Learning to Imagine the Invisible: Using New Technologies to Enhance User-Friendly Architecture.

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INTRODUCTION

Emerging technologies present extraordinary opportunities and potential for creative design solutions to benefit the users of all building types. But technology is only as good as the imagination of the designer, whether architect or engineer, in making useful and effective environments or products. Architectural design may appear to be more concerned with building form and less with the users, for whom everyday buildings could be more ‘friendly’ rather than being merely efficient. In the last century mechanical building services were refined to provide various means to make interiors more comfortable, while aesthetic considerations were largely regarded as separate entities in the design process. Engineering in the service of humankind has always made up for the limitations of the body and brain, such as the means to lift heavy loads, to travel or process information at ever faster speeds. Some aspects of technology have potential for enhancing the aesthetic qualities of building, such as structural expression or good auditorium acoustics, but the perceived benefits to occupants of such aspects are difficult to quantify in convincing terms, when compared to measuring the physical comfort that the same building delivers. Could our present technologies open up the possibility of being able to measure and define users’ preferences in aesthetic aspects and hence allow designers to make more informed rather than ‘intuitive’ decisions on these?

Recent advances in sensor technology and machine learning show that there is the capability to anticipate both the physical needs of the users and, more significantly, their preferences. Furthermore, we can now imagine buildings that can adapt according to the feelings of their occupants, rather than simply responding to definable physical aspects such as temperature, motion, or sunlight. ‘Affective computing’ refers to computer systems or devices capable of inferring emotion or psychological affect. This may be achieved by observing and interpreting aspects of behaviour as varied as facial expressions, movement patterns or voice inflection, through video, sensoring or sound recording. All of this data is also available to a human observer: we constantly receive and process this information in order to infer what the emotional state of others is, and to decide how to react to it. A computer system can be enabled to receive and process such data for similar ends. In addition, such a system can have available to it information which a human observer could not possess, for example, bio-signals such as heart-rate, blood pressure, skin conductance, all of which exhibit patterns and changes that are indicative of changes in an individual’s emotional state. A system can be programmed to learn and predict an individual’s patterns from interpretation of such data. It is beginning to be possible to gather and interpret biosignal data on a real-time basis, and for a system to use the processed data to initiate changes, for example in a room environment controlled by a Building Management System (BMS), also on a continuous, real-time basis. The notion of such a responsive architecture was anticipated by Nicholas Negroponte (1971), who focuses on responsivity, geared at improving function in the built environment.

The emerging discipline of interaction operates at the interface between the user and the technology; interaction design is likely to become of increased significance in the built environments, as wireless technologies and sensor networks become commonplace.

ART VERSUS TECHNICS?

Technology provides an array of means, but without a real and holistic awareness of the users' needs and wants the net result may be sterile. The dichotomy between Art and Science lingers in architectural education and the fallacy still persists in some tutors' minds that functional requirements will diminish the designer's creative freedom. Examples of the tectonic and visual expression of award-winning buildings sometimes demonstrate the disparity of care in design between achieving spectacular visual qualities whilst also providing the requisite environmental standards for such a building; the interesting and rich architectural language is not matched by satisfactory acoustics in the lecture theatres, for instance.

FIG 1. Spectacular architectural features are not matched by adequate acoustics in this building; the iPhone is popular - not for its stylish looks but for the fact that it is also very usable - function and aesthetics are in harmony.

A factory obviously needs functional aspects such as lighting, functional planning or environmental control to be correct above any aesthetic qualities, or else efficiency or production could be affected. For an office space the quantifiable environmental conditions must be right, achieving the 'well tempered environment' that Reyner Banham (1969) has described so succinctly. But for real efficiency the staff also need to be satisfied with more intangible environmental conditions of the space in which they work: a sense of community, the quality (rather than the quantity) of the lighting, both natural and artificial, and other factors. Our built environment includes buildings that we need in many forms; some are workaday and some are special. A church or cathedral, for instance, may be created to uplift the soul through its use of space, light and soaring structure. For these reasons we are less critical of any lack of thermal comfort or functional efficiency – although we might not want to spend a lot of time in its cold interior.

Fitch (1975) has argued that architecture may be seen to have contradicting requirements of functional as against formal criteria; but is this argument still valid? Not all buildings are based on the same parameters; an operating theatre, Fitch reminds us, has a different set of criteria to a church. *"The more complex or vital a process to be housed, the more critical the contradiction becomes. Hence the architect's freedom to create necessarily diminishes in inverse proportion to the criticalness of his task"* (Fitch 1975, p.25). (Fig 1.) But this argument is only true up to a point. Even though some buildings must be more functional than 'intuitive', this does not mean that they must inevitably be less humane and aesthetically considered. Indeed, there is evidence that buildings which have the intangible qualities that we may describe as 'satisfying' or 'cheerful' are likely to have a positive effect on their inhabitants (Dilani, 2008).

FIG 2. Adapted from J. M. Fitch (1975)

EDUCATING DESIGNERS FOR TOMORROW

The education of the architect must include exposure to the sort of design problems described by Fitch, where both the functional and the intuitive are reconciled in equal measure. An appreciation of the capabilities of those technologies that make this possible thus becomes a vital factor in the design studio programmes set in schools of architecture. What skills do the architects need to be equipped with to take advantage of the accelerating change in future technology, and how could this effectively bring the particular needs and wants of each human being into the equation? In order to go beyond the necessary but dry logic of the ‘human factors’ approach, real creativity is needed. Selected projects should be set to encourage different imaginations and allow the student to explore the hidden potential of ‘the World that has never been’, to provide something better, both aesthetically and functionally: rather than reiteration of accepted styles.

Environment-behaviour studies allow some degree of investigation into these less tangible aspects of the built environment, but because real measurement of users’ feelings about a space are not easily quantified, these aspects lose out against more technical factors when used as justification for a particular design decision. The observation and understanding of human behaviour receives less attention than it deserves in design education, and yet it remains a fundamental in the creation of good architecture. Student design projects should encourage investigation of the possibilities that this throws up and make the connection between what they observe about people and their ‘fit’ in buildings and reinterpret this positively in design. By encouraging a consistent study of human behaviour designers may learn to satisfy human needs qualitatively and spiritually, not just functionally.

Imagining new futures through role-playing has the advantage of extending the young designers’ imaginations to enable them to see the world through the eyes of a range of users, not only about their diverse physical needs, such as wheelchair accessibility but also about their expression of the degree of emotional satisfaction and kinds of qualities that made them feel that the architecture embraces them (Zeisel, 2008). Imagine the potential of an environment which can adapt to the feelings and emotions of an occupant, or the aesthetic possibilities of an architecture where colour, image and lighting is constantly mutable, regardless of constraints of siting and seasonality. A potential application currently being researched at CCAE employs environmental responsivity actuated by observing, anticipating and ameliorating stressed states. This has particular significance in healthcare architecture where there is already a significant body of evidence to support the thesis that certain aspects of the built environment can influence user well-being. Such is the acceptance of the evidence that, in the UK, ‘well-being’ is currently being considered as an aspect of rating for building interiors**.**

However, for an architect to embrace fully the creative potential of sensoring technologies in the built environment requires knowledge at least of interaction design, if control of design outcomes is not to be lost. There is also a role for the architect/designer in research teams developing of sensor technologies for specific user-groups, as an interpreter of needs for ICT researchers, and as “technology gatekeepers” for user groups in whose needs the architect is well-versed. These might be, for example, children in an educational setting, users with special needs, elderly people, patient in hospital settings, all of whom present a particular set of challenges. Imagine the potential of an environment which can adapt to the feelings and emotions of an occupant, or the aesthetic possibilities of an architecture where colour, image and lighting is constantly mutable, regardless of constraints of siting and seasonality.

ADAPTIVE ARCHITECTURE

Buildings are one of the most static creations that mankind produces; they often last longer than the functions for which they were created. Standards improve and tastes change, so that any design factor may become outmoded and redundant. Occupancy can also change and functional requirements may thus require adaptation; traditionally this can be a slow process of retrofitting, relying on predicted usage in the near future. How much better it would be if some inbuilt factors could respond to the more rapidly changing requirements and so be adjusted over the course of any time frame.

Virtual and augmented 3-dimensional reality, ubiquitous computing and embedded network sensors are all technologies that promise a range of exciting possibilities. Though many designers seek inspiration through precedents to some extent, so far we have few useful built examples of buildings or environments that respond in an unthreatening way by adapting conventional settings to suit the needs and preferences of their occupants to inspire or inform us. In current examples of adaptive architecture, for instance, walls and roofs may be designed to slide and adapt according to climate change. Though such responses are useful, they may be less significant to the occupants than aesthetic variations, such as daylight playing onto textured walls and vegetation, or artificial light enhancing particular spaces.

Most ‘adaptive’ buildings respond to climate or function, rather than to human responses. Collecting the physical data for modifying the external envelope for environmental control is far easier than trying to assess user preferences, since measurement of people’s satisfaction remains difficult to undertake. But while human physiological comfort and security are more constant and far more readily understood and provided for, this does not mean that aesthetic satisfaction is any less important. Although Maslow’s well-known Hierarchy Diagram (Maslow, 1943) does not overtly include the individual’s emotional response to built environments, yet this aspect must surely be part of the ‘sense of belonging’ in the Third Level.

Fig 3. Maslow’s Hierarchy of Needs

Is it then possible to create environments that can simultaneously serve the aesthetic, spiritual or experiential needs of everyone, since these are so diverse and intangible? One potential way to predict these emotional needs and preferences is through the use of Networked Embedded Sensors**.** These allow occupant’s biofeedback data to be monitored in various ways and then processed to provide optimal conditions without the need for constant human control. Sensors might be wearable, and completely non-intrusive, supported by research trends towards miniaturisation. Alternatively as sensors become more sensitive, and wireless networks capable of operating over greater distances, sensors might be embedded invisibly in the architecture. Beyond this, Machine Learning enables the system to provide wider responses that are sensitive to users' changing feelings and emotions. Conditions that have positive effects on their users can be achieved and can be shown to be doing so, but until now, only through traditional survey methods that are relatively simplistic or generalised. *"Good design contributes significantly to the health outcomes of patients*." (Lawson and Phiri, 2003)

But how are we to determine 'good design' and so turn a mundane building into a piece of real architecture? The functional aspects of any design can usually be given specific values, the qualitative aesthetic ones are more difficult to evaluate. If these subjective qualities could now be defined more positively through the use of sensor technology, this presents a potentially powerful tool in assessing what constitutes 'Good Design' in terms of user-friendliness.

ETHICS OR AESTHETICS?

In the book 'Architecture Depends', Till (2009) discusses the design uncertainties with which architects have to contend, but deflates the dichotomy that, in the design process, aesthetics and ethics are mutually exclusive, since there is always the obligation to provide more than just the basic physical environmental conditions. Aesthetics, he argues, are not an arcane appreciation of tectonics and spatial refinement, things which ordinary people, the building's essential users, are unable to appreciate. The modernist view that refined buildings would lead to better moral behaviour in society has proven to be largely unfounded, but there are emerging opinions that some of the more natural elements of the world around us are important, not only in providing orientation and comfort, but as reassuring and calming influences; 'salutogenesis', the opposite of Pathogenesis, equates healing of the body with predictable and benign sensory conditions and, by extension, reduced stress or aggression in the occupants (Antonosky, 1984).

Describing a current NEMBES Research Project, based in the Cork Centre for Architectural Education and Cork Institute of Technology, the MyRoom design prototype allows real-time observation of user reactions to variations in the room environment, ultimately facilitating contributions to the knowledge base of EBD, based on objective measurement" (Dalton and Harrison, 2011). While the current research MyRoom project promulgates the concept of an individual's physical responses being monitored and interpreted to provide changes in a single personal space, the question arises of if/how this might be extended to be applied in spaces used by a number of people, who may not even use the space regularly. Could the findings of the project suggest its potential development as a tool to quantify these aspects which have always been applied 'intuitively', since we cannot put any absolute values them?

IMAGINING THE INVISIBLE

The well-known Vitruvian definition of architecture as constituting 'Commodity, Firmness and Delight' has a certain relevance in any architect's desired aims. But although not all buildings may necessarily be delightful, they should never be dismal or disappointing. Vitruvius' idea of what constituted architecture must, of course, be rather different to our own in the 21st Century. Architects now design a wider range of different types of building, but the qualities that elevate mere construction to become good architecture have not changed, even if they are hard to define absolutely. Notably, we have limited words to describe places that are uplifting to the spirit***.***

But how are we to assess the value of these compared to providing physical comfort of the occupants? Good architecture must serve the less tangible needs for environments that are emotionally satisfying, whilst also being appropriate to the diverse uses that buildings serve. For instance light, one of the essential ingredients that make architectural spaces perceptible, can be accurately measured as a level (on the working plane) but it can also be provided (naturally or artificially) in so many different ways, which will affect the user; we know that in extreme cases a high intensity harsh lighting can be a form of torture, whilst at the opposite end of the scale it can be satisfying and restful even if inadequate to read by. But it is not simply the amount of light that is significant. In some settings, dim lighting may seem romantic and yet the same light levels may seem gloomy and oppressive in others. How the light is directed, its colour temperature and the ability for it to be adjusted according to mood or time of day will also have a strong influence on whether or not it is a pleasant experience. At very least the interior should be "well-tempered" – quietly appropriate and not having any disturbing qualities that might detract.

EVIDENCE-BASED DESIGN

Evidence-Based Design (EDB) is a powerful tool to convince clients and also help the architect to shape the design in better ways. Increasingly EDB is used to provide positive justification for design decisions - *especially where cost is involved*. Typically this may help to confirm visual observation of how people use and respond to their physical settings and thus forms one of the underpinning incentives for creating therapeutic environments in healthcare. Research shows that such 'salutogenic' environments significantly reduce in-patient recovery time, so proving cost-effectiveness where a higher aesthetic standard of healthcare facility is provided. Collecting and analyzing occupants' biofeedback responses to their environment can provide useful evidence to assist the designer to take *responsible* design decisions. There are, of course, some ethical questions that might be raised. The use of polygraphs or lie detectors serves an example where simplistic technology failed to be convincing in providing evidence in criminal law. Subjective aesthetic qualities could, however, be more positively assessed in broader terms, from a much wider range of bio-data, to allow these to become the 'evidence' in EDB.

DEVELOPING CREATIVITY AND IMAGINATION

"The key agent in this transformation is that of imagination, because it is only through the exercise of imagination that one can see the potential for change in what otherwise might appear restrictive. Social or architectural reality, if viewed as a set of determinate rules and procedures, tends to shut down the imagination, because the apparent certainty leaves no gaps for it to open up. However, the contingent, with its multiple but uncertain potentials, allows the imagination room to project new futures." (Till, 2009)

The current NEMBES ‘MyRoom’ research project uses embedded networked sensors which allow evaluation of users’ real-time reactions to environments, and how this may adapt to suit their individual preferences: colour, lighting and other factors, but ‘blue-skies’ thinking about more imaginative ways that the space may adapt could form an excellent basis for an undergraduate design project. Moreover, the research model could potentially help students to be able to make appropriate aesthetic decisions based on users’ detected preferences, not just on their arbitrary and untested opinions – at an early formative stage in the design process. Role-playing and similar exploratory techniques could then be backed up by with real information. Through future developments of the experimental model they may be able learn more confidently about how real people feel about the environments that they occupy.

ANALOGY AND NARRATIVE

How can we educate designers to create design buildings that satisfy and uplift the spirit rather than just providing the functional necessities? Until now most of the aspects that designers have to manipulate in any design are visible and imaginable, but probably will lead to a predictable built outcome. A narrative or role-playing approach allows us to imagine changes for different users, adaptable by different means, but these would be activated either by the users themselves or some form of automatic programming, relating to changes in, say, external environmental conditions. Analogies for a really responsive environment might include historic references to an intelligent and caring manservant, thoroughly wise to his master’s likes and dislikes, devoted to his personal comfort and satisfaction. The ‘servant’ is able to read the occupant’s /his master’s moods, and so predict and provide for these. Through ‘ubiquitous computing’, where the sensors and the hardware to deliver the required services or environmental conditions are embedded in the building fabric, the ‘manservant’ is now invisible and the means to deliver a completely satisfying environment can be embedded in the building itself. Louis Kahn’s often-quoted ‘served and servant spaces’ description begins to take on a different character, as they become integrated into the building itself.

CAN ANY DESIGN PLEASE ALL OF THE PEOPLE ALL OF THE TIME?

If the current NEMBES project experiment demonstrates that MyRoom is able to adapt in response to a single occupants physiological signals, then how much further could this be developed? In principle it should be possible to gather and process information from a number of individuals and to make some broad but appropriate assumptions about their general likes and dislikes. From this data it may then be possible to provide an environment that can adapt in various ways and is capable of at least “pleasing some of the people all of the time”. ‘MyRoom’ may eventually become OurSpace in due course!

As well as using sensors to respond to users’ feelings or emotional state directly they should also be capable of gathering data to be processed and used, through machine learning, as potentially useful feedback – which, properly analysed, could provide the verifiable ‘evidence’ in Evidence Based Design (EBD). This would enable designers to make more rational decisions, without necessarily dictating the outcomes of any design problem. The evidence could confirm what is generally preferable to users, information which so far has been either guesswork or the results of cumbersome survey techniques with potential semantic problems. Surveys also have the disadvantage of being able only to qualify a limited number of separate aspects of any environment. Sensor technology, using ‘affective computing’ which can simultaneously read and interpret a number of signals immediately, could pave the way to establishing reliable values that can be easily-applied in any design decision-making process, human or mechanical.

CONCLUSION

The joy of an approach that exploits continuous sensoring and responsiveness is that it can, with imagination, be enabled to adapt to any user. From the systems’ point of view (and it may well have one, if it is made capable of experiencing psychological affect), everything is data, either received from the user or transmitted to actuators. The architect is called on to make the imagined real, in the same way that she has always aspired, but is now faced with an almost entirely new set of technologies, which are only just being imagined as part of the arsenal of technologies, old and new, becoming available to the designer. This ever-expanding battery of technologies offers the architect the potential of multiple creative solutions to situations where technical and functional aspects previously conflicted with aesthetic considerations.

By applying *“What If?”* thinking into the curriculum through design projects, these ideas could become a valuable resource to prepare young designers for the future. Invisible technologies offer real challenges for designers to learn about ways to reconcile functional requirements with the qualities that make ‘good design’. Through an understanding of how the principles of sense-responsive architecture can be applied, stimulating and instructive topics for design studio projects may be evolved with many educational possibilities. By making students in undergraduate years aware of the current research thinking taking place within their own schools, though less-experienced, these students have less constrained imaginations and so might incorporate relevant ideas into otherwise unremarkable schemes, yielding fresher ideas.

In the recent past most of the technology available to designers was visible and its physical principles apparent, making its application relatively straightforward. Current technology, however, is increasingly more invisible, as well as developing at a pace with which it is hard to keep up. Yet building remains far behind communication or automotive engineering in its versatility and ability to adapt itself, rather than be modified at a later date. Much architectural design relies on learning from other buildings, often recently constructed. Examples of real cases where the technological potential of intelligent embedded sensor techniques have has been applied are few, but the hardware and software are already there, awaiting further development and viable applications. ‘Blue-skies’ thinking about where these might be gainfully applied demands real imagination; some may call it science fiction, but this remains to be seen. If 19th century writers had not envisioned journeying to the moon would NASA have been motivated to make it happen? It is said that necessity is the mother of invention, but how true is that in today’s world, where technology is moving faster than ever? Many potentially useful forms of technology currently available await someone to find a valid use for them, to envision connections that could enhance quality of life. Designers may not really need to know exactly how it is done, but should rather be made aware of what could be done, what information is needed to put into the system and what innovative outcomes could be provided. However, this is not to underestimate the complexity of the design of software, hardware, interfaces, and such systems as a whole.

Education has a role to fill this lacuna, but few initiatives appear have been taken up into the curriculum to extend thinking about possible ways in which technology can better serve a building's occupants. Future technologies should offer exciting challenges for designers to learn about the opportunities to reconcile stringent functional requirements into designs for efficient buildings and spaces that are equally elegant, beautiful **and** user-friendly. Even at an early stage in their architectural education, designers of tomorrow should be challenged to imagine the invisible, where technologies that have yet to be developed are integrated into the design to achieve more satisfying, well-tempered and delightful places for everyone to enjoy.

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