Seminar for Computer Science
Literature Review — Interactive Architecture

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Introduction

> **Interactive architecture** refers to the branch of architecture which deals with buildings featuring the trio of sensors, processors and effectors, embedded as a core part of its nature and functioning. Interactive architecture encompasses building automation but goes beyond it by including forms of interaction engagements and responses that may lay in pure communication purposes as well as in the emotive and artistic realm, thus entering the field of Interactive art.[3]

This includes human-building interaction (HBI), ambient displays, media façades and many types of technology that is designed to interact with and adapt to its inhabitants[6]. The field of interactive architecture encompasses the integration of digital technologies into built environments to allow easy reconfiguration, so as to serve many different purposes[7].

Intersection of architecture and interaction design

These two major fields seem to be separate on the surface, but have been intertwined for a long time and are getting closer to each other with new technology. Interaction design is being influenced by architecture, as interfaces use architectural metaphors, use space more as something to interact with and not just stuff. [8] There are several encounters between HCI, architecture and urban design such as [1]:

- Ubiquitous computing, where interactive digital artifacts are situated in the environment
- Media spaces, where, through video and other forms of media, distance is made less prevalent
- Notions of space for example in virtual reality
- Design and development of virtual worlds
- In learning from architecture to combine form and function as well as the symbiotic relationship between people and artifacts

Architecture is also being increasingly affected by interaction design as technology allows for more interactive systems in buildings. [7] Alavi et al. [1]

also mention that there are overlaps between architecture and interaction design. Dalton et al. [5] discuss the emergence of technology that allows for interfaces, that are not bound to a specific device and/or display. As devices become progressively more diverse in their type of interaction, space becomes a topic of importance that has to be dealt with. *Virtual reality* and many other new types of interfaces like *ambient displays* [8], call for types of interactions that allow usage of these technologies.

Architecture on the other hand rather is focused on space but not as much with individual interaction design. Wiberg [7] writes extensively about these two being intertwined. The first overlaps between architecture and interaction design can probably be found in the mid 1980s with early attempts in *computer-aided design* tools (CAD). These allowed for greater detail to draw, edit, scale, zoom and have many different layers of the same blueprint. With advancements in 3D-print technologies this includes "printing" models and even buildings themselves with help of drones and robots.

Another facet of architecture and interaction design interconnecting are *embedded systems*. These systems are designed to be embedded into our built environment. Recent technologies such as *ubiquitous computing* and *the Internet of Things* (IoT) have fueled this topic to be more present, even though embedded systems existed for much longer than that. The focus is here to enhance rooms or even buildings through implementation of these digital technologies. Many implementations center around mechanics that would lead to more energy-efficient buildings such as smart thermostats. There are also bigger ideas that go beyond temperature regulation, such as flexible walls or *smart cities*.

There is also the architectural influence on the structuring of digital technologies, also mentioned by Dalton et al. [5] A direct representation of that is the game *Minecraft*, which allows the design of architecture in a virtual world. Another portrayal is the use of metaphors in interfaces, such as the *home screen* and the *back* button on smartphones and web browsers, as well as being *away* on messaging platforms.

There is an even more direct connection between the two, which is **architectonic technology**. This takes the idea of technology in buildings of embedded systems even further, and suggests technology that is not just added into buildings but function as a part of the building. These include *media façades* which work as technology that is seen as being part of the architecture of a building itself and not just as an added feature. This enhances the appearance of certain aspects of a building, the whole building or even delivers interactive possibilities, as seen in the ARS Electronica building in

Linz.

Most interaction design projects remain restricted to a mostly fixed size, like web design to laptop screens and smartphones. If we consider technologies that are an inseparable part of the building itself, we have to change our scale, from small objects to buildings. This in turn changes our perception in how to design these things, not only from the point of interaction design, but also from that of architecture. Further, interaction design usually deals with a specific user interacting with an object, while buildings rather deal with many different users interacting with a building, that is fixed in space for a long time. Moreover, architecture is seldom strictly used, but rather inhabited or visited. These concepts are crucial for the design of *architecture elements with interactive capabilities*.

Surprisingly little collaborative work between people from the two disciplines has been done. In recent years this starts to change, as advancements in sensors and actuation systems, IoT, robotic architectural elements and the new user expectations and environmental concerns that call for new life, work, and mobility styles. [1] The notion of *human-building interaction* (HBI) seeks to bridge this gap between architects and interaction designers, in hopes to initiate collaborative projects. In these projects, HBI seeks to address physical, spatial and social opportunities and challenges that emerge from these new environments. As built environments become more interactive there are many facets that have to be discussed.

One section is concerned with *interfaces*. Other than those between the building and the occupants, where change is enacted, there are also interfaces between buildings and their services. As some smart devices do things on their own, the *agency* of those become important. How much control does the user have to change certain behavior? Human decisions and automation efficiency have to be carefully balanced. These devices being implemented directly into key elements of a buildings infrastructure also raises concerns of *security and safety* in case of failure or exploitation.

Architecture and products of interaction design have a very different lifespan, so questions about *compatibility of design processes* come up. Buildings have to be maintained, as well as these new technologies that are now part of that. As buildings change their purpose, how are these elements being used in this new environment? Adding interactive technologies also includes the risk of *adoption*, as there are barriers to the introduction of those. One barrier might be construction norms and standards. These must be observed in the process or must change to allow them.

In the discussion between architectures and interaction designers (and also drawing from philosophy, art, geography, dance, mathematics, computing, and still other domains) emerges the field of human-building interaction that tries to find collaborative solutions with these emerging technologies.

Adaptive architecture and feedback loops

A subset of interactive architecture concerns itself with *adaptive architecture*. Adaptive architecture in this context is defined as *buildings specifically designed to be adaptive to their environments and to their inhabitants.* [6] This definition is broad on purpose and therefore includes even buildings that are not augmented with computing technology.

As Richard Coyne [4] points out, buildings are already quite interactive and adaptive. Activities such as parkour and skateboarding take architecture and use it for how they see fit. Traceurs (practitioners of parkour) and skateboarders observe the structures that have been built for functional or aesthetic purposes and make them *adapt* to their ideas. Richard Coyne mentions these activities and proposes that architecture needs to focus more on the interaction between humans and buildings that are beyond touch, gestures, commands, etc.

Keeping those interactive capabilities in mind, we can chart the field of adaptive architecture. Coyne not only describes the adaptive and interactive abilities that buildings already have, but also examines the underlying ideas that they share. He describes ideas about contest, specifically the type of interaction in game design that is *agon*, which defines battles or fights between people and the environment. These ideas are examined and he pictures the implementation of games into architecture. In implementing those games, designers should think about the interaction between humans and cities, as well as humans and systems.

Schnädelbach [6] also mentions this interaction but goes a step further. In his paper he not only describes how technology can make buildings more adaptable, he focuses on the feedback loop between humans and systems. Oftentimes systems — not limited to ones implemented in architecture — are being deployed without regards to how they are being used in practice. Through recognizing the feedback loop in practice of interaction between people and the system we can greatly improve those systems.

Movement being a particular example, he shows that systems should be flexible to allow for corrections in how buildings are being used. Through sensors

in a building, we would be able to find patterns in the movement of people, and make the building itself change itself to adapt. Many occupants may be forced to walk along an unnecessary long path to get to their different destinations. An adaptable building would be able to change walls in such a way to improve routes to make them shorter, or could dissolve bottlenecks.

Schnädelbach points out that all expressions of our behavior are motor acts, while not all behaviors are expressions (e.g. thinking). These motor acts results in movement somewhere in our body and every time we interact with others or the environment movement is involved. In order to better make use of these expressions we need to classify these movements. These movements vary in on many different measurements and scale.

The blinking of eyes or rather the movement of the eyelids themselves are very different from walking where the whole body is involved. Classifying these movements also has to take into account how expressive and detectable those are. As an example he mentions the movement in the gut as being least expressive, while smiling, grimacing and other faces are most expressive. There is also the question about the level of control we even have on some of these expressions. Compare the autonomic nature of our heart to speaking, which is a rather intentional activity.

Another reason in the interest of movement is the fact that elements in architecture are increasingly designed to move. Examples of manually adaptive homes are Rietveld's Schröder house, Holl's Fukuoka housing, and Ban's Naked House, where movement of architectural elements are mapped one-to-one to human movement. Schnädelbach notes, that architectural movements need physical effort and force to trigger.

In prototypes such as TU Delft's Muscle Tower, Ruariri Glynn's Reciprocal Space, and the ExoBuilding, several human movements are technologically coupled with architectural movements. These movements range from respiration to whole-body movements and which those systems pick up through sensor infrastructure. This will be processed through software middle ware to a system for actuation. With those systems, movement in people is coupled to movement in architecture through which an action-reaction feedback loop emerges.

Apart from this coupling, movement behavior can also give us interesting information about their location, spatial relationship to other people, objects and places. Using digitally driven adaptive architecture, such information is being sensed, recorded and stored to enable actuation in architecture. Combined with other personal data, such as physiological, identity, activity, and

social networking data it is possible to allow for even better usage of adaptive architecture. It would enable a much better and immediate feedback loop between people's behavior and the behavior of the built environment.

However with so much data from sensors being stored and used, as well as personal data from occupants, data privacy concerns become a factor. A building acquiring these kinds of data makes it even more problematic, because it is less visibly recording, storing and linking data about its occupants. This data could make its invisibly journey to thirds parties without much control or knowledge for those who are being recorded.

Improving communication between humans and buildings

Usually when we talk about interaction design, we are talking about a screen with an interface that we control. Through implementing interactive technology into buildings, this is most often the default solution to how to control things. This may work but in architecture we have much more possibilities that we can take advantage of. In their paper Wisenski et. al [8] introduce *ambient displays* as an usage example.

Ambient displays take advantage of other types of interfaces that don't rely on displays. They use the entire physical environment as an interface to interact with all kinds of senses. In Wissenski's prototype called *ambientROOM* they introduce a room that relies on *ambient media*. This media includes ambient light, sound, airflow and physical motion that should be working as peripheral displays. As those ambient media channels are emitting information, they should work at the background of user attention.

Through this technology of ambient displays, there is a push to separate background and foreground information. Using displays for information that is background and foreground makes it harder to separate those two things as they both have to share the same device or display. Ambient displays allow for background information to really be in the background and opens up possibilites for a better fine-grained separation. Examples of such an implementation could be air-conditioning, introducing the functionality to convey information through the changes in airflow. One usage would be to improve human interaction as ambient media could show human activity. Subtle changes in the room could convey such information without it diverting as much attention if not necessary.

With such a way of implementing information into rooms and buildings, we

have much more alternatives when it comes to conveying information from a building or room to its occupants. Through tracking of inhabitants activities, the interaction experience of those could be greatly enhanced. [1] In combination with adaptive architecture this could lead to a great improvement in how humans communicate commands to buildings and how buildings communicate information back and execute those commands. Automatic sliding doors for example don't need direct manipulation by humans and only rely and sensors to detect presence.

Conclusion

Interaction design and architecture have more and more topics that need both their expertise. Fields such as interactive architecture and human-building interaction emerge, that require architects and interaction designers to meet and share ideas. These groups already got ideas inspired by the other but rarely work together on projects. Many projects could profit from a deeper collaboration and enhance each others perspective on their respective field.

Finding the overlapping themes in interaction design and architecture will help in constructing better designed future interfaces and buildings [5, 7]. Building should have more interactive capabilities, which would result from this collaboration, such as spatial, social and physical impacts. [2] Enhancing architecture is not only a concern while planning its construction, but also long after its in use. Allowing buildings to be adaptive, to be malleable after finishing construction allows for better insights and enhancement of buildings. [6] In enhancing our understanding of human-building interaction and their built manifestations, such as ambient displays, this would have positive results.[1, 8]

References

[1] Hamed S. Alavi et al. "Deconstructing Human-building Interaction". In: *interactions* 23.6 (Oct. 2016), pp. 60–62. ISSN: 1072-5520. DOI: 10.1145/2991897. URL: http://doi.acm.org/10.1145/2991897.

[2] Hamed S. Alavi et al. "Future of Human-Building Interaction". In: *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*. CHI EA '16. San Jose, California, USA: ACM, 2016, pp. 3408–3414. ISBN: 978-1-4503-4082-3. DOI: 10.1145/2851581.2856502. URL: http://doi.acm.org/10.1145/2851581.2856502.

[3] Wikipedia contributors. *Interactive architecture — Wikipedia, The Free Encyclopedia*. [Online; accessed 10-November-2018]. 2018. URL: https://en.wikipedia.org/w/index.php?title=Interactive_architecture&oldid=837624173.

[4] Richard Coyne. "Places to Play". In: *Interactions* 22.6 (Oct. 2015), pp. 54–57. ISSN: 1072-5520. DOI: 10.1145/2834891. URL: http://doi.acm.org/10.1145/2834891.

[5] Nick Dalton et al. "Interaction and Architectural Space". In: *CHI '14 Extended Abstracts on Human Factors in Computing Systems*. CHI EA '14. Toronto, Ontario, Canada: ACM, 2014, pp. 29–32. ISBN: 978-1-4503-2474-8. DOI: 10.1145/2559206.2559226. URL: http://doi.acm.org/10.1145/2559206.2559226.

[6] Holger Schnädelbach. "Adaptive Architecture". In: *Interactions* 23.2 (Feb. 2016), pp. 62–65. ISSN: 1072-5520. DOI: 10.1145/2875452. URL: http://doi.acm.org/10.1145/2875452.

[7] Mikael Wiberg. "From Interactables to Architectonic Interaction". In: *Interactions* 24.2 (Feb. 2017), pp. 62–65. ISSN: 1072-5520. DOI: 10.1145/3036203. URL: http://doi.acm.org/10.1145/3036203.

[8] Craig Wisneski et al. "Ambient Displays: Turning Architectural Space into an Interface Between People and Digital Information". In: *Proceedings of the First International Workshop on Cooperative Buildings, Integrating Information, Organization, and Architecture*. CoBuild '98. Berlin, Heidelberg: Springer-Verlag, 1998, pp. 22–32. ISBN: 3-540-64237-4. URL: http://dl.acm.org/citation.cfm?id=645968.674740.