THE CASE FOR A THEORY OF INTERACTIVE ARCHITECTURE

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ABSTRACT: Historically, architecture's cultural role has changed in sometimes radical ways. A theory of contemporary architecture must deal with the proliferation of information and communication technologies, seeking a transformed role for the physical setting in a digital age. This paper reviews perspectives from computational disciplines, proposes the outline of a theory of interactive architecture, and presents a preliminary exploration of heuristic methods as a tool for the design of interactive architecture.

Computation began agnostic about physical setting, focusing on symbolic systems. But in diverse disciplines, theorists and researchers are questioning the validity of abstraction without an understanding of physical and cultural settings. *Ecological psychology* investigates how perception must be based on the physical setting rather than only interior mental processes. *Actor Network Theory* proposes that humans and physical artifacts are interchangeable within a network of meaningful activity. *Embodied interaction* demands that the meaning of human behavior arises from the physical and behavioral setting. *Physical cognition* studies how we reduce cognitive load by storing information in both physical settings and symbolic systems. Based on this understanding of the role of the physical in meaningful settings, a case is made for a theory of interactive architecture. This theory is aligned with the activity model of interaction design, privileging the experience of the users of space in mixed settings containing both physical forms and media. This paper will explore these approaches with a specific question: does the physical setting influence in important ways the manner in which we understand and use information? Using both a modification of Nielsen's heuristics and the use of a design science experiment focused on a taxonometric understanding of design possibilities, this paper speculates on a set of interactive architectural heuristics.

KEYWORDS: Responsive architecture, ICT (Information and Communication Technologies), HCI (Human Computer Interaction), Media

Figure 1: Public space at a college campus: information and space without interaction; Source: (Author 2005)

INTRODUCTION

> *As the developmental logics of contemporary architecture are being conceived increasingly more for the display of audiovisual information than for the framed location of real bodies, a mode of built environments, as overwhelming as the datameshes that they seek to ground, is now being jettisoned globally.*
> *John Beekman, "Merge Invisible layers" (Beekman, 1998, p14)*

In 2004, Blockbuster Video operated more than 9,000 stores both in the US and across the world. These stores employed 60,000 and controlled 45% of the video rental market. The trip to a Blockbuster store, the stroll down the aisles and the search for a video on Friday and Saturday nights was an integral part of life for millions of users. In 2010, Blockbuster declared bankruptcy and was down to 500 stores, and its share of the video rental market has shrunk from 45% to 3%; it has since disappeared altogether. Netflix had initiated a service that delivered DVDs directly to consumers, using an Internet site for browsing, sales and scheduling. The search and the stroll had become virtual.

While it is a stretch to claim any exulted architectural status for Blockbuster stores, it is clear that in this case at least, the physical has been replaced by the virtual. It is cold comfort to Blockbuster that Netflix itself is under pressure from services, both legal and illegal, that do away with not just the architectural setting of the store but the physical artifact of the DVD. Bits will be bits.

And, of course, this is not a new story. William J. Mitchell draws a series of contrasts between sites on "the Net" and sites in the traditional city. He uses the terms spatial/antispatial, corporeal/incorporeal, focused/fragmented, synchronous/asynchronous, narrowband/broadband and contiguous/connected to highlight the challenges that digital settings make to architecture. In the end, we are left with an open question: does architecture matter or will it be replaced by the virtual?

An extreme position, prominently taken by Hans Moravec, is that the physical setting is irrelevant, or worse, a hindrance (Moravec, 1998). He imagines a "brain in a vat", gradually relocating the contents of the brain to electronic form, eventually erasing any vestige of its original body. He imagines that we will find our sense of awareness distributed over many locations, carbon based life replaced by silicon, meatspace by cyberspace. This view holds no special place for the tangible and specific settings that have been assumed to be fundamental to architecture. At best, the skills, cognitions and insights that underlie architecture may find digital expression, virtual desktops supplanting tangible armoires and metaphorical space replacing physical extension. It is difficult to imagine an architectural theory that does not include the tangible in a prominent role. It is equally clear that for Moravec, architecture has been erased.

This shift in the position of architecture has been the subject of a long historical discourse. In 1831, Victor Hugo devotes an entire chapter in one of his novels to a discussion of the changing and diminishing role of architecture (Hugo, 20120. Hugo begins with the premise that the invention of the printing press and the concomitant spread of literacy changed the role of architecture in the most fundamental way possible. Before the printing press, the building was the primary source of knowledge and enlightenment, and as he points out, one that can be tightly controlled by the hierarchy of the church. The position and content of architecture can shift over time, and it can address different issues at different times.

Walter Benjamin, in "The Work of Art in the Age of Mechanical Reproduction", is focused on the manner in which new forms of art engage their viewers in new ways (Benjamin, 2008). He contrasts earlier ideas of presence in art, which have been destroyed by new techniques that render authenticity impossible to determine, with new forms of engagement with art such as motion pictures. In contrast to Hugo, he understands new forms of art as requiring radically new forms of engagement and analysis. New forms of art require new forms of engagement, both political and aesthetic.

Marshall McLuhan focuses solely on the mode of expression, believing that content is shaped by the medium (McLuhan,1967). Over and over, he rejects ideas that the content of television (his primary object of study) can be somehow aimed toward "correct" goals. His archetypal example of a pure medium is the light bulb, free of any content but redefining the way in which we confront and understand the world. The critical issue is the medium, and it determines the quality and possibilities of engagement by a community of users.

Summerson's "Case for a Theory of Modern Architecture" is oblique about the theory itself, instead referring to a "source of certainty" for designers (Summerson, 1957). He observes the change in this source of certainty from history to program, from a repository of inherited form to a fragment of a social organization. If we were to construct a theory of contemporary architecture, it would undoubtedly need to deal with the onslaught of the virtual and of information within the culture. The question has become "what is the role of the tangible setting in an age of information."

The new disciplines arising around the issues of computation and information began agnostic about the idea of physical setting. Computer science, engineering and information science have until recently focused on algorithms that are abstract and repeatable. But increasingly, in a number of venues, there have arisen voices that question such abstraction and instead look to the particularities of settings to understand meaning. These questions have arisen from fields as diverse as ethnography, science and technology studies, human computer interaction and perception. In each case, prominent theorists have questioned the idea of abstract processes without an understanding of the physical and cultural settings in which they arise. None of them are explicitly architectural, but each has a particular place for the tangible as a central part of their formulation of meaning. And, of course, none of them by themselves lead to an architectural theory. But in the sense that Summerson invokes the need for a source of certainty, each of them suggests ways in which we might sees the emergence of a new position for architecture.

1.0 INFORMATION AND SPACE

In diverse disciplines, theorists and researchers are questioning abstraction without an understanding of physical and cultural settings. *Ecological psychology* investigates how perception must be based on the physical setting rather than only interior mental processes. *Actor Network Theory* proposes that humans and physical artifacts are interchangeable within a network of meaningful activity. Embodied interaction demands that the meaning of human behavior arises from the physical and behavioral setting. *Physical and distributed cognition* studies how we reduce cognitive load by storing information in physical settings and shared systems.

This paper will briefly explore each of these approaches with a specific question: does the physical setting influence in important ways the manner in which we understand and use information? Our goal is develop a coherent position for architecture in contemporary culture, one which acknowledges its intimate connection to its physical settings while at the same time connecting to emerging concepts of information and computation.

1.1. Ecological psychology and affordance

Ecological psychology began as a reaction to behaviorism, emphasizing the role of the physical settings to the perceptual capabilities and apparatus of human perception. J. J. Gibson, the leading exponent of this field, is interested in the role of the physical setting in reflecting the ecological niche within which perception operates (Gibson, 1979).

Gibson focused on the reciprocal role of cognition and the environment. Until his work, cognition had been treated as an internal process, separable from the external environment. Gibson begins by noting that men, like all animals, have developed cognitive and perceptual systems that are uniquely suited to their ecological niche. Hawks have eyes that can see details at very great distances to enable them to hunt prey; dogs have hugely development sense of smell to track their pack and their dinner. Gibson labels this reciprocal relationship with the environment with a term of his own invention "affordance". By this he means that the physical environment makes possible certain kinds of behavior, based both on the physical properties of the organism and of the environment. Gibson's seminal work focused on problems with aircraft landings, and the failure of existing models to help with issues of complex perceptual fields combined with motion.

The salient feature of the concept of affordance is that it combines objective qualities of the environment with assessments by individual animals within the environment, and that it values some aspects of the environment over others based on their usefulness for possible actions. The floor plane, occlusion, and wayfinding are all aspects that will become important to such a view. The concept of affordance has also become an important idea within HCI through the work of Donald Norman, who extends the term affordance to mean both the physical as well as the cultural setting.

As a framework for an interactive theory of architecture, affordance offers advantages. It connects human action with physical space in a direct and measureable way. Many measurements and positions are possible, but some are more important than others because of the manner in which they afford human behavior. This separation of the specific contribution of the physical space connects space and behavior.

1.2. Actor network theory

Actor Network Theory is primarily the work of Bruno Latour and Michel Callon (LaTour, 1979). The unique characteristic of ANT is that it regards all actors, both physical and human, to be equivalent. Rather than treating sociology as one discipline and technology as another, it attempts to understand them together.

ANT studies society in terms of the relationships between people and objects, understood as nodes of a network and relations between them. The theory was grounded on English science and technology studies, but it shares some common themes with the French post-structuralist: instability in the human sciences, due to the complexity of humans themselves and the impossibility of fully escaping structures in order to study them. It utilized existing French academic knowledge from multiple fields and the studies on large technical systems. The initial goal was to try to understand how innovation and knowledge are created.

ANT focuses on the mechanics of life: the ways in which people and objects interact with each other. The main aim of ANT is to overcome the subject-object divide, the distinction between the social and the natural worlds and to see the reality as enacted. Translations are about continual displacements and transformations of subjects and objects, and the insecurity and fragility of the translations and their susceptibility to failure. An illustrative example of LaTour's approach is his paper describing the human and physical "actants" using the example of the humble door closer (written under a pseudonym to apply the same analysis to academic papers as a construct.) (Johnson 1988)

The importance of actor network theory is its insistence on seeing the physical setting and human behavior simultaneously as a single system.

1.3. Embodied interaction

Within Human Computer Interaction, embodied interaction is a position that seeks to understand interaction within a specific social and physical setting. Paul Dourish, the most prominent proponent of this approach, combines an understanding of phenomenology with an historical understanding of the evolution of computer interfaces (Dourish, 2004). Dourish merges ideas from social computing and physical computing to propose a new interface paradigm that is specifically situated in physical and social space.

In his book, *Where the Action Is*, Paul Dourish summarized the motivating ideas behind two emerging research fields: tangible computing and social computing. Physical computing allows the user to interact using multiple external input devices, such as cameras, RFID tags, and everyday objects that have been programmed to respond to the system. Social computing takes into consideration that there are multiple factors in a setting that affect the activity of users. These activities, embedded in the social, organization and cultural setting and the everyday visual settings of work, influence what and how users interact.

Embodied interaction includes both of these ideas. Tangible computing is intuitively interactive and inherently integrated into everyday objects and places, not separated as desktop and world. Social computing is involved not only with the computer but also with the surrounding space and environment including social and cultural aspects. Embodiment involves existence in the world, including but not exclusively physical.

These aspects of the HCI field can be important to architecture through the design of space. Architecture will become a large part of the new interface of computing. This can include the integration of computing into architecture and space, such as a media walls, facades, and interactive materials, and the effect of the embodied interaction of non architectural objects on an architectural space.

1.4. Distributed cognition

Work done by Edwin Hutchins, "cognition in the wild", seeks to uncover the relationships between the physical and social settings relating to research in physical cognition and distributed cognition, both of which emphasize the use of the settings as part of the process of understanding and solving complex problems (Hutchins, 1995).

The organization and division of cognitive labor creates the means by which information is gathered and processed by members of a group, and by which appropriate actions are taken to accomplish tasks and achieve goals. Some of this coordination is accomplished through communication practices of spatial arrangements that may clarify aspects of the current situation or that generates expectations about an unfolding situation. Hutchins' archetypal study focuses on navigation aboard carriers within the US Navy. He carefully studies the use of cultural and social structure, organization procedures and spatial positions aboard the bridge of the ship.

Distributed cognition looks at how social organization influences patterns of the transmission and transformation of information within a group. It seeks to understand how cognitive processes may be distributed across the members of a group. This approach is helpful to understand how a group works together in order to solve a problem that is too complicated for one individual to perform. A group has this ability because their combined cognitive process has greater knowledge, processing capacity, and speed, which enable them to complete a task too complex for a single person.

When applying the theory of distributed cognition to a social group, it is essential to observe their activity "in the wild". While Hutchins' approach is wide ranging, the physical setting that a group occupies during their interaction provides critical context in understanding how they work with each other and with their relationship with materials or tools within their environment.

2.0. INTERACTIVE ARCHITECTURE & HEURISTICS

An interactive architecture requires a model of human computer interaction as an important theoretical foundation. The dominant theory of human computer interaction has been the cognitive model (Card, 1983) that imagines two information processing units, one in the machine and one firmly in the user's head. These are conceptualized as directly parallel and reciprocal, and are based on the internal structure of the computer programming as it evolved during its first 30 years. An alternative to the cognitive model is activity theory (Kaptelinin, 2006). Rather than assuming that humans are only symbolic information processors, it proposes a more holistic understanding of the use of computing in physical cultural and social settings. Two key concepts are consciousness (considering mind as a whole) and activity (considering interaction with all dimensions of reality). Activity theory places an emphasis of the study of computations tasks in their natural settings. It is clear that activity theory approach reflects many of the issues raised by the four approaches discussed in Section 1.

Therefore, heuristics for an interactive architecture will rely on activity theory as a paradigm. Two approaches are discussed in this paper; a transformed set of existing HCI heuristics and a test implementation of augmented reality interface in an architectural setting. Together, these approaches speculate on the outline of an interactive architecture.

2.1. Translated heuristics

Evaluating interface design has been the subject of extensive research, and has led to the development of accepted heuristic evaluation techniques. The most widely used methodology is Nielsen's 10 heuristics (Nielsen, 2014), which is used both as a general evaluation metric and as a baseline for developing heuristics for innovative and emerging interface technologies. This paper speculates on a set of architectural heuristics for the role the physical and digital dimensions in architectural settings by presenting a brief description of each existing heuristic and its possible transformation for application in architectural settings.

1. **Visibility of system status:** keep users informed about what is going on
   Movable or changeable architectural elements (door, lights, etc.,) can indicate status
2. **Match between system and the real world:** Follow real-world conventions, natural & logical order.
   User movement and position are primary affordances in architectural settings
3. **User control and freedom:** Users often choose system functions by mistake; support undo/redo
   Allow architecture and information to decouple and reconnect later
4. **Consistency and standards:** Follow platform conventions
   Use clear and consistent architectural vocabulary
5. **Error prevention:** careful design which prevents a problem, ask confirmation
   Architecture will work with or without digital interaction; allow for catch up
6. **Recognition rather than recall:** Minimize the user's memory load; make objects options visible
   Only present spatial information aligned with architectural elements; present only when needed.
7. **Flexibility and efficiency of use:** Accelerators for the expert user; tailor frequent actions
   Afford enhanced views for different groups of user with different needs or interests.
8. **Aesthetic and minimalist design:** Dialogues should not contain irrelevant information
   Keep all information simple and infrequent
9. **Help users recognize, diagnose, and recover from errors:** Error messages in plain language
   Distinguish between information and architectural errors. Assume errors can be ignored until later time by one media or the other.
10. **Help and documentation:** documentation easy to search, on task, small
    Density of information should vary with proximity to key locations (public displays, intersections)

2.2. Design taxonomy

A second approach to the development of heuristics for interactive architecture involved research on the use of augmented reality in architectural settings employed a design science research methodology (author, 2017). We considered the design of architectural space and augmented reality applications simultaneously. Combining the efforts of twelve architectural designers with a team of AR developers, we develop a taxonomy of affordances, feedback mechanisms, and output/ display options. This taxonomy constitutes preliminary usability heuristics for the use of AR as an embodied device for interaction in architectural settings and is indicative of larger issues for interactive architecture. These include afforded and interactive inputs and tangible and display based outputs.

Afforded inputs are those that because of physical or cultural factors are understood without need for visual feedback. These include: **proximity**, moving closer to or further from an object in the model was understood without the need for feedback; **gaze target**, the direction of a user's gaze was immediately apparent to user of the system; **gaze duration**, because obvious after a few minutes of use by the Holo Lens; and the **orientation** that a user faces is apparent in at least two ways; inside/outside can be understood wherever the architecture makes it obvious; **geometric orientation** is made obvious when the architectural arrangement is strongly delineated.

Interactive inputs require some visual feedback from the Hololens to make it cognitively present: **angle of view**: head motion can be understood as an input in either the vertical or horizontal direction, but require visual feedback to be understood; **hand gesture**: the standard interface in Hololens of finger or hand gesture require significant feedback to be obvious; and **voice**: the use of voice recognition can be used to provide rich input to the system; feedback verifies the system is engaged.

The output of the architectural/AR system can assume either display or physical aspects; **physical computing**: the rearrangement of physical objects based on a user's position; **overview/detail**: details can be made to appear to come closer to user and be available for inspection; **transparent/opaque**: walls can be selectively closed and opened; "**x ray vision**": one can creates display that appear to allow users to see into other rooms or into the city beyond; **virtual space**: can be generated around a user as they move through space, guiding or circumscribing movement; a **heat map** can show the locations of classes of objects; **cognitive maps** can capture the interest of an individual that later guide a customized tour of the site; explanatory **text** can appear at appropriate locations, and can become more detailed as one approaches; **virtual objects** can appear in the space to connect other objects from the site or from a larger corpus); and a **direction path** can be created to guide users

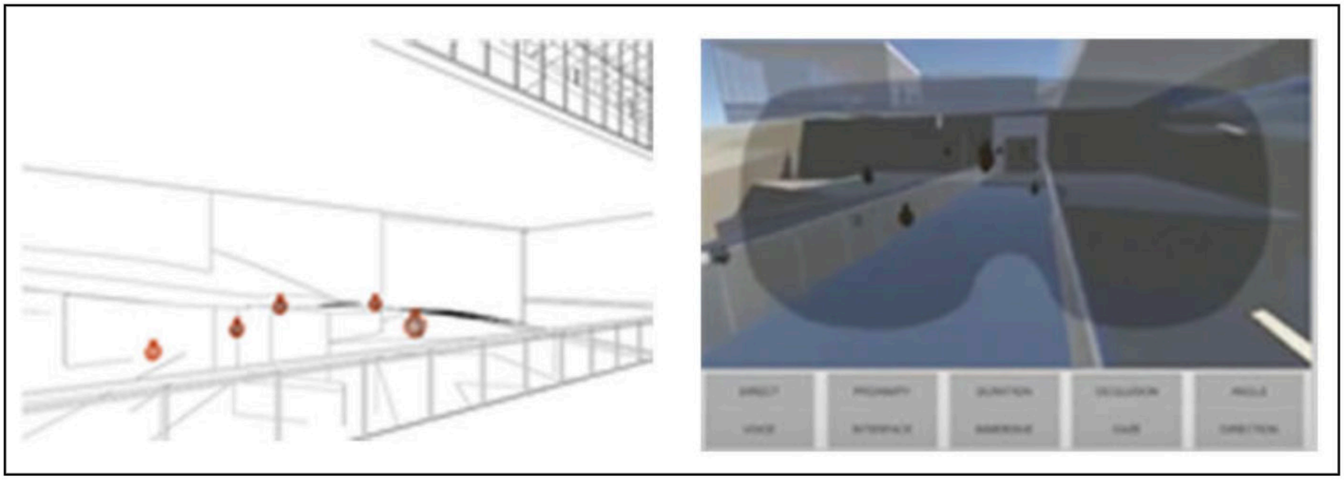

Figure 2: A design science based exploration of the integration of augmented reality and architecture design. Left, architectural space with markers; right, the Hololens interface for design of interaction and space; Source: (Author 2017)

CONCLUSION

The development of interactive architecture will require the simultaneous integration of information and setting. Neither the computational disciplines such as HCI nor the traditional conceptual basis of architectural design will be sufficient to understand and design for this mixed environment. This paper presents some early attempts to combines these fields. Without some new conceptual framework, we will be left with technology that only haltingly understands its settings or architecture that uses technology as decoration.

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