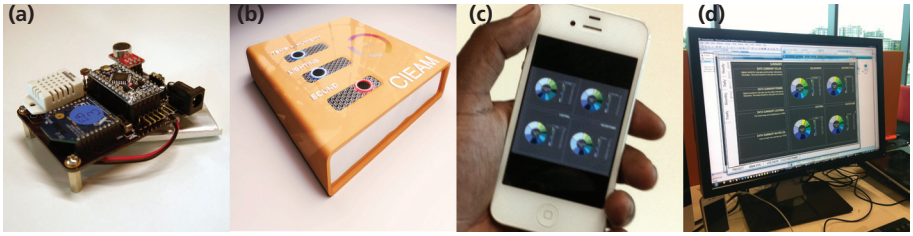

Figure 2 (a, b, c and d). Personal sensor modules and screen interfaces.

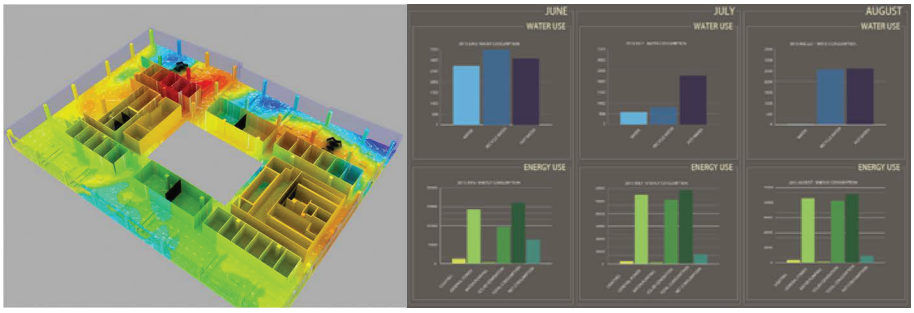

Figure 3. Dashboard interfaces for high-fidelity building information.

fidelity information and accurate analysis for building users to take informed actions. Figure 3 shows possible temperature distribution in our office floor and further information. A building-user may study this and choose to move to a hot-desk that matches better to their personal needs. High-fidelity information could ultimately allow building-users to stay in touch with flows of information and them to access further information to look for better alternative possibilities. We speculate that this could engage some building-users to a level comparative to those who look after their gardens with dedication and so some people who eagerly customise their computers and smart-phones. With the introduction of the Active Layer, we argue that the environment in their building becomes theirs.

4. Discussion

The use of BIM by FM and other experts as the means to visualise information has been explored by some researchers (Babsail and Dong, 2006; Liu and Akinci, 2009). Our approach to extend the use of BIM to all building-users however, is unique. Combined with the range of interfaces that provide ambient information for keeping users in touch with their environment, we speculate it is possible to

organise and maintain a community of building-users to become the effective agency, along with FM, for managing and maintaining their building. The Active Layer could ultimately allow designers and engineers to design buildings that are beyond what the current BMS and FM could effectively manage. The principle could apply to all buildings regardless of whether they had technologically advanced systems that would require advanced BMS and trained experts, or highly sophisticated passive systems that would require cooperation by building-users.

Our ultimate aim is to convert building-users who currently are the "passive recipients of the outcomes of" environments created by designers and researchers (Cole et al., 2008, p. 325), into active participants who will be responsible for the operation of their own environment. This research was conducted largely in interpretive methods (Swann, 2002) where we came up with quick assumptions or hypotheses, constructed hardware and software to test solutions quickly in an ad-hoc manner within our own spaces and evaluated the consequences. All issues discussed in this paper were examined with iterative collaboration process. The research reported in this paper remains relatively personal and it does not intend to provide any effective or measurable solution. The focus instead has been to make contributions by suggesting opportunities and possibilities in technologically enhanced environments, directions for possible future research for us as well as others, and sharing our investigation and methods of constructing hardware and software systems.

We are currently in discussion with FM and other stakeholders to gain access to the BMS of our building that was completed in November 2012. The next research goal is to study the implications of the Active Layer with a wider community of building-users rather than just about 10 researchers (us) discussing it amongst ourselves in a highly experimental and an ad-hoc manner.

5. Conclusion

There is, currently, little means for building-users to actively transform their environment to their liking. Our study proposes that we could give them the means to interact with their building environment with as much ease and intimacy that we used to have with our older simpler buildings. We propose this means can be successfully implemented with the use of the Active Layer. Through a series of interfaces that provide low (ambient) and high fidelity information, the Active Layer provides the means for building-users to access building information that would normally be beyond their comprehension and reach. So through this interaction, building-users are able to become active participants of their environment.

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