Co-Adaptive Environments

Investigation into computer and network enhanced adaptable, sustainable and participatory environments

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Abstract. This paper presents research in response to environmental concerns we face today. In a search for a better method to manage spaces and building resources consumed excessively through traditional top-down architectural solutions, the research began by speculating that the building spaces and resources can be managed by designing architectural systems that encourage a bottom-up approach. In other words, this research investigates how to design systems that encourage occupants and users of buildings to actively understand, manage and customise their own spaces. Specific attention is paid to the participation of building users because no matter how sophisticated the system is, the building will become as wasteful as conventional buildings if users cannot, or do not want to, utilise the system effectively. The research is still in its early stages. The intention of this paper is to provide a background to the issue, discuss researches and projects relevant to, but not necessarily about, architecture, and introduce a number of hypothesis and investigations to realise adaptable, participatory and sustainable environments for users.

Keywords. Adaptive; Interactive; Participatory; Tangible; Ubiquitous

Background

Knowledge for designing, constructing and managing spaces had always resided locally. Accumulation of the knowledge, through trials and errors, became the knowledge of the local community and was passed from one generation to the next. This had typically been achieved by younger members of a community working with senior members. The knowledge was communicated by being at the same place at the same time. Built environments and knowledge associated to them were shared properties of a local community.

An example of this with a very long history can be found in Mie prefecture, Japan. All shrines within Ise Grand Shrine complex have maintained their original forms for over thirteen thousand years. This is achieved by systematically reconstructing all shrines every twenty years.

Reconstruction of shrines follows a very strict procedure. First of all, each shrine is built on site with empty land adjacent to it. Every twenty years, constructions of new shrines begin on each of their adjacent empty space. The responsibility of builders...
is to construct new shrines identical to existing ones. All features of shrines, including materials, construction methods, furniture, ornaments and other objects that belong to the shrine must perfectly match those of existing shrines. When new shrines are completed, old ones are demolished and the land on which old shrines existed will be kept empty for the next twenty years (Fig. 1).

Every shrine thus serves as a precise blueprint for the new one when it is twenty years old. It has also been a common practice to utilise every possible material recovered from old shrines for various purposes for the local community. In order to guarantee future availability of construction materials, especially timbers, sites were nominated hundreds of years in advance to grow required trees for constructing shrines (Yano 2006). The future proofing has been a crucial strategy that sustained Ise shrines for more than thirteen thousand years.

One of the most critical elements of this strict reconstruction strategy, however, is the preservation of construction knowledge. Although the record has been lost and there are a number of theories suggesting alternative reasons, it is believed that the twenty-year reconstruction cycle was determined by the life expectancy of people at the time. The theory suggested that twenty is an appropriate number of years to allow the knowledge of one generation to be passed over to the next (Yano 2006).

Shrines are sustained through high degree of motivation and pride of countless number of people over many generations. A very strong community is built and sustained around Ise Shrines for as long as the building existed. While the history proves that this is an extremely successful method to maintain and sustain buildings for more than one thousand years, is there anything we can learn from this strategy to design, construct and maintain our ordinary contemporary buildings in the twenty first century?

Communication Strategies

The strategy that kept Ise Shrines in their original form for centuries is an ultimate method for communicating building information for generations. We obviously need to note that Ise Shrines have always been religious and cultural symbol of eternity and it is impossible to expect a same level of dedication from communities of ordinary building users. We also need to note that Ise Shrines are extremely inflexible because changing any aspect of buildings is strictly prohibited. It is very important to recognise, however, that this is because keeping their original features is the requirement. It therefore is more important to note that the building has satisfied the requirement for over thirteen thousand years. What can we learn from this?

With regards to communicating building information, we can easily imagine that one of a pair of buildings is virtualised and kept as a BIM entity to monitor, repair and improve the physical counterpart. Sydney Opera House recently was reconstructed virtually to keep its building information intact for future maintenance and refurbishment (CRC for Construction Innovation 2007).

With regards to communicating construction methods, mass-customisation and modularisation with a computer aided fabrication technology can be utilised effectively so that even the community of
building users can continue to maintain, repair, re-construct and recycle their own environments.

If BIM and CAD/CAM technologies are combined and every stage of changes is recorded as accessible data, a system that drives highly adaptable, sustainable, cost effective and environmentally friendly buildings that last for generations, with a fraction of dedication and resources Ise Shrines historically required, can be imagined. There, however, is a crucial issue that has been overlooked since the industrial revolution when skills and knowledge of ordinary people to manage their own environments are lost and the responsibility was passed on to specialists in the trade (Davis 1999). Development of spaces and objects they use are no more influenced directly by their users. In other words, participation of end-users to maintain and sustain their own buildings was lost. As Ise Shrines example strongly demonstrated, we must remember that it is frequently people and their motivation that are the driving force to successfully maintain and sustain built environments. As many other monumental buildings, Ise Shrines would not have existed without the collective motivation of generations of community members.

Technologies can provide extensive means to understand, respond and alter their environments. It does not automatically guarantee, however, that people are given access to, capable of utilising or willing to utilise technologies that are available to reconfigure their environments. Many projects that advocated customisable or adaptable environments did not work, or would not have worked if realised, as envisaged due to the lack of information, motivation, or collaboration between users to take part in improving their environments. This can be summarised into three communication issues, which are; 1) users are not informed enough to understand possibilities offered by the system; 2) when they are, the system does not promote and encourage users to understand their environments to make changes and; 3) collaborating with other users to come to an agreement is difficult.

When occupants, users and ultimately stakeholders are not content with their built environment, and the three communication issues are not resolved, it leads to termination. This happens even when a building or a space is designed to be adaptive. The consequence of termination, which in most cases is demolition, is a large amount of financial and environmental waste. Nakagin Capsule tower, for example, was designed to be adaptive so that occupants can renovate or renew their capsule apartments by removing it from the core structure and sending it to a factory for refurbishment or to be replaced by a new version without the requirement to reconstruct any core element of the building. The irony is that, as of today in 2010, not a single capsule was replaced since the tower was built in 1972. While there was a technical flaw that made it difficult for capsules to be removed individually from their core structure, a crucial factor was that occupants were never presented with any good scenario that convinced and motivated them to go through the effort of upgrading their apartments. Some occupants even went further and made alterations to their apartments in a DIY manner as shown in Fig.2. (note the container below the air-conditioner to catch water).
This clearly demonstrates that the occupant did not have access to the solution the system was designed to provide. Although the date is not confirmed, the tower is due to be demolished in a near future because the developer expects much higher return on investment by constructing a new building in the tower’s current location. This makes the intended use of the system designed to make the tower long lasting and sustainable completely redundant.

The environmental cost of demolitions is high. This problem is understood and discussed (Duffy et al. 1998) and various attempts were made to find solutions. None of them, however, lead to a long-term sustainable architectural entity that is worth comparing to how Ise Shrines were maintained for over thirteen thousand years. It can be speculated that many buildings could have been far more sustainable if designers considered continuous user engagement as an important design factor. If we are to recognise user participation as an important factor, what can we do as designers to arouse motivations and enthusiasms of users to the level comparative to what Ise Shrines attracted for centuries? In other words, how can we encourage users of ordinary buildings to; 1) understand current situation and condition of their environments; 2) study how their environments can be altered and improved; and 3) execute changes to retain desirable and sustainable environments for their own benefits?

**User Requirements**

Various design, management and construction tools and technologies have been invented, developed and utilised successfully to build and manage our environments. Various attempts were made in projects such as Quartiers Modernes Frugés by Le Corbusier, which explored the possibility of serial production and standardisation; Wichita House by Buckminster Fuller, which explored mass-production and deployment of light-weight residential houses for everyone in need of houses; Self-built projects by Walter Segal, which was an attempt to empower ordinary people in need of low-cost residents to construct their own houses; Support Structure and Infill Components concept discussed by John Habraken, which promoted architectural systems that allow mass-customisation of residences by occupiers; and Fun Palace and Generator by Cedric Price, which advocated user-customisation of their environment through advanced computational power and architectural systems that respond to user needs. Each project was a fine example of modular and adaptive architectural solutions to provide buildings for users in need of unique, sustainable or customisable environments.

Among these architects, Price was particularly interested in computers as an important element of social environment, rather than simply a tool to design a space. While the idea of experimenting with computers had already been solidly present with Art and Technology movement, Price was unique in that his proposal was for real built environments within a real social context (Mathews 2007). This consideration, however, never became a mainstream architectural issue while attention to possibilities of computer-aided design/drafting has exponentially increased. Architects somehow became more interested in computer aided/enhanced tools than computer enhanced environments. This issue was pursued, instead, by researchers in ubiquitous computing and interaction design since early 90’s.

Dourish quoted “[we] need to be able to customize the space to our changing needs; we need to be able to appropriate it to the purposes at hand. [...] The important point to recognize here is that these practices emerge not from the designers of the system, but from the actions of its users. This means two things; first, that true places emerge only when really occupied day-to-day, not in demonstrations or experiments that last a few hours; and second, that place can’t be designed, only designed for.” (2001, 97)

It is interesting to note that statements similar to this with respect to our (built) environments are coming from researchers in ubiquitous computing
and other design disciplines while most mainstream architects in the twenty first century are still busy brushing their computer skills to utilise digital tools rather than thinking about how their spaces can be designed to utilise digital technologies.

One of Price’s most influential projects, Fun Palace, had challenged the very definition of architecture by suggesting a construction of matrix that is not a building at all in any conventional sense, to encourage social participations by offering user-customisable adjustable environments (Mathews 2007). Although it is widely claimed that Fun Palace strongly influenced many architects, such as Piano and Rogers for the design of Pompidou Centre in Paris (Spiller 2007), its significant contribution for the twenty first century is not with its hi-tech element of how it was to be constructed or its visual appearance. While ideas behind a series of proposals made by Archigram in 70’s, promoting reconfigurable spaces in various scales, can be considered as conceptual responses to social demands of the time, the contribution Price made, as noted by Mathews, was that Fun Palace was a fully realisable series of physically reconfigurable spaces in a scale of architecture that was to provide solutions within a real social context (2007). Fun Palace was never built and architects, for the last four decades, are yet to provide any long-term design solution that successfully utilise technology to provide highly adaptive spaces. Ise Shrines can be considered as an ultimate opposite of what Fun Palace attempted to achieve, but there is one strong resemblance. For both Ise Shrines and Fun Palace, the significance is with the systems people utilise, rather than the building themselves that continue to be reconstructed or adapted. While Ise Shrines continued to engage their community with their historical, religious and cultural importance, Price attempted to utilise technologies of his time to help and engage users.

Other than some further projects proposed by Price himself, such as Potteries Thinkbelt and Generator, there has hardly been any interest in developing architectural systems for engaging users to interact with, modify and adapt their environments. Since the industrial revolution, buildings left most people with only three options when their needs change. The first option is to discuss issues with specialists, such as architects, builders and/or facility managers, and hope that they make a collect interpretation of their problems and fix them. The second is to live with what they have. The third is to demolish the building.

Benthall quoted Lifton’s programme note for “Event One”, the exhibition organized by the Computer Arts Society and held at RCA (London) in March 1969. It stated, “[the] Modern Movement in architecture has perpetuated the classical tradition that man exists within a physically determinate environment. The basis of design may have shifted from beauty and proportion, via beauty and convenience to ergonomics and functional fitness, but the basic attitude is still the same.... We must start again from a fresh hypothesis: ‘The relationship between individual and environment is an information processing system.’” (1972, 74)

Lifton went further to suggest that our environment can be made to learn and respond intelligently to our needs and behaviour, and people and environment can thus become fused into one extended system. Co-Adaptive environments need a set of sub-systems under this idea. Firstly, a system that allows and motivates occupants and users to constantly communicate and collectively stay in touch with building information. Secondly, a system that allows them to study possibilities and request changes. Thirdly, a system that evaluates and responds to requests. In short, a participatory system for users is needed to realise Co-Adaptive environments.

User Participation

Although technologies can be made available to provide opportunities to allow participants to manage and customise their own environments, the majority of buildings still face premature death because technologies are not utilised and coordinated
effectively to work as one integrated system. McKean looked back to 70's when architects, including himself, discussed Systems Approach, with which architects attempted to design prefabricated building systems since the early 20th century, was not about 'systems as assembled kits of buildings parts, but systems thinking' (McKean 2006). This is a very important idea but users were left out of their picture. It basically assumed designers to be the thinker but did not anticipate end users to become thinkers. Habraken described occupants can act as 'agents' (Habraken 1998) but he did not go as far as describing a specific system that allows users to actively contribute to discuss, control and manipulate environments that they share. Price’s concept was superior in a sense that Fun Palace and Generator fully incorporated users as a very important aspect.

With the advent of digital and network technologies, end-users in general are beginning to receive more attention. Fuller and Haque presented quasi-versioning-system for the development of built environment through participation by different levels of users, inspired by open-source movements for software and hardware developments (2008). Pachube [1], developed by Haque, attempts to introduce digital infrastructure to allow various architectural and other devices and components to be monitored and interacted in real time in a global scale so that built environments can become an integral part of a real-time system. Methods to understand the usage of mobile network infrastructure for city dwellers and visitors have been explored to provide effective links between physical and digital layers (Vaccai et al. 2009), such as WikiCity project conducted by Senseable City Lab at MIT [2]. Ratti and Berry at Senseable City Lab argues that the emergent trend of real-time usage of the urban digital layer became so profound and widespread for urban dwellers that it has become as important as the physical layer of cities (2007).

While projects such as Pachube and WikiCity attempted to understand the digital infrastructural usage and provide a new type of information infrastructure for city dwellers and visitors, utilising digital fabrication methods to rapidly produce architectural components can provide means for participants to fabricate or choose building components that can be assembled or replaced based on changing needs. The method demonstrated by Housing for New Orleans project (Sass 2007) provides wide range of opportunities for building users to influence the physical layer of cities.

Brown and Cole analysed that it is crucial for building users to have access to the information about their building and how it works to provide desirable environment in order for them to feel comfortable (Brown et al. 2009). By extending this idea further, we can argue that a participatory systems approach with integrated tools and interfaces that connects users and building information, and building components that are designed to be manufactured specifically to respond to the need identified by the system, is desirable.

It is important to recognise that a modification of one space in a building has a direct influence or impact to others, unlike a personal device that can be customized by each user without directly and intrusively influencing devices of others. It therefore is essential to provide a system that offers abilities for building occupants to effectively communicate to negotiate, identify and produce desirable and functional spaces as a community. It is equally important to design spaces that can be reconfigured in response to the collective desire of all participating

![Figure 3](Next21)
users. An integrated system has to be designed to encourage largest possible user participation so that the building continues to evolve and offers the best possible architectural entity for everyone concerned. While there has been a range of examples of reconfigurable architectural spaces, hardly any of them has occupants and users as the integral element.

Next21 (Fig.3), a building with support structure and infill systems with a strong influence from Habraken’s concept, was built in 1993 in Osaka. It is a remarkably successful building that adapts to user needs. The building, however, was owned by Osaka Gas for a research purpose and occupied solely by employees of the company. The community, therefore, was established and with heavy involvement of researchers and building managers, they do not need any additional layer to motivate user participation. Although the motivations come from very different background, Next21 is maintained and sustained in a very similar manner as Ise Shrines. If Next21 is left without any involvement of researchers and strong sense of community, however, the building is very likely to turn into an ordinary fixed and rigid architectural entity, which most likely would follow suit of Nakagin Capsule Tower.

Although there hardly is any architectural project that dealt with the idea of users as the active agent and provided system for them to modify physical aspects of their building, Fun Palace and the Generator project proposed by Price were exceptions. Neither were realised, however, and the study to identify the element that motivates building users to become the driver for the adaptation of technologically enhanced buildings continued to remain non-existent. The important contribution Price made with them was that he attempted to introduce a system that, with the aid of Gordon Pask for Fun Palace and John Frazer for Generator, encouraged users to interact with their environment, allowed them to form user communities and communicate effectively to successfully evolve their spaces, and demonstrated with their study that it is in fact viable (Haque 2007). At least both projects came very close to being realised and they were not mere experiments or manifestation of architectural possibilities unlike most visionary concepts such as those developed by Archigram (Spiller 2007).

It is difficult to evaluate whether Fun Palace and Generator would have performed as intended. Although occupants and users were to be the active agents for maintaining and sustaining their building, there was no indication to suggest how user-friendly and attractive these systems were for users to participate willingly, actively and collaboratively so that they could in fact become key agents for the positive development of their environment. It was simply assumed that they would. Generator, however, was more advanced in that it had a built-in function to motivate users to interact. This was achieved by allowing the system to become “bored” when users did not interact with them for longer than a certain period of time. When the system is bored, it provokes users to do something with the system. User-friendliness, however, would still have been the issue.

In the twenty first century, most architects are yet to be involved directly with new issues in the society that is heavily interconnected with digital technologies. Exchange of symbolic representations, typically designed by graphic, web and multimedia designers, artists and engineers but not architects, has become the essential means to provide social ties over geographically distributed locations, including those in different parts of a same building or in some cases those in a same room. This issue was taken more seriously by interaction designers and social scientists. They have become the key advocators to design digital and network layers of our built environments, or in some cases built environments themselves, since the early 90’s. Wiser, for example, advocated the idea of ubiquitous computing by suggesting computers should disappear into our environments (1991). Ishii and Ulmar had been experimenting with the idea of spaces as ambient interfaces (1997). Dourish and Bell explore implications of the development of ubiquitous computing for encounters with space (2007). Architects do not
need to compete with them but need to have more discussions with them.

Speculation and Proposition

Communication is active behaviour. We argue the crucially missing component for reconfigurable, adaptive and flexible architecture is the integrated communication system with which people can become active agents for the change. Archigram re-oriented “architecture toward changing social and ideological patterns, recognising that individualism and consumerism were the prevalent postwar European and American social movements” (Sadler 2005) in 1960’s. 50 years later, we need to reorient ourselves to recognise how individuals can be united to control our environments through an architectural system. The system needs to motivate people to understand the current status of the building and needs, provide means for them to actively discuss possibilities and give sufficient authority to active members of the building community to alter and maintain their own environment.

One simple but potentially very useful means to bring people together is to design a tangible user interface that are designed for lay-people to interact with their environment by playing with the interface. Frazer’s Self-builder design kit for Segal and its more advanced version Calbuild kit (Fig.4) attempted to help ordinary people to design and understand their own buildings and study their ideas before they are built (Frazer 1995). Frazer developed the idea further to provide a more generic tangible interface called Universal Constructor for users to study and interact with their built environment.

With an attempt to take this further, Santo developed a set of tangible I/O interface modules to understand types of interaction users can make to interact with their environments (Fig.5). We then developed a set of networked user interfaces to study possibilities of user interaction. CoEx communication kits (Fig.6) were developed to explore the sense of coexistence through tangible means between people distributed across two or more places (Santo et al. 2004). Deep Space project (Fig.7&8) explored the problem of how digital technologies can enrich the experience of spatiality and social interaction in space(s) (Jachna et al. 2007).

Further basic study was conducted to understand how a series of interfaces, tools, infrastructural support and architecture itself can be deployed to complete Co-Adaptive environments in which
people can discuss, interact, maintain and sustain their own built environments. Fig.9 demonstrates essential components to drive Co-Adaptive environments and their relationships. The ideal Co-Adaptive environments are consisted of; 1) two or more buildings with tangible and digital interfaces, sensors to monitor various activities and environmental information, digital and mechanical responsive systems and their users; 2) tangible and digital interfaces to study building information and run simulations for design, educational and research purposes; 3) web-interfaces to provide predefined level of information for selected members of the general public; 4) infrastructure for manufacturing, recycling and just-on-time delivery network; and 5) one database for all data. As seen in the diagram, there is no radically new idea in components that constitute Co-Adaptive Environments, but it is the way they are linked and related that make this investigation unique. It is envisaged that this can be expanded into a scale that the ecosystem of an entire city can be described and driven as a single Co-Adaptive Environment.

Conclusion

There are examples of tangible user interfaces for lay-people to retrieve building information, but there has never been a set of interfaces that were designed and built specifically for building users to actively ‘interact’ with the building they occupy and its community. Systems Approach has been studied, modular buildings have been constructed, some user interfaces and building management tools were developed, but we are yet to construct technologically enhanced systems to maintain and sustain our buildings to the level religion, culture and history have attracted us to do so.

This research is still in its early stages and this paper served as an introduction to our unique approach to construct sustainable environments through user participation. We have identified that there is no example of participatory systems that was designed along with adaptive buildings for their users to understand, study, manage, reconfigure, build user community and, most importantly, maintain and sustain their own built environments. We consider this is a unique and innovative approach to bring ecological and sustainable environments to
our lives and further investigation of how Co-Adaptive Environments can be a means to introduce sustainable built environments for cities in the twenty first century.

References


Davis, H 1999, The Culture of Building, Oxford University, New York.


