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Architectural User Interfaces: Themes, Trends and Directions in the Evolution of Architectural Design and Human Computer Interaction

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This paper reviews the historical and contemporary relationships between architectural design and Human Computer Interaction (hereafter HCI). Through this discussion the paper focuses on the enduring use of architecture as a metaphor in interaction design and the growing recognition that architectural space shapes the territory within which we interact with computational information. The paper begins with a brief discussion of the History of HCI before examining the relationship between the development of the computer Graphical User Interfaces (hereafter GUIs) and more recent work on Ubiquitous and Pervasive Computing. The paper then explores some current themes in HCI with a view to looking for potential overlaps between architectural design and new trends in the design of computational systems.

I. INTRODUCTION

There is growing recognition of the importance of computation to the design of buildings and, in parallel, to the augmentation of architecture using computational systems, including digital projection and pneumatic and motor articulated building components. In addition to these emerging themes, which might be broadly described as: studies on the affect of computational systems on the design and experience of architectural space, this paper will suggest another important and emerging theme: the affect of architectural design on the development of computational systems. More specifically, it will suggest that there has been an, often overlooked, relationship between the idea of architecture as a social and informational interface and the design of computer interfaces. Furthermore, it will be suggested that in an age of 'ubiquitous computing', in which digital devices are distributed throughout our living and working environments, there are important correlations between the design of computing systems and the design of physical spaces and places.

The recognition of this relationship between architecture and the design of computational systems is not new. However, it will be suggested, in this paper, that the fields of Architectural Design and Human Computer Interaction (hereafter HCI) have so far remained, at best only loosely tied and, at worse, isolated from each other. As a result there are under-explored areas in both fields, which have the potential to be developed by merging the Architectural Design and the HCI communities through common goals and interests.

This paper is framed by the notion that the built environment is increasingly being conceived as a user interface analogous to the Graphical User Interface of the personal computer. Understanding architecture in this way, i.e. as Architectural User Interfaces (hereafter AUIs), entails a certain conception of the built environment as a mediator between human beings and computational information. The study of AUIs is, therefore, distinct from those areas of architectural computing concerned with the application of computing to the design of architectural space. Through a critical analysis of AUIs, I will isolate some trends that have the potential to both challenge conventional disciplinary boundaries and facilitate a fruitful dialogue between HCI and Architectural Design.

The remainder of this paper is split into four parts.

Part one will give a brief outline of the history of HCI as a design discipline. Whilst not exhaustive, this history is meant to provide a basic introduction to HCI for those outside the field and will describe how HCI has evolved into a discipline which encompasses social sciences and arts as well as cognitive science and engineering.

In part two I will briefly examine the relationship between architecture and HCI, focusing on two areas:

- 1) Early work in HCI on the development of GUIs and the use of the built environment as a metaphor.

- 2) The shift in emphasis from virtual environments to physical environments through the evolution of pervasive and ubiquitous computing.

This section will then conclude with a critical analysis of the way in which architectural ideas have been absorbed within HCI with reference to commonly cited architectural works and the occurrence of terms such as 'architectural space' within the HCI discourse.

Part three will isolate some key themes from recent HCI literature that have architectural implications and may lead to new research. It will take the form of a sampled literature review, derived from current HCI research, which will act as a useful starting point for anyone looking for potential crossover projects which have both HCI and architectural implications. Through this literature review, this section of the paper will develop four broad research themes described here as, Ambient Interfaces and Atmospheres; Place, Space and Context; Fields and Thresholds and Programming Architecture.

Finally, this paper will conclude with some closing remarks on the nature of the relationship between Architectural Design and HCI and suggest some themes for future research and design work.

2. A BRIEF HISTORY OF HCI

The history of computing, and specifically HCI, is often divided into three generations or 'waves' of computing device. Each wave represents both a technical revolution and a change in the way humans interact with computers.

The first wave coincided with the earliest computational machines at a time when there were few large and expensive computers which were operated by specialist experts. HCI, as a discipline, doesn't emerge until the second wave of computing, through the evolution of personal computing and the corresponding change in ratios of computational devices to users from one to many to one to one. A host of innovations, including the mouse and keyboard [1] and the GUI [2], made computational devices accessible and, in parallel, computer science looked to psychology to explain 'human factors' in computing systems. Methods from applied psychology allowed user interfaces to be evaluated and created design frameworks through which to design usable and intuitive systems. Experience with these systems, however, showed that psychological descriptions of human behavior where, on their own, insufficient to explain the complexity of human computer interaction. A new generation of HCI researchers (for example [3]) extended the discipline to include a wide range of the social sciences including sociology and anthropology, on the basis that the design of information technologies could not be isolated from their broader social and cultural context.

Finally a 'third wave' of computational devices has been characterized as many to one where computing is pervasive and ubiquitous in our environment and everyday objects are computationally enabled and identified. The prediction of this third wave of architectural computing is often credited to Weiser who coined the phrase the 'disappearing computer', predicting that, as computers became cheaper, smaller and networked, the age of the single computational device would give way to ubiquitous computational systems in which every day objects could be embedded with computational capabilities, weaving *'themselves into the fabric of everyday life until they are indistinguishable from it'* [4]. Weiser's predictions have, to some extent, been realized and the fields of Pervasive Computing and Ubiquitous Computing along with Embodied Computing are now recognized as fields in computer science with their own conferences and proceedings [5].

Embedding computation into everyday contexts and attempting to create interaction methods that are 'natural' [6] has extended HCI to embrace many other fields including art and design. The lowering costs of computational devices and the development of software tools such as Processing [7] and hardware tools such as Arduino [8] have meant that it is now possible for non-engineers to build experimental computational systems. A modern HCI conference such as ACM Computer Human Interaction (hereafter CHI) wide array of contributions including descriptions of highly technical engineering approaches to produce novel technologies; research which adopts the methods of applied psychology to describe User Experience (hereafter UX) in formal terms; papers which adopt methods from sociology and anthropology to test devices and interaction techniques, and descriptions of highly experimental interfaces and installations derived from artistic practice. In addition, the research challenges set by HCI have also changed. HCI emerged as a discipline concerned with the usability of computer systems but recognition of the relevance of many other disciplines to HCI is also a recognition that many HCI problems are, in Rittel's terms: 'Wicked Problems' [9] i.e. problems which have no optimum solution but are derived from a complex network of variables which have many possible outcomes. The recent history of HCI has also become characterized by what we might call diffuse problems. Rather than simply seeing computational systems as functional objects which must be tested in terms of their usability, the impact of computational systems on society and on the emotional and aesthetic aspects of human life are also considered to be relevant topics. At the recent (2011) CHI conference for example workshops were being offered on topics as diverse as how can HCI engage in political activism [10] and papers were presented on topics such as using HCI to help prevent war [11]. HCI practice has thus evolved into the new field of 'Interaction Design' [12] in responding to wicked and diffuse problems.

3. ARCHITECTURE AND HCI

Through this evolution, HCI has come to encompass a complete spectrum of disciplinary practices from empirical scientific enquiry to provocative artistic experimentation. HCI, therefore, represents a seductive field for anyone interested in engaging in research that is both multidisciplinary and practice based. HCI also mirrors architectural practice, traversing the tree of knowledge and simultaneously balancing a technical rigor and artful practice with the aim of tackling wicked and diffuse problems. The similarities between these disciplines don't end there and in this section I will discuss two critical phases in HCI's development in relation to Architectural Design, through the development of GUIs, and more recent experiments in Ubiquitous Computing (hereafter UbiComp).

3.1. GUIs and Architecture

GUIs are among the most important products of HCI research and are still the most ubiquitous way of interacting with computers. GUIs are at the heart of most modern operating systems and similarities between the basic organization and appearance of, for example, Microsoft Windows and Apple OS belies a common heritage in research conducted in the Xerox Parc research labs in the 1970s and one of the first computer operating systems to use a GUI – Xerox Star [13]. Part of the success of the personal computer has been that it adopts metaphors with which computer users feel familiar, such as files and folders and iconic representations of tasks and processes. In an effort to make computing accessible to a wider public, however, the early history of HCI research is littered with examples of attempts to extend the surface of the computer desktop both literally and metaphorically. Why not, for example, have a whole *room* or *set of rooms* [14] or allow tasks to be spread over *multiple galleries* [15]. Proposals also emerged for user interfaces based on virtual offices, museums and even whole cities [16]. This GUI movement was based on a principle summed up by Kuhn and Blumenthal in their 1996 workshop for CHI called 'Spatialization: Spatial Metaphors for User Interfaces':

Space as we experience it daily, from our desktops through the rooms and buildings we live in, to the cities and landscapes of our environment, has essential properties required from source domains of general-purpose interface metaphors [17].

Based on the notion that space offers an intuitive interface for the representation of information, Kuhn and Blumenthal and others focused on architectural space as a metaphor through which visual screen space could be articulated. The legacy of these systems, however, is less than clear. Whilst the logic of extending the desktop seems straightforward, we are not yet navigating the WWW as a city or browsing our desktops through

virtual rooms. Virtual environments (although very popular) are confined to specific entertainment and social networking spaces (i.e. video games which simulate aspects of real or imagined places and multiplayer social applications such as Second Life). This era in the history of Graphical User Interfaces has been summed up by Johnson as representing a '*hysteria of total simulation*' [18] and doubt has been cast on the usability of 3D GUIs and criticism leveled at the over use of metaphors of the built environment [19].

Although 3D GUIs would seem to be natural extensions of the 2D office environments of common personal computer interfaces, it seems increasingly unlikely that the next generation of GUIs will be realized through a metaphor of the built environment in 3D. As an historic paradigm, however, the relatively brief foray of HCI into the world of architecture is interesting on two counts:

- 1) The architectural research community remained relatively mute on the topic of 'spatialization' in GUIs. There were some extensive and speculative discussions on the emergence of 'cyberspace' and its implications through, for example, Michael Benedikt's edited *Cyberspace: First Steps* [20] and through special additions of the journal *Architectural Design* (AD) entitled *Architects in Cyberspace* and *Architects in Cyberspace II*, but these publications tended to reflect on the, potentially revolutionary, implications of virtual environments (and other digital technology artifacts) on architectural design rather than the way in which architecture was been used as a way of articulating GUIs.
- 2) Despite the lack of interest from the architectural community, a number of references to architectural theory did begin to appear in HCI literature. In particular, I have noted elsewhere [21] that the work of a number of structuralist architectural theorists, including Christopher Alexander's concept of Design Patterns and spatial analytical methods like Space Syntax were increasingly being used to bridge the gap between cognitive theories in computer science and their design. Among these theorists is Kevin Lynch with his book on Urban Design *The Image of the City* [22]. While it would not be accurate to suggest that Lynch has had a profound impact on HCI, it is worth noting that there are 42 references to Lynch in the ACM archive of the CHI conference. These references tend to cite Lynch's concept of 'imagability' to conceptualise interaction with GUIs and thus make a claim of cognitive parity in navigating real and virtual environments. Through people such as Kevin Lynch, there has been an attempt to bridge a gap between design as an architectural practice and HCI as a practice concerned with cognition. Furthermore, architectural theory is being introduced as a way of trying to make sense of increasingly complex graphical metaphors and of rationalizing interactions with computer technologies.

3.2. UbiComp and Architecture

Reviewing HCI through CHI papers we can note an interesting pattern in references to Kevin Lynch. From 1994 to 1998 Lynch is referenced by at least one paper every year. There is then a gap between 1998 and 2002 followed by a re-emergence of references to Lynch (again one per year) until 2011. The real interest, however, comes in the way these references are being used. Before the gap every paper referencing Lynch is a study of virtual environments. After 2002 every paper is related to systems which support the navigation of real locations. This shift from virtual to physical indicated by references to Kevin Lynch reflects a greater shift in HCI research which has been noted by Malcolm McCullough in relation to the first publication of ACM's journal 'Ubiquity':

Digital networks are no longer separate from architecture. Unlike cyberspace, which was conceived as a tabula rasa, pervasive computing has to be inscribed into the social and environmental complexity of the existing physical environment [23].

This transition away from cyberspace also indicates a shift in emphasis away from the image-based technologies of the GUI and also coincides with the emergence of a generation of people who were born with computers as part of their lives and who, therefore, rely less on computer interfaces which are framed by metaphors of old media. A teenager about to go to university now, for example, is likely to have encountered a file as a computational representation well before its physical counterpart. In this new era of HCI, computers are not studied as simulations or metaphors of existing environments but are studied as extensions or additions to our environment.

The potential of UbiComp has been recognized in architectural discourse. Notable chroniclers of the impact of new technologies on our understanding of place and space have included William J. Mitchell's *City of Bits Trilogy* [24, 25, 26] which extends the study of Urbanism to include networked technologies, Malcolm McCullough's *Digital Ground* [23] which brings together architecture and interaction design in a quest for a new liberal art and Richard Coyne's *The Tuning of Place* [27]. There have also been a plethora of research groups and other endeavors, often initiated by university architecture departments, to explore the architectural implications of ubiquitous technologies, including research on Urbanism through, for example, MIT's Senseable Cities Group [28] and in Europe through groups such as Digital Urban Living [29] in Aarhus. Similarly, architectural approaches to interaction design have also become prevalent with equivalent themes being explored in journals such as AD [30, 31] and new guides to Interactive Architectures [32].

In the context of this rich engagement with digital technologies we might expect that Architectural Design would have had more impact in the

context of HCI, but reviewing the CHI literature reveals a mixed picture. Of the architectural chroniclers of the third wave of computing McCullough, Mitchell and Coyne are referenced only a handful of times [33]. This is not a criticism of these authors (who have been referenced extensively elsewhere) but it does indicate that Architectural approaches to the design of computation systems are not necessarily gaining ground in the HCI community.

Given that there is a rich and active dialogue on the implications of architecture for digital technology, is it important that there is no apparent explicit relationship between architectural theory and design and HCI? In the next part I will argue that despite the lack of explicit references to architectural theories or design methods there is an implicit relationship evidenced through persistent references to issues of architectural space and architectural design in contemporary HCI.

4. EMERGING THEMES IN HCI AND ARCHITECTURE

I have described the third wave of computing both in terms of technology and of research culture. In this part I want to expand this description by suggesting that the third wave of computing also represents a shift in the scale of interaction. Design research in UbiComp has become synonymous with theories of embodiment, where computational artifacts are considered in relation to their material manifestations and through physical human interaction with them [34]. This change leads us away from the visual paradigm of GUIs to a tactile paradigm often described through Tangible User Interfaces (hereafter TUIs) and this shift from visual to tangible computing has the potential to change the scale of interaction. When interacting with a screen (as with a GUI), no matter how expansive the visual environment is, it is still restricted by the edges of a frame or metaphorical window. Interacting with several devices in a real environment, however, extends the space of interaction beyond these bounds, making physical movement, in terms of the interactor's bodily traversal of space, into a potential interaction input.

In the third part of this paper, I will introduce some of the key themes to have emerged in the recent history of HCI which reflect this shift in technology and scale and which imply new approaches to spatial and technological interactions.

4.1. From Ambience to Atmospheres

Of all the emerging fields in UbiComp, studies of Ambient Interfaces make the most direct and explicit references to architectural space. The origins of Ambient Interfaces can be traced to Wieser's paper on the 'Computer for the 21st Century' [35] and the notion of moving computer interfaces away from the center of our perceptual fields.

Research in this area is exemplified by the work of MIT's Tangible Media Group [36] and summed up in their 1998 paper [37]. Whilst not making explicit reference to architectural texts (although the paper does reference Dunne and Raby's article entitled *Fields and Thresholds*, a version of which appeared in AD [38] a year later) the paper blurs the distinction between digital and physical spaces. It suggests that digital technologies might allow us to turn everyday architectural spaces into interfaces. The group's work is manifested through a series of interventions integrated into an Ambient Room filled with devices through which information is mapped on to different output modalities. Examples include: a lamp which projects light onto a ceiling through a bowl of shallow water which can be vibrated to create patterns and 'pinwheels' which are suspended on a ceiling and spin in response to the amount of network traffic moving through them. Since this early contribution, ambient interfaces have been realised through a range of interventions and approaches to create architectural elements including facades, walls, ceilings, lamps etc. using architecture as a computationally "expressive medium" [39] (see for example [40, 41, 42]).

In seeking to extend the development of ambient interfaces, architecture must surely have a role to play. Whilst the HCI literature focuses on the notion of ambience, we might extend this term to atmospheres, where atmospheres represent the synthesis of many ambient cues. The devices in Ambient Room are expressive but also idiosyncratic (particularly if we consider devices such as the water lamp in which the vibrations of the device are, in the demonstrator, mapped to the motion of a hamster on an exercise wheel). As computer user interfaces they are not necessarily providing useful functional information but are, rather, attempting to augment the atmosphere of place. Taken individually, the devices in Ambient Room are subtle and peripheral, taken together, however, they may represent a cacophony. Some work has been undertaken in an attempt to understand the concept of atmospheres in ambient interfaces. Ross and Keyson, for example, seek a broader notion of functionality for ambient interfaces, suggesting that *'Social, personal, and emotional engagement as well as expression are salient factors in interaction and values beyond functionality need to be taken into consideration such as playfulness and personal expression'* [43].

An architectural approach to ambient interfaces may be able to better articulate the concept of atmospheres with a view to better understanding the integration of the many ambient cues which make up architectural experience and of how this experience is modified by technology. Architectural spaces are not neutral canvases on which to present and interact with digital information and whilst ambient interface research conceptualizes architectural space through elements (walls, ceilings etc.), experience of architecture is an experience of a synthesis of all of these elements taken together.

4.2. Context and Place

One of the most important theoretical discussions in third wave HCI is the nature of both context and place in relation to technology. The emergence of UbiComp has seen the rise of, so called, context aware devices. Context aware applications are often GPS enabled (e.g. in smart phones) and can filter information pertinent to a given location (e.g. geographically close shops and services). However, 'context' in HCI also has a broader and more complex meaning. Among the most important theoretical discussions on the issue of context are two papers, the first from Harrison and Dourish [44] and latterly from Dourish on his own [45]. The earlier paper distinguished between space and place, describing space as the:

geometric arrangements that might structure constrain and enable certain forms of movement and interaction' and "place" which "denotes the ways in which settings acquire recognizable and persistent social meaning in the course of interaction" in other words "space is the opportunity; place is the (understood) reality.

The two papers are indicative of the shift in definitions of place and space from the 1990s focus on the development of virtual environments, to the more recent research on physical contexts and places. However, both papers are bound together by the search for a richer understanding of place, space and context within HCI at a time when physical environments are considered as user interfaces. Space, suggests Dourish, in the second paper, structures more than an environment's material and geometric properties. Designed spaces are, he suggests, strategic where function and spatial location are closely coupled. Place, in contrast, is a product of tactics and not simply of programs. Tactics suggest the possibility of appropriation where function can be altered, challenged and even subverted. In observing Dourish's distinction between strategic spaces and tactical places enabled by technology, we can also recognize the challenge of designing architectural space and, in particular, the ongoing distinction between architectural program (i.e. the necessity to understand and articulate a buildings patterns of functions) and the flexibility inherent in a buildings use and adaptation over time. This difference between strategic and tactical spaces has a significant implication if we consider architecture to be a computer user interface. It is difficult to imagine a GUI in which the locations and meanings of the icons changed depending on factors such as the time of day and the mood of the user. At the same time, however, it is also difficult to imagine an architectural space on which every surface has a fixed functional purpose. Yet the latter view of architecture is prevalent in research of computationally enabled 'smart spaces'. For example, Lan describes a design approach for a smart office environment through, what he defines as, 'Situated Life Patterns'. This approach involves the mapping of activities on to physical space through a rigorous analysis of places within an office and their associated activities. His description of such an analysis runs as follows:

Prof. Lan walks into his office. When he stands in front of his office, he is identified and allowed to get into his office by the smart door at the entrance. His status of 'inside office' triggers a spatial event to display the daily schedule on the smart wall. He notices his students will come to his office for a group meeting later [46]

Lan describes how various computer enabled surfaces are distributed throughout the office, mapping actions to particular places and times and distributing relevant information to 'smart walls', 'smart doors' and 'smart tables'. Such descriptions of what we might call 'place-actions' are deterministic, turning physical space into an enhanced GUI with locations connected to applications. Whilst examples of this nature are fairly extreme, a growing awareness of ubiquitous technologies, their functional distribution and spatial behavior change are prevalent in a range of contemporary HCI papers presenting computer systems which augment architectural space through computational interaction (see for example 47, 48, 49, 50). Others have noted that smart space installations have, historically, tended to reinforce 'nineteenth century configurations of home interiors based on "social/intimate/service areas tripartition and compartmentalized room layouts' [51] and Rodden and Benford [52] have challenged some of these notions of programmed space by introducing architectural theory in the form of How Buildings Learn [53] and suggesting that there needs to be an understanding of the temporal layers of a building's form in terms of 'site', 'structure', 'skin', 'services', 'space plan' and 'stuff' (i.e. the static and dynamic contents of a building).

4.3. Fields and Thresholds

In contrast to strategic conceptions of architectural space, tactical appropriations of space in HCI have recognized the seamfulness and heterogeneity of spatial interaction. For example, Can You See Me Now, which is considered to be a classic piece of HCI Research [54], consists of a game of cat and mouse played by both physically and virtually co-present users. The physically located players used Global Positioning Service (hereafter GPS) enabled devices to plot their movement and to see the virtual players piloting avatars in a parallel virtual world. Whilst both the virtual and physical environments are mapped on top of one another, the two sets of players are not persistently co-present. The layer of technological infrastructure, in this case the GPS, means that players are able, for example, to use GPS black spots to hide and ambush opponents. In addition, therefore, to the physical barriers and thresholds, which afford the possibility of hiding, the networked layer creates what Dourish describes as "a new spatiality of access, presence and interaction and Benford refers to as a 'hybrid spatial structure' [55]. Public interactions with large media screen installations are known to alter the behavior of people within their context and, in turn, different contexts afford different

possibilities of interacting with the same system [56]. WiFi networks have also been shown to significantly alter the use of public and private spaces [57]. It is also interesting to note that the material basis of wireless networks means that the data collected from, for example, mobile telecommunication masts can be used as a way of mapping and classifying activity in real spaces.

More recent work in HCI has also picked up on the potential to capitalize on the 'seamfulness' (term defined in HCI by [59] and discussed by [60]) of technologies deployed in physical spaces discussing, for example the nature of digital boundaries [61] and experimental applications such 'Weightless Walls' which allow a user to create a virtual threshold which, through the use of headphones and microphones, can shape an acoustically shielded space without any physical intervention. Gaver et. al. also make explicit reference to 'Threshold Devices' [63] which include their 'Local Barometer' and the 'Plane Tracker' and which gather information from their *'surroundings to suggest how here is connected to and situated within there.'* These projects all imply that the implementation of new virtual thresholds, far from reinforcing spatial programs, could blur physical thresholds. These projects give an insight into a new type of architecture shaped by a new socio-digital system of physical and virtual thresholds enacted in architectural space.

4.4. Programming Space

Threshold devices extend the way architecture is articulated and they also reveal how architecture is considered as an informational interface. Creating a boundary or threshold delineates functions and activities as well as space. Where previously discussed examples of spatial context (e.g. Lan) have sought a deterministic definition of space within which place and function are coupled, a challenge for AUI comes when function and place become entirely decoupled.

It is interesting to note that, where the first of Dourish's Space and Place papers made use of architectural and urban theory (notably Alexander's *Pattern Language* [64] and a *Timeless Way of Building* [65]), the later paper contains far more references to studies in anthropology and human geography. In this final part of the paper, I want to reflect on some of this literature in the context of approaches to programming space. The notion of programming is implicit in architectural design as the articulation of functions through the configuration of spatial relationships. In HCI the notion of programming refers to a different design activity, namely the configuration of software code to perform computational functions. However, in UbiComp the two notions of programming can come together and while this association has been discussed in relation to Architecture [66], the relationships between programs in space and programs in software have been more comprehensively discussed by researchers in human

geography, particularly by Crang and Graham [67] and Kitchin and Dodge [68]. The interaction between software and space has been discussed by Crang and Graham, for example, through their development of the work of Nigel Thrift [69] on the 'technological unconscious' by describing three types of digital/spatial process: 'Augmenting Space', 'Enacting Space' and 'Transducing Space'. In the previous sections I have given examples of augmented space and, in terms of AUIs, technologies of Augmented reality often use architectural elements which are enhanced by, for example, projections or mechanical devices. The process of 'enacting space' builds on the technologies of augmented space but introduces an intermediary process of inference and filtering. A decision is taken by a computer system as to which piece of information needs to be presented in specific contexts. Agency shifts from the user's activity in interacting with an environment to the agency of the computer. Examples include mobile applications which act as recommender systems: using the technologies of augmentation to project relevant contextual information on to space through a mobile phone camera and displays which have been filtered through heuristics which infer relevance to the user's interests.

Crang and Graham develop a third spatial process described as 'Transducing Space' in which an object, or indeed a person, can be located in ways that they are unaware of, so that the identification of relevant information and the decision making part of the system creates a 'technological unconscious'. This technological unconscious can become insidious and can create a new type of spatiality that can be problematic because it is largely invisible. Graham uses the example of automated telephone queuing systems for access to services such as banking [70]. When making a call to a bank, the user can often be recognized from their phone number and, from that identifier, the system can ascertain the 'value' of the customer from their balance and banking record. Based on this information, the customer, without their knowledge, can be placed in the queue at a position which reflects their importance to the bank. If we transpose such a system into physical space we might expect the bank to lose custom quickly. While there are examples of the enacting of social status in physical spaces (first, business and standard classes on an aircraft for example) the discursiveness of actions within, particularly, public spaces tends to have a democratizing affect so that high street banks don't tend to have multitier queuing systems based upon a customer's current balance.

Digital technologies have the potential to compartmentalize experience and to hide interaction. Interaction with mobile phones, for example, tends to promote private experiences (particularly when they are used to do things other than make phone calls) which are disconnected from their spatial contexts and HCI research increasingly favors devices and interaction methods that are hidden and non-discursive. This trend in HCI has been challenged recently by Jones [71] who suggests the need for new types of

interaction which he describes as, 'extravagant' and which challenge the 'introverted' nature of many human computer interactions and 'puts us back in touch with our surroundings'. Jones's notion must surely be good news for architecture and it challenges notions of architecture as icon; as a visual interactive canvas or as programmable space and perhaps challenges the notion that Architecture can be a user interface at all.

5. CONCLUSION

In this paper I have used the notion of AUIs as a way of critically reviewing the relationship between the disciplines of HCI and Architectural Design and of considering architectural space as an interface with computational information. This analysis has been both historical and contemporary and I have shown that there is a long-standing interest in architecture from the HCI community, both for the design of the GUI and more recently UbiComp. However, I have shown that notions of architectural design, the built environment and space and place have changed.

In the context of the design of GUIs, architectural space was considered to be a useful metaphor. Buildings become both literally and metaphorically iconic and architectural space was considered, through graphical simulations, to extend Desktop computing and to afford the possibility for an intuitive interaction. These attempts at graphical AUIs also recognized a new scale of interaction, exchanging point and click direct manipulation with navigation and this opened up the possibility of influence from Urban Theorists such as Kevin Lynch.

Graphical AUIs have yet to emerge outside specific gaming and social applications and the turn of the century saw a shift in focus from GUIs and virtual environments, toward pervasive and ubiquitous computing. This shift also brought with it a renewed interest in architectural space as a site of interaction and as a type of user interface in its own right. Discourse on, for example, ambient interfaces, see architectural space as composed of surfaces and components which can be augmented to present digital information in the periphery of the user's perceptual field. This trend towards seeing architectural space as a site of interaction also raises questions over the nature of context and I have described, in this paper, a distinction between approaches which 1) see architecture as an interface, analogous to a graphical user interface which can be 'programmed' and where actions and interactions can be coupled together; and 2) space as appropriated, 'tactical', public and democratic. Through contemporary HCI discourse, terms which are common in architecture, such as place and threshold, have gained new significance. I have attempted to move beyond a superficial understanding of concepts such as context and space to understand the implications of spatial programmes (spatial behavior) and thresholds, ambience and atmospheres (spatial experience).

The use of the term AUI is meant, in part, to be a provocation. Architectural experience is much richer than is implied by conceptualising architectural space as simply an interface to digital information. However, where graphic design supported the development of the GUI and product design supported the design of tangible user interfaces, I propose that the new century may prize architectural design, along with relevant cognitive theories, in the development of situated and pervasive computing interfaces. For this to be the case, however, there needs to be an active discourse between architectural design and HCI. Now with many programmatic descriptions of interacting with computational systems in real spaces it seems that reality has become display. To be convincing, however, collaborations between HCI and architectural design must move beyond previous work that has seen computational space through the metaphor of architecture and architectural space as a programmable site for interacting with technology. Architectural Design has the benefit of many thousands of years of evolution where HCI has been around for less than 5 decades yet the products of HCI research and design are increasingly shaping our experience of architectural space. Finding appropriate places for collaboration, therefore, is vital for both disciplines.

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