Human–Computer Interaction Series

Nicholas S. Dalton
Holger Schnädelbach
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Tasos Varoudis *Editors*

Architecture and Interaction

Human Computer Interaction in Space and Place

Springer

Human–Computer Interaction Series

HCI is a multidisciplinary field focused on human aspects of the development of computer technology. As computer-based technology becomes increasingly pervasive – not just in developed countries, but worldwide – the need to take a human-centered approach in the design and development of this technology becomes ever more important. For roughly 30 years now, researchers and practitioners in computational and behavioral sciences have worked to identify theory and practice that influences the direction of these technologies, and this diverse work makes up the field of human-computer interaction. Broadly speaking it includes the study of what technology might be able to do for people and how people might interact with the technology. The HCI series publishes books that advance the science and technology of developing systems which are both effective and satisfying for people in a wide variety of contexts. Titles focus on theoretical perspectives (such as formal approaches drawn from a variety of behavioral sciences), practical approaches (such as the techniques for effectively integrating user needs in system development), and social issues (such as the determinants of utility, usability and acceptability).

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Preface

This book emerged from a chance collision of the editors, and others, at an ACM SIGCHI conference in 2011 in Vancouver. We were a disparate collection of academics and researchers who came together, all of us surprised that there were others who held an interest in, or connection to, architecture and the built environment at a conference on human-computer interaction (HCI). While we talked about it, it became clear that we were not the only ones who had this singularly quixotic preoccupation. In the process of creating a workshop for the subsequent ACM SGICHI conference, we were able to begin to articulate the nascent synthesis of the hitherto seemingly divergent areas of human computer interaction and architecture. Through the process of creating and running the workshop, we have begun to feel that these areas are both complementary and likely to share a future together.

As the chapters in this book will attest, architecture is exploring the use of digital technology and, at the same time, many digital technologies are exploring their integration into buildings, contexts and places. Given other prior and ongoing research and events in this area, our meeting and subsequent workshop appears less the consequence of chance and more the inevitable process of building/computer convergence.

This book and this field are still highly formative, much of the work we did in editing the book was identify themes, issues and concerns. As two disciplines collide, it is inevitable that new terms and new languages have to be shared and mutually comprehended. This is not an inconsequential task and in overcoming these early communication problems we hope we are creating the foundations for later research to build upon. The objective of this book is to initiate discussions, initiate collaborations and reveal a shift in perspectives.

Historically, when human computer interaction moved from command line interfaces to early graphic user interfaces, it was realized that the domain of graphic design was not a trivial area of expertise which could be easily discounted or subsumed into the interaction process. Visual design became a domain of knowledge which added to the richness of the interaction process and interaction research.

Similarly, as we move into the realm of interaction in the built environment, human computer interaction researchers might then see those with knowledge of space, inhabitation and architecture as bringing new knowledge and expertise into the realm of interaction design. Fundamentally Weiser's vision of ubiquitous computing was that of 'technology beyond the desktop', embedded in the fabric of the world around us. While interaction specialists see the potential benefits, both in the utility and simplification of interaction that this 'embeddedness' brings, they are less likely to be aware of the wealth of design expertise which has developed over many millennia in the design of built form. The objective of this book is to introduce those design professionals and interaction researchers to each other, so that the possibility of solutions to their current problems already existing might be discovered.

At the same time, we hope that some of the wealth of projects in this book show that architecture is not a passive partner or a consultancy in waiting to HCI. We hope to show that architects are highly passionate about the integration of digital components into the design of the build environment. From an interaction point of view, there is a great deal about the process of designing for interaction, which the architectural world is equally unaware of.

The central task, therefore, of this book is one of introduction. If this book could encourage those on either side of the divide to cross over, as our workshop participants did, then its purpose will be fulfilled and the efforts of the authors, editors and organizers will be well rewarded.

Finally, we would like to use this space to acknowledge the organizers of the original workshops: Prof. Keith Green, Professor of Architecture and Electrical and Computer Engineering at Clemson University; Prof. Christoph Hölscher, Chair of Cognitive Science at ETH Zurich; Prof. Ruth Dalton, Department of Architecture, Northumbria University; Dr Paul Marshall, UCL Interaction Centre, University College London; and Dr Anijo Mathew from the IIT Institute of Design. They, along with the editors, committed a great deal of time, energy and effort to both the workshop and the formulation of the book. Without their energy and commitment, this project might not have happened. We would like to thank them for their time, energy and effort.

Newcastle upon Tyne, UK — Nicholas S. Dalton
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February 2016

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Chapter 1
Introduction

Nicholas S. Dalton, Holger Schnädelbach, Mikael Wiberg, and Tasos Varoudis

Abstract Ubiquitous computing has a vision of information embedded in the world around us. Yet the built environment, while familiar is also the subject of design. Recently, architects have also seen digital elements incorporated into the fabric of buildings as a way of creating advanced spaces and environments to meet the dynamic challenges of future habitation. Historically, both sides have progressed based on their own practice in largely mutual non awareness.

This book, based on a series of workshops held at the prestigious international ACM CHI conference seeks to bring these research communities together. This chapter introduces the ideas, themes and issues approached in the book.

To the average reader it might feel rather incongruous as to the necessity for a book on Architecture and Human Computer Interaction (HCI). However, the editors feel that these subjects are not discordant. While there are clearly differences, Architecture, as a design profession is hundreds of years old, while human computer interaction is relatively new, but they offer many similarities. The editors would argue that in terms of complexity, Architecture and Urban planning are one of the few technologies which exhibit the same kinds of scales, heterogeneous hardware, distributed ownership and complexities that large software and digital technologies

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do. It seems natural that we explore the existing commonalities between these two fields as a source of more than inspiration; in this book we hope to show how the destinies of the two fields strongly intersect.

From the days when computing abandoned the command line interface, Human Computer Interaction has dealt, rather implicitly, with space. From the earliest two-dimensional graphical user interface to three-dimensional representations, gaming and virtual reality, emerging into mobile computing, context aware computing, urban computing, public displays, ambient computing, tangible computing and ubiquitous computing, our awareness of space and its role in the interaction process is becoming more distinct. As computing becomes embedded in our homes, our streets and our buildings, the demands to understand the role of space and architecture are becoming critical to HCI.

At the same time, architecture is becoming far more engaged with the digital experience. Architects are already introducing digital components into buildings. For example, architects at ART+COM have designed a museum for BMW using complex projections and ambient displays (ART+COM 2008). Hyposurface by Mark Goulthorpe et al. (2001), Blur Building by Diller et al. (2002), and Bubbles by Michael Fox et al. (2006). Kas Oosterhuis and Ilona Lénárd (1998) and Oosterhuis et al. (2002) have used digital projectors to create complex adaptive spaces. Yet these practitioners have had little access to the techniques and methodologies of human computer interaction, potentially compromising the user's or occupant's experience.

With the rise of the graphical user interface and later with the web-based Internet, HCI evolved by extending it's collaboration to those from a graphic design background (Mackay et al. 1997). Historical precedence suggests that computing will, by necessity, begin to engage with architecture much in the way that it did with the graphics community. Yet this can only happen well if both sides are aware of their own expert knowledge, have some understanding of the expertise of others, and, finally, have some awareness of their own ignorance regarding the other discipline.

This book emerged from a series of workshops at a succession of ACM/CHI conferences (Dalton et al. 2012, 2014), which attempted to bring these diverse communities together to explore what mutual cooperation might bring to each field. The organizers included computer scientists, architects, architectural robot designers, cognitive psychologists, human computer interaction researchers, and architectural researchers, just to give an idea of the scale of the community brought together. What we discovered was not only a number of overlapping concerns, but also divergences over methodology, terminology, and practice. This book is an attempt to record some of these perspectives and begin to create an overarching framework to understand how these two communities could begin to interact and collaborate. Our hope for this book is to begin to form a roadmap for future collaboration and research. To do this we must begin by understanding that both communities have different research arcs which seem to be drawing towards the same point: that there will be a merging of digital information flows embedded in the built environment which we will occupy.

The purpose of this book, much like the workshops, is to initiate and facilitate this partnership rather than ossify the positions. Our aim is to create awareness, define terms, and map out research. To facilitate this, the book is aimed at both human computer researchers and practitioners, and those engaged in the architectural profession. The editors and authors believe that a number of forces have set both disciplines on a collision course resulting in circumstances where incomprehension can no longer be tolerated. These collision vectors come from two directions, which we will now describe in turn.

Space in the Direction of Human Computer Interaction Research

If we scratch the surface of Human Computer Interaction (HCI) we see architecture as a metaphor buried beneath (Chen and Rada 1996) it. HCI is awash with spatial and architectural metaphors. We have the home button, we navigate to a page, we surf the web or the information super highway, we click the back button, we mine information, the website is under-construction, we get lost in cyberspace, we follow 'trails of bread crumbs' to navigate 'up' to the top level and software is built by software architects who perform 'cognitive walkthroughs'. Even Donald Norman's seminal work (1988) is littered with architectural details such as door push plates, and shower systems as examples of affordance and cognitive models. It is of little surprise then that cognitively computing, like architecture, is one of those systems which cannot be wholly appreciated from one perspective. Like a building, to operate complex software it needs to be explored and learned, forming a cognitive model. For complex software and websites new software users behave like new residents to a building or neighborhood, they move beyond initial fixed memorized paths and memorized routes to combine different paths through software flexibly. Eventually routes and commands become like words in a sentence, almost infinitely interchangeable in pursuit of a goal. Like a pedestrian or a driver, an expert user can navigate through a digital habitat with very little consideration or apparent mental effort. Even in the realms of previously two-dimensional interaction space does not escape from the potential influence that research into space might bring. There is some evidence to suggest that users who have difficulty navigating space have difficulty navigating websites (Kim 2001; Jones et al. 2007; Chen and Rada 1996). This introduces questions into the field of Human Computer Interaction. When we talk about being 'lost on a website' or interface, are we talking metaphorically or literally in a cognitive sense? If the answer is literal, what can one of the most established professions, dealing with navigation design, tell us about the construction of software for navigability? Given that architecture isn't free to perform empirical experiments, can the insights of interaction design help us to redesign more navigable landscapes? Navigation is an on-going concern in Human Computer Interaction, as it is indeed in architecture, and environmental psychology. As such it is likely that these two fields will begin to overlap to ever-stronger degrees.

Ubiquitous Computing

Moving beyond the graphical user interface, Marc Weiser's (1993) original vision of ubiquitous computing, saw computing receding into the background, and by background he meant the fabric of the world around us including clothes but specifically the built environment. In his 1991 Scientific American article, terms from architecture fill most of the world, very different to the writing in Doug Engelbart's 'mother of all demos'. Weiser's Sam character distinctly moves between rooms to create new contexts. Sam has an urban context of a neighborhood, a home, she navigates traffic to go to work, she shops, buys coffee. She looks through windows, uses offices, signs, meeting rooms and leaves items near doors. In short the very thing which computers were receding into, was the architectural structure around us. Direct descendants of Weiser's vision, smart homes like Georgia Tech's aware home (Kidd et al. 1999) were built around the turn of the millennium. In a review of smart homes, Chan et al. (2008) reported on 54 papers discussing smart home installations mostly with a Tele-care bias. Significant by it's absence in this work, is any information about the homes as buildings. There seems to be an implicit assumption of neutrality to the level of naturalness. The built environment that computing was meant to recede into did not come around accidentally; it is also the product of much investigation and reflection, the extent of which is currently unclear in Computer Science.

Spatial Approaches in Interaction Research

There are also research perspectives that view space as an active participant in the interaction system. Proxemics (Ballendat et al. 2010), for example, shows how an understanding of space, occupant, and device may lead to new interactional dynamics. Ishi and Ulmer (1997) and Wisneski et al. (1998) describe ambient computing as fusing architectural surfaces with active interfaces, but, by doing so includes the role of space, spatiality, and architecture in interaction as mentioned in (Wiberg 2011). From a theoretical perspective, Rodden and Benford (2003) point to new directions in HCI observing that ubiquitous interaction had so far focused on 'stuff' and had failed to explore space. Kostakos et al. (2006) also argues that, "*We have no fundamental theory*, *knowledge base*, *principled methods*, *or tools for designing and building pervasive systems as integral elements of the urban landscape*." He further contends that space is a fundamental part of this urban picture. Numerous authors have also written to challenge our notions of context. Brignull and Rogers (2003), for example, are a strong proponent of leaving the lab and engaging with ecologically valid contexts, part of which is the role of the building and space. Hornecker and Nicol (2012) observed that re-contextualizing museum interfaces from the living laboratory to the museum environment changed many factors of the interaction model. Fischer and Hornecker (2012) discuss the

complex arrangement of seven types of space in an interactive media façade, yet this highly specific framework for media facades seems to be the most complex description of space yet available.

While space in interaction is as old as Fitt's Law (MacKenzie et al. 1992) and while there have been some very notable exceptions, architecture and space have always been approached on an ad hoc and extemporaneous basis. The field of HCI has very little well-organized literature on the role of space in interaction. This is echoed by Harrison and Dourish (1996) who reviewed the simplistic models of space in CSCW and suggested that place, rather than space, should configure interaction.

The lack of well-organized literature should not suggest that the HCI community is ignorant of architecture and space. On the contrary, there is a growing interest in HCI in the overlap of architecture and interaction design. This growing interest surfaces right now in many ways, stretching from a new ACM interactions forum on architecture and interaction (Wiberg 2015) to the coining of new terms such as "architectural informatics" (Wiberg 2011). Further on, Wiltse and Stolterman (2010) suggest that in many ways interaction has already been informed by and drawn on architecture design principally through the use of virtual reality as an interface metaphor. They go on to suggest that through the mediation of permeability and co-presence computing is moving slowly to overlap a realm previously exclusive to architecture. They argue that the growth of digital technologies mediating the awareness of the world, computing is becoming more like architecture. They suggest that with the arrival of third wave HCI (Bødker et al. 2006) computing could benefit from an architectural perspective and critique of interaction. One significant example they identify is the holistic approach of architecture, which they compare to the focus on specific goals and specific tasks common in interaction design. They argue we should see interactive spaces not as just functions and workflows, that we should think about experiencing experiential wholes in for the functional parts, and that we should link specific design decisions to potential social dynamics. In this context, research by Schnädelbach (2012) and Varoudis et al. (2011) have moved into the liminality between Architecture, digital communications and Virtual Reality by using digital techniques to merge physically remote spaces to redefine both CSCW and architecture. This area known as 'hybrid' architecture (Harrison et al. 1996) is hard to fully place within the realm of human computer interaction research, being so critical to the knowledge of and rethinking of architecture.

In his article *Learning from Architecture* (Ingram 2009) Ingram highlights that HCI can also learn from the deep historical precedence that architecture brings to the table. He also suggests that interaction design is very similar to the profession of architecture in the manner in which it melds art and engineering along with its deep impact on the cultural landscape. This immediately leads to questions about how we, as interaction experts, can both expand our understanding, approaches, and methodologies using architectural insights. Bratton (2008) goes one stage further and suggests that interaction design and architecture are set on a convergent course. As computing effects the way that we live, work, and communicate, Bratton foresees the evolution of 'universal interface design' which is a fusing of both subjects. In her

paper Thomsen (2008) reinforces this use of contemporary architectural concepts of space and inhabitation as a way of allowing for a new framing of interactive experiences.

Mikael Wiberg in his book *Interactive Textures for Architecture and Landscaping* (Wiberg 2010) has also promoted the many complex ways in which spatiality has existed within interaction design. While computers have frequently promoted the concept of 'the death of distance' (Cairncross 1997; Wiberg 2014) he points out that computers are always used in some kind of spatial context. Wiberg promotes the spatialising of interaction via *Architecting Interactables*, the use of space and flows as a way of dealing with interactional complexity. This suggests that the design process would overlap with that of architecture to deal with the notion of flow.

Smart Cities

Up to this point we have discussed the role of architecture and space in HCI's core role of creating, extending and simplifying the user interaction process. Any discussion of HCI and Architecture would not be complete without briefly identifying some of the related areas where Architecture isn't an agent in the interaction process but the interaction process is an agent for architecture. One principle research area is that of 'Smart Cities'. The considerable interest in the field of smart cities combined with expenditure by research funding organizations suggests that urban interaction (Fischer et al. 2012) will be a considerable field in the near future. The growth of computing research into smart cities where digital technology is drawn together with urban intellectual and social capital can extend and rejuvenate many of the traditional physical infrastructures (mobility, places of living and work, social and electronic networks, energy). Smart cities demand that we cannot exclude, an understanding of the complex social and cultural dynamics that defined the streets we live in. As Rogério de paula says "*A city is not just a static backdrop against which our everyday lives as city dwellers unfold. Rather, it plays a critical role in shaping how its inhabitants experience their everyday lives*" (De Paula 2013). This suggests that Urban HCI is moving towards a position in which the city no longer plays a passive role. For Smart Cities to be more than a vague marketing term it seems that computer scientists and interaction designers should be as aware of what cities can do for computing as well as what computing can do for the city. It seems natural then that HCI will begin to explore the regularities between these two fields as a source of more than inspiration.

Finally, if the Weiser vision (Weiser 1993), where computing is at least partially embedded in the physical environment, is to become a practical reality, it seems reasonable to assume HCI will have to engage with architecture and architectural design to the same extent it did with graphic design with the introduction of the graphic 2-D interface and later the web. Human computer interaction, like architecture, is a diverse and consciously evolving community. While the delivery of data

by means of the environment is not the only possible direction for computing, it is currently a significant research direction. Given the developments in ubiquitous and pervasive computing already taking place, it seems natural that computing is becoming more spatial and that the context of digital technology in the build environment will become a significant factor in the Human Computer Interaction process.

Directions of Architectural Research

Architects have long been interested in the architectural opportunities of digitally enhanced spaces (McCullough 2005; Mitchell 1995). As far back as 1966, architects like Iannis Xenakis were incorporating electronic elements into their work as a fundamental aspect of the building's experience (Xenakis and Kanach 1976). In 1992, architect Prof. Michael L. Benedikt published his book *Cyberspace*: *First Steps* (Benedikt 1992), a collection of articles dedicated to the impact of virtual worlds on the world of architecture. Architectural and computing pioneer John Frazer preempted many developments in tangible interaction and digital inhabitation back in the early 1990s (Frazer 1995), yet his developments are unknown to many in the field of ubiquitous computing research. Many of the architectural ramifications of early digital technologies on the physical environment were explored by authors such as William J. Mitchell. In *City of Bits*: *Space*, *Place*, *and the Infobahn* (Mitchell 1995), for example, MIT Professor of Architecture Mitchell, discussing the future impact on the city of digital connectivity, augured the laying of ever shorter fibre-optic cables for algorithmic trading.

Architecture has always seen itself as engaging with modern social and technological innovations, so it comes as no surprise that it has engaged with digital computing on a dizzying number of fronts. To further facilitate the comprehension of these fronts, we categorized the principle ones under the twin streams of process of design and product of design.

Process of Design

Thinking and imagining in three dimensions is a complex cognitive activity, so it is natural that architects might use digital means to augment their design processes to explore new creative designs. Thus, even buildings with no digital components can be highly influenced by digital technology. Computer aided architectural design (CAAD) is certainly the most visible adaptation architecture has made to computing. In his book *Hybrid Space*: *Generative Form and Digital Architecture* (Zellner 1999) Peter Zellner identifies that, by engaging with computer aided design, architects have been able to define forms that would previously have been unachievable. Frank Gehry's Guggenheim Museum in Bilbao (Fox and Kemp 2009), for example, would be impossible without software and Gehry's practice had to engage in a software development process to build something that possessed the right degree

of expressiveness. The roof of the Great Court at the British Museum, designed by architects Norman Foster and Partners, is also a good example, where every triangular component of the curved roof was of a slightly different specification. Without the use of specifically designed software to compute every triangle, and machine it, this approach wouldn't have been attempted (Harrison et al. 1996).

While HCI works with digital technology as a 'product', the above examples demonstrate how the field can also lay claim to having changed what is achievable in the architectural design and manufacturing process. There is much to learn about the practice of augmenting the design process with software, which Patrik Schumacher, a partner at Zaha Hadid Architects, approaches through parametric design as a creative process. This blurs the boundary between the designer and the machine, giving some control over the design process to the digital partner. This process stretches as far as Marcus Novak in the 1990s who employed algorithmic techniques to define form, creating something which has yet to be achieved in the world of interaction design. With popular software, such as Grasshopper 3-D showing that augmentation of the architect with digital software in the design process is not an idiosyncratic digital retreat of the few. Here the architect is using code as a reflective sketchbook.

Product of Design

While the use of digital technology in the design process is not the subject of this book, it does highlight that architects are seriously and reflectively engaging with digital materials as part of their design process. It can be of little surprise then that architects would begin to incorporate digital elements in the products of the design process. As part of the process for engaging with social and cultural issues, architects from the modernist school, such as Frank Lloyd Wright and Le Corbusier, believed that new technology rendered all traditional styles of building obsolete. The work of architects like Ludwig Mies van der Rohe's Seagram Building in New York (1956–1958) (Carter 1974) was an attempt to honestly reflect the new materials being used in construction at the time (steel and glass). It seems natural that, when new digital media became available, architects would begin to try to create new types of architecture based on these new materials. Parallel to the way that artists, like Thomson and Craighead (Sánchez et al. 2009), began to engage with digital multimedia as a cultural response to the social rise of pervasive computing, it would seem natural that architects will also try to engage with digital elements as part of the lived hermetic of building occupation. In his book, *The Digital Turn in Architecture 1992–2010*, Mario Carpo (Picon 2010) gives a comprehensive anthology of digital architecture using papers by many well-known authors in the field to give a historical context to the many future trends. In a similar way, architect Neil Spiller, who reports on the numerous digital architects in his book, *Digital Architecture Now*: *A Global Survey of Emerging Talent*, (Spiller et al. 2008) shows architects and discusses how architects are engaging with digital experience as well as digital processes. These and many more architects fall under the general rubric of

'Interactive Architecture'. In their book, Michael Fox and Miles Kemp (2009) see architecture with digital technology becoming more process orientated, dynamic and, in many ways, humanistic. Like their contemporaries in the Netherlands, Prof Kas Oosterhuis and Xin Xia (Oosterhuis et al. 2010), they use practice as a means of further reflecting on their materials and process. The sheer momentum behind all these projects suggests that architects will more fluidly engage with digital technologies than computer scientists might first suspect.

Historically, Nicholas Negroponte, architect and founder of the media lab, had a vision of a more robotic environment where the building would conform around the needs of the user, he foresaw "a man-made environment that responds to and is 'meaningful' for him or her" (Negroponte 1975). The notion of the robotic building has a long history going back to the psychotropic house in J.G. Ballard's *The Thousand Dreams of Stellavista* and is currently a subject of study as 'architectural robotics'. Sitting comfortably between robotics and architecture, 'architectural robotics' (Gross and Green 2012; Weller et al. 2007) creates a whole number of design affordances which could be used to change both buildings and future cities. This work sits firmly in the practice of architectural research, as Gross and Green say, "*Perhaps the greatest challenge for architectural robotics is defining its community*" (Gross and Green 2012). That is, technical architectural research like this lacks a clearly defined path from research to industrial uptake, something the HCI community seems more familiar with.

From an academic perspective it seems clear that both sides of this divide are becoming slowly mutually aware. In his 2011 book, Dade-Robertson (2011) begins to discuss the impact of ubiquitous computing from an architectural and architectonic perspective. The importance here is the growing awareness that architects will not only be the users of computers and digital technologies, but will play a part in the configuration and presentation of those technologies to users/occupants. Malcolm McCullough's book *Digital Ground* (McCullough 2005) is probably the most well- known book dealing with architecture and pervasive computing. Here McCullough introduces pervasive computing to the world of architecture from an architectural perspective. Using architectural theory and criticism, McCullough challenges the notion that computing is an a-spatial technology, and argues that it is the spatiality which can reconfigure the interface. From the perspective of architecture, he argues that pervasive computing is another in a historic line of cybernetic technologies that architecture has previously responded to. Comparing pervasive computing to virtual reality technologies, he says, "*Whereas previous paradigms of cyberspace threatened to dematerialize architecture*, *pervasive computing invites a defence of architecture*."

McCullough argues that pervasive computing probes fundamental aspects of architecture and, to a similar degree, that pervasive computing challenges fundamental aspects of interaction design. Above all, *Digital Ground* poses the fundamental necessity for the two disciplines to work more closely together. "*The need to connect architecture and interaction design comes from overlapping subject matters and escalating social consequences*." What McCullough does for the building, Mark Shepard's book, *Sentient City*, demonstrates for the city. He suggests

that urban design is also becoming aware of the growth of ubiquitous computing. This is still an active and on-going area of investigation from the architectural and urban design perspective, as witnessed by the 2013 Urban Interaction (UrbanIDX) (Smyth et al. 2013) Symposium.

The Collision

Given the literature described, it seems inevitable that, despite different practices and histories, both architecture and interaction will eventually stand over almost literally the same ground. Both are concerned with an artefact (the building of technology) and how that artefact informs and changes the experience of the inhabitant/user.

The purpose of this book is to begin to create a framework in which this collaboration can take place. For this purpose, the two conceptual lenses of space and interaction are useful tools to frame the work included in this book. We present these two lenses very briefly here.

Space

For many in the field of HCI, location and space become synonymous, yet in architecture numerous diverse spatial representations allow architects to more fully understand the role of space within the social organization of a building. One important translation, which needs to be established, is the notion of space in architecture versus computing. Helen Couclelis (1999) gives a good introduction to the use of space in geography, stating that there are five uses of the term for that field alone. The first term is that most common in mathematics, a series of orthogonal attributes' specific values which form a 'point' in space. This kind of space derives from the geometric notions and is most familiar in the notion of 'Cartesian' space—coordinates which are infinite, measureable, infinitely scalable and inseparable.

For architectural historian Adrian Forty (2000), the concept of space was absent from architectural vocabulary until the 1890s. For him, the previous term was that of 'volumes' and 'voids' with space used as a synonym or in the context of 'void spaces'. Frank Lloyd Wright is quoted as saying, "*Space is the breath of art*" or "*The space within becomes the reality of the building*" or "*All architecture is shelter*, *all great architecture is the design of space that contains*, *cuddles*, *exalts*, *or stimulates the persons in that space*," or Le Corbusier, "'*Architecture is the learned game*, *correct and magnificent*, *construction of space assembled in the light*." These quotes appear to be based on the belief that architects make space, which, from a scientific concept, seems incomprehensible. From a practical point of view, buildings are typically sold on the amount of space they contain, developers don't sell a certain number of meters of wall but square meters of floor space. So architectural use of space is closer to that of 'place' but leaving it in the realm of the designable. Architectural space is the kind of space you experience when you enter a large room

in a house and remark on how ‘spacious’ it is. It is best to leave this translation with the observation that architecture typically specifies and records only the item, which defines the boundary of the thing which it actually designs—space.

Interaction

Interaction is as familiar a term to Human Computer Interaction specialists as space is to architects. For HCI designers, the core desire is to create a smooth dialog between user and machine. While you could speak about the interaction between a user and a can while drinking a beverage, this diminishes the level of sophistication digital interaction can achieve. While wanting to avoid delving into the deeper aspects of ‘present-at-hand vs. ready-to-hand (Heidegger 1962), a more familiar experience of what HCI means by interaction might be understood from computer gaming. The gaming community talks about the diaphanous ‘playability’ (Sánchez et al. 2009) of a game. This is separate from the plot, graphics or music of a game, it is the measure of the intangible pleasure the responsiveness of the game has to the user. A game might be difficult to control, yet this might contribute to the experience and lead to high ‘playability’. This ‘playability’ is at the aesthetic extreme of interaction but does highlight the general interpretation of interaction to HCI. More recently, emphasis has started to move away from the interaction with a single software artefact, such as a game, production application or distributed system. ‘User experience’ captures our interaction with software in situ and covers many of the concerns architecture has with space. The organisational and spatial context of software use is critically important, as Suchman has highlighted (Suchman 1987). With the rapid expansion of computing into all aspects of our lives, the scope of this context is expanding at an equally rapid pace, with, for example, UrbanIXD specifically looking at the integration of user experience across the city.

Using these two lenses we hope that you can begin to view the chapters in this book not as two distinct areas of research but the boarders of one continuous area of enquiry which need to be knitted together. We see this book as the beginning of this process and hope that you, like us, are as excited by the research potential as much as the outcome for both future architecture and future interaction.

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Part I
Interdisciplinary Dialogue

In the introduction we highlighted the rise of pervasive computing over the last three decades. Technological and architectural developments have been rapid, while they have sometimes occurred in relative isolation, 'protected' by disciplinary boundaries. Such separation can lead to multiple false starts, when things are tried and tested even though someone else has already discovered that there is an issue. This separation will also lead to missed opportunities when potential synergies between sets of expertise are not realized. We have argued that separate research arcs are coming to the same nexus and the two chapters in this section react to this.

Krukar begins with a view that seems to be at odds with many of the preconceptions someone from human-computer interaction might bring to this book. Rather than looking at computing as the young discipline with much to learn from the older design professions of architecture, Krukar's work declares that buildings are also artefacts and talks about looking to human-computer interaction to bring user-centred design to architectural design. Citing the rise of the evidence-based design movement, Krukar discusses the use of HCI familiar personas in architectural design. In many ways, this opening chapter underlines the reciprocal nature of design enquiry exchange to both HCI and architecture. Beneath the headline messages, there are some themes that will be reflected repeatedly in later chapters.

Luck's work begins by stating some of the obvious changes that have occurred to office buildings partly or wholly engendered by digital technologies. Once upon a time, computers occupied buildings and now, to some extent, she suggests we are approaching the world where buildings occupy computers. Commercial office architecture has had to respond to the demands that computational furniture has placed upon it. This may be the datacentre with the massive air conditioning requirements or the floor and ceiling increases along with ventilation problems caused with the rise of the extensive use of desktop computing. Even today the electromagnetic properties of the building can limit the use of wireless network connections. This chapter examines the changing interactions between people, buildings and computation, using the re-design of the office as a building type to

illustrate. **Luck** suggests that 'the design of the physical locations for work (the built form) has more in common with the design of technology for work than these largely separate, fields acknowledged.'

Like the other writers in this chapter, Luck suggests that analytic ethnography under the rubric of 'work place studies' is a way to study activities in their natural habitats. Further Luck suggests that 'The setting, location or place of work is integral to its analysis and thus are concerned with far more than jobs and tasks; rather, the focus has always been on entire 'workscapes".

These workscapes are not strange new objects of inquiry but, in fact, admission of elements that have always been present. As Luck states '*at Xerox*, *we understand that we cannot separate the operation of a photocopier by people from its setting-situated contexts of use provide import insights for design important. What these studies all point up is that the places where we work*, *in various ways*, *become part of the work that gets done there*.' All this must be done with a clear realization that the practice of work has become mutable. At work we use the technology resources for play (fun would be a better choice) but with the rise of mobile technologies the workplace can extend to our homes and third places like coffee shops. As Luck points out the rise of drop-down spaces, the introduction of cafes into the workplace, all speak to a blurring distinction between the workplace and other environments. This is a chapter about digital technology, and the reconceptualization of the workplace, from an embodied phenomenological perspective, as such it seems to be the Keystone on the bridge between computing and architecture.

Chapter 2
Applying HCI Methods and Concepts to Architectural Design (Or Why Architects Could Use HCI Even If They Don't Know It)

Jakub Krukar, Ruth Conroy Dalton, and Christoph Hölscher

Abstract The act of designing a building is indirectly, but conceptually very closely, linked to the user experience of its final outcome. It is this experience which often constitutes a major criterion for assessing the quality of the architect's work. And yet, it would be a gross overstatement to suggest that architectural design is a user-centered process.

On a more generic level, designing any physical object acting as a catalyst for the final experience can be viewed as an act of designing a human-artifact interaction where the 'artifact' (be it a building or a computer device) serves as an interface for the ultimate behavior or emotional reaction. This chapter argues, that the field of Human-Computer Interaction (HCI) can be viewed as a source of inspiration for architects wishing to incorporate, or enhance, user-centric planning routines in their creative workflows.

Drawing from the methodological toolbox of HCI, we demonstrate how user-centric planning can be placed in a structured framework, with tested and easy-to-apply methods serving as the vehicle for holistic user-centered planning processes.

The chapter proposes a formal model for understanding usability and user experience in the architectural context, demonstrates a number of methods suitable for its application, and concludes with a case study of an attempted use of one of such methods in an award-winning (yet, not necessarily user-friendly) public library project.

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Introduction

It should be self-evident that architects design buildings for the people who will ultimately come to inhabit them and therefore it could be assumed that the architectural design process might exemplify a user-centred design approach. The reality unfortunately falls short of this ideal. Frequently, the needs of a building's end-user/s fade into the background due to the fact of being subsumed by numerous other, and often conflicting, design constraints: these include the needs of the client (where the client and end users are not one and the same) or functional, programmatic, structural, material and legal requirements. Conversely, the needs of the user may receive less consideration, as experienced architects may believe that they can intuitively (and hence implicitly) design for building's inhabitants without any need to make this an explicit part of the design consideration. Sometimes this is true; sometimes it is not. It is the position of this chapter that by explicitly placing the needs of users at the centre of the architectural design process, the overall quality of public architecture and cities can be increased. If so, how might this be achieved? One suggestion is to look to another field where the needs of the users are integral to their methodologies, namely human-computer interaction (HCI; see e.g. Dix et al. 1997; Preece et al. 2011).

Ultimately, human-computer interaction is a type of human-artifact interaction, and HCI research is characterized by analyzing human behavior, cognitive processes and task structures faced by the user. Buildings can also be understood as artifacts, and humans interact with these artifacts in numerous ways. In the behavioral sciences, this has been investigated under the label *environmental psychology* since the 1970s and, more recently, also within the *spatial cognition* domain. While a large number of studies in these two fields have tried to identify how people react to environmental settings (e.g. Kopec 2006) and how they mentally represent spatial relations (e.g. McNamara 1986), such research has had little impact on architectural design practice in comparison to the established role of HCI professionals and their methodology in contemporary software and IT systems design.

In the last 10 years there has been an important revitalization of the interaction between cognition and architecture. One example is the *evidence-based design* movement in architecture, which calls for better understanding of human behavior inside buildings. The main thrust is to obtain performance measures of implemented designs (existing buildings) and/or derive predictions of such measures for design options under consideration. The *evidence-based architectural design* movement has emphasized the need for adopting a human-centered, empirically grounded perspective and for developing scientifically appropriate evaluation methods (Hamilton and Watkins 2009). This approach is most prominent in health care and office architecture (e.g. Suttell 2007; Ulrich et al. 2004; Sailer et al. 2008). Evidence-based design has been significantly inspired by the success of evidence-based medicine with its core demand for decision-making based on unbiased, reliable data-sets that often question expert intuitions and long-held preferences (Sackett et al. 1996). Besides issues such as energy-efficiency, human factors are now seen as

a component of building performance, involving perception, emotion and aesthetic appraisal, psychological well being, as well as behavioral and cognitive factors of movement in a building or through cities.

In HCI, the usability of a digital system typically can be described by a triangle of user characteristics, task properties and system features (including the user interface and underlying functionality). In architectural design we find a similar triangle, here of the building user, building-specific tasks, and the features of the building. Consequently, methods for capturing the usability of buildings must be able to take these factors into account. In order to do this, we must first, however, unpick what exactly is meant by the term *usability* when applied to architecture rather than to a digital system. And since in HCI the importance of usability is most often seen through the wider lens of the holistic *user experience* we must define the relation between these two concepts in the architectural context; this will be addressed in the first section of this chapter.

Building Usability and User Experience

Reviewing the Existing Usability Models in HCI

Understanding what is a *usable building* varies significantly between publications (Hölscher et al. 2006; Leaman and Bordass 2000; Norman 2002) and a universal acceptance of quantifiable measures defining it is still a distant goal. Such an understanding is necessary on an interdisciplinary level, since many design-related fields could benefit from such knowledge transfer (Ingram 2009) – particularly with respect to architecture, where emerging, reliable means of measuring usability require a clear framework of reference. One of the aims of this chapter, therefore, is to contribute to the debate on building usability by appropriating existing knowledge from the field of human-computer interaction.

In software engineering usability has been investigated thoroughly and has been clearly defined in ISO standards; defining the concept from different perspectives. Abran et al. (2003) provide a review of some existing definitions, identifying the two most widely accepted ones:

1. [Usability is] "the capability of the software product to be understood, learned and liked by the user, when used under specific conditions" (ISO/IEC 9126-1, 2000).
2. "Software is usable when it allows the user to execute his task effectively, efficiently and with satisfaction in the specified context of use" (ISO 9241, 1992/2001).

It should already be noted that both of these definitions encompass similar ideas, describing the ability to be "*understood*, *learned and liked*" by the user in the former example and used "*effectively*, *efficiently and with satisfaction*" in the latter one.

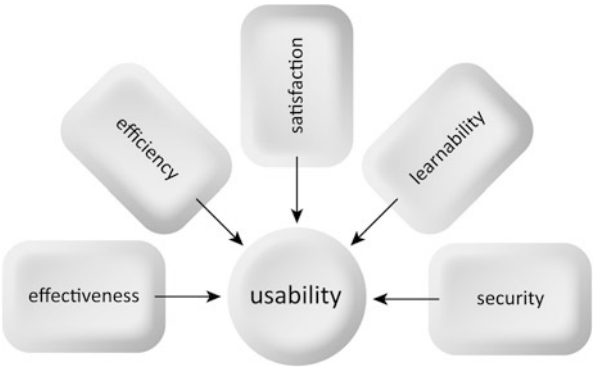

Fig. 2.1 Enhanced usability model (After Abran et al. 2003)

All of these concepts relate to how well a user is able to perform a given task whilst using a given interface (or whilst 'using' a given building in the new context to follow), as well as what resources or features he or she must make use of in order to perform their undertakings (whatever they may be) successfully. The reference to "*specific conditions*" and "*specified context of use*" are also important parts of both definitions, emphasizing the need to take into account various meanings of usability if and when a different context of use is being considered. Using these ISO standards as a starting point, Abran et al. (ibid.) combined a number of existing definitions with their own interpretations and presented an *enhanced usability model*. This is shown in Fig. 2.1.

This model can be explained as follows:

- *Effectiveness* relates to how many mistakes people make while performing a task;
- *Efficiency* is described by how much time and resources it costs to perform a task;
- *Satisfaction* could be measured as the ratio of favorable to unfavorable opinions about or comments on the process as elicited from the users;
- *Learnability* describes the time required to learn how to perform a task;
- *Security* is important in terms of access controllability.

In architecture, each of these factors has been considered for decades, if not centuries, but almost only in isolation from each other. *Effectiveness* has been studied, for example, by counting the number of wayfinding errors at decision points (Golledge 1992; Williamson and Barrow 1994). *Efficiency* might be indicated by the time needed to find a specific room in a wayfinding task. *Satisfaction*, from the building experience perspective, has been measured as part of standard Post-Occupancy Evaluation research (Leaman and Bordass 2001). *Learnability* in the building context indicates how long it may take a user to become familiar with a building (Peponis et al. 1990). *Security* in an architectural context relates to the way in which buildings have to accommodate the needs of different user groups with differing levels of control, access, and hierarchy (medical staff vs. patients vs. visitors in a hospital or the myriad complex levels of non-intersecting access, occupation and egress required by the different groups such as judge, lawyers, jury, prisoners, police and the public in a courtroom; Pati et al. 2007).