AUGMENTED ARCHITECTURE

Interplay between Digital and Physical Environments

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Abstract. In an increasingly connected world where computers are everywhere, surrounding us in embedded small portable devices, appliances and inside buildings, implementing these interconnected and embedded computers have now become common practice in the design of smart spaces and intelligent environments of today. Digital information is constantly being collected and distributed by a network of digital devices communicating with users and vice versa. New behaviors and activities that may have not been considered before in the design of architectural building types are now commonly found in public and private spaces throughout the world. In an attempt to explore and experiment with the concept of interplay between digital and physical environments, an option studio was proposed to 4th year architecture students to develop a new type of augmented architecture that corresponds to changes in human social behavior due to digital technologies. Five pilot projects are presented with experiments conducted to question three social activities commonly found in everyday lives using Arduino prototypes installed in real physical locations. The prototypes were then used as a basis for the development of large-scale projects proposed as augmented architecture.

Keywords. Human-Computer Interaction; Ubiquitous Computing; Virtual / Augmented Reality; Computational Design Research; IoT for Built Environments.

1. Introduction

We live in an age where multiple computers are everywhere, surrounding us in embedded small portable devices, appliances and inside environments where we live and conduct our daily life routines. The concept of interconnected and embedded computers or “ubiquitous computing,” described this future scenario when it was first coined in the late 1990s, is becoming a commonplace in the design of smart spaces and intelligent environments (Wieser 1991). We are now witnessing the impact of such integration where useful information is offered to users within a space to enhance their periphery perception beyond the physical space itself.
Today, digital information is constantly being collected, connected and communicated between computers and users or vice versa, and can become tangible feedback as the analog and digital world collide seamlessly (Ishii 1997). Through various intelligent sensors and Internet of Things (IoT), it is also possible to analyze and get insights of undiscovered human behaviors. However, as architects living in the digitally divided world with those who are constantly connected online and those who are not, what does the future bring to the world of physical architecture when the rest of the world is connected to the digital realm? How can we then transform digitally connected architecture and enhance user experiences in a meaningful way?

This scenario can be summarized as an interplay, one in which users, human or nonhuman, are coupled to computational interfaces and networks of physical and virtual environments creating new architecture of speculation (Bratton 2016).

1.1. OBJECTIVES
To investigate this interplay between digital and physical environments, an option studio is offered to 4th year architecture students under the title of “Augmented Architecture” as the premise of the design brief. The studio questions the creation of architecture that is fundamentally formed by its user behaviors that later turn into common activities and if frequent enough, become permanent or dedicated spaces for such activity. However, changes in social behavior of people in the past decade due to digital technologies has been so rapid that we can no longer keep up with new typologies of hybrid spaces or new health syndromes related to the impact of digital technology towards the human body.

The objectives of the studio are to question the existence of architectural typologies in the digital world today, observe new behaviors enabled by digital technologies and ultimately challenge students to create a combined hybrid or augmented architecture that embodies the best of both worlds.

1.2. SCOPE AND LIMITATIONS
The scope of the studio is divided into two phases. The first phase encourages students to research relevant case studies and projects to understand how digital technologies impact user behaviors in a physical space and similarly, how physical spaces can be enhanced with digital technologies to change user behaviors. Students are then required to explore and identify certain behaviors impacted by digital technologies and vice versa. The behaviors selected are then put to test with built prototypes using Arduino microcontrollers, various input sensors, visual and audio feedback, and combined with a physical interface in real world situations. Feedback is collected and analyzed for the effectiveness of the hypothesis and the prototype.

The second phase challenges students to propose novel ideas for an augmented architecture developed from prototypes proposed during the first phase. The transition from prototype to architecture must be relevant and coherent in order to assess the scalability of the behavior that is converted into actual spaces. Limitations of the project include time and expertise of students, since students
participating in the studio had no previous experience in Arduino programming and the 15-week long project is divided into two phases allowing a limited time to produce, test and evaluate each deliverables.

2. Digital and Physical Interplay

There is no question that if our behavior changes i.e., how we work, play, learn, rest, eat, read, contemplate, conference etc., then our activities in space is no longer constrained by past tectonics and classical typologies of architecture. On the other hand, if one looks into how changes in behavior can alter our use of space, it is also possible to explore how digital technologies can alter user behaviors in the space to become aware of digital information that is communicated through user interactions or within the border of digital and physical interplay (Mitchell 1995).

Three selected case studies showcase how digital and physical environments can be combined to create a new unique and meaningful user experience. Users can interact with physical, virtual or mixed realities, each having their own pros and cons in responding to human behaviors.

2.1. TANGIBLE MEDIA

Tangible media with physical input and output in various scales can be easily perceived and understood by users. Interactions are straightforward and reflect upon common human behaviors and responses and therefore require no prior explanations. For example, the “Fun Theory” campaign experiments conducted by Volkswagen in 2009, presented a project called the “Piano Stairs” by embedding musical notes on plates disguised as piano keys on a physical staircase at the Odenplan subway station in Stockholm. The project encouraged users to walk up the staircase instead of standing on the adjacent escalator by means of “fun” play as an incentive and hence changed user behavior through tangible media interactions. Another example is the Network Sensory Landscape that creates geographically dense web of sensors, which produce data to enhance a sense of space and presence (Dublon & Paradiso 2014). Incorporating environmental sensor networks platform embedded in the landscape can provide real-time sounds and visualizations (Mayton et al. 2017) as augmented components in architecture for end-user applications.

2.2. VIRTUAL REALITY

On the virtual reality side, one can argue that in the future, the physical environment is no longer relevant to people and humans can spend most of their lives online and assume a virtual avatar representation similar to the Hollywood film, “Ready Player One.” Total immersion in virtual environments can leave users isolated and incapable of leaving the virtual world to spend time living in the real world. The presence experience through virtual reality may eventually equal to consciousness (Sanchez-Vives & Slater 2005) when selective attention, perceptual fidelity and other sensory factors all interact (Witmer & Singer 1998). However, in the virtual environment, there is much flexibility with less physical risks involved unless it ties back to natural human life cycles and social norms.
The question then comes back to what is considered the right balance for present times during this critical social transition.

2.3. MIXED REALITY

Finally, in mixed reality and the use of Internet of Things (IoT) to create smart environments can provide personalized experiences based on user movement and interactions paired with smart devices in a museum (Hashemi & Kamps 2017). For example, teamLab’s commercially successful interactive installations, “Borderless” and “Planets” exhibited at Odaiba, Tokyo are examples of the future of exhibitions that offer a unique mixed reality experience to visitors combining continuous virtual projections with physical interactions and tangible object displays. teamLab is a group of interdisciplinary professionals combining the creativity of artists, programmers, engineers, animators, architects and designers that form one “ultra-technologist” team. Their artworks move in and out of rooms freely, forming connections and relationships with people, communicate with other works, influence and sometimes intermingle with each other, and creating a unique sensory experience for visitors like no exhibition in a typical museum. Their collective aim is to achieve a balance between art, science, technology and creativity.

3. Project Prototypes

Five pilot projects were explored in this studio with five distinct experiments proposed by ten architecture students from Thailand, Japan and France. Students were asked to identify a unique set of human social behaviors that have changed in the past few years and create new activities using new digital technologies within an architectural space. These behaviors include waiting for a bus, dining at a restaurant, jogging in a park, crossing an underground tunnel and meeting strangers at a lift lobby. Then, with no prior knowledge in computer programming and electrical engineering, students were required to create physical prototypes using Arduino and various sensors and output to interact with users in real situations and spaces of choice. The five projects can be grouped and categorized into three main activities consisting of waiting, exercising and meeting.

3.1. WAITING

The act of waiting for someone or something is usually accompanied by conducting some kind of activity to kill time. A common waiting experience that was identified is waiting for a bus at the bus stop and the most common killing time activity observed was using a smart phone to do various small tasks. With this premise, one of the projects titled “Sumaho Secchi” or put down your phone in Japanese, was developed to encourage users to put down their phones and to be aware of their surroundings and notice people next to you.

The prototype is situated between two seats at a local bus stop in the university campus. The system is activated when a user puts down a smart phone to wirelessly charge the battery. Once a user puts down one phone, the red display is turned into green and blinks inviting a second user to do the same action and pair up with the
first user. When both users are free from their phones, a simple game of Pong is activated and can be played by both users bouncing the cursor from one side to another until one player misses. The game stops when someone loses or picks up their phone and leaves on a bus. The prototype built by students was based on two Arduino units and utilizing switches, LEDs, buzzers and a simple numeric display. Power is supplied for the wireless battery charging stations as well as the microcontrollers (Figure 1).

Figure 1. Diagram showing user interaction while waiting for a bus and the design of the microcontroller unit.

Figure 2. Diagram of the game design with a single Arduino unit and testing the prototype game with four concurrent users.

Another project is also an act of waiting at a coffee shop. The time spent while waiting for coffee to be served can be easily wasted on personal mobile phones rather than to socialize with friends and family that accompany oneself. The site of this project is located in a local coffee shop and the prototype is designed to be an interactive game embedded in the coffee table itself with an interactive game to be played by one to four users at the same time with three levels of difficulty (see Figure 2). The game is designed to allow maximum participation of users paying attention to each other’s moves in synchronization. Feedback from initial user tests has been positive as users find the game to be a social activity that engages users to communicate more.
3.2. MOVING

The second group focuses on the act of moving or human movement. One project was the jogging correction assistant system. Students took notice of an activity of jogging that is usually conducted incorrectly by people who try to maximize the length of their jogging strides. The correct way to jog is actually to minimize the length of each stride so as to step on the forefoot rather than the heel. Doing so will decrease possible risks of damaging the knee and increase the effectiveness of exercising to the runner. An interactive system is therefore designed to assist runners in landing their feet at the right position from a guiding laser light on the ground. The jogging correction assistant system comprises of several Arduino units connected in chains throughout the length of the jogging
track. For experimental purposes, the prototype was limited to a length of five meters with an average stride of 30 centimeters each (see Figure 3).

An additional moving project focuses on the behavior of people crossing an underground tunnel beneath a road separating a university campus in two sides. The investigation takes place during peak operations in the morning, lunch, and evening hours observing how people move from one side to the other and walking chaotically to avoid colliding with one another. The project then proposed a system to encourage users to walk more in line within one side of the wall rather than in a zigzag pattern. To do so, the prototype incorporated proximity sensors along the tunnel to detect movement of users from one side and activate lights on the wall and audio sounds to visualize the sequence to users (see Figure 4).

3.3. MEETING

The last group was the act of meeting. The project is called “Let’s Meet, Neighbors” focusing on the activity of greeting a stranger in front of an elevator lobby in the international student residence. The goal of the project was to use an interactive game to initiate small talk among strangers and encourage international students to meet new friends. Users will see a light panel installed around the elevator buttons. When users touch the elevator button, a sensor will detect proximity and activate the light panels with light and sound. Users will have to touch the lit panels in a correct sequence similar to Simon Says in order to complete the game (see Figure 5). The actual prototype system was installed in the elevator lobby of the international residence as proposed and user tests were conducted with real residents. Initial responses were puzzled by the real purpose of the game but users found it intuitive enough to play along with the interactions.

As all the small prototypes were completed, installed, and tested, the next phase of the project was to transition from simple prototypes and scale them up to a larger architecture scale. The transition although seemed deliberate, was more challenging for students and therefore only two projects succeeded in linking both phases together coherently.
4. Augmented Architecture

Architecture is fundamentally formed by user behavior that turn into common activities and if frequent enough, become permanent or dedicated spaces for such activity. Behavioral changes of people in the past decade due to digital technologies has been so rapid that we can no longer keep up with new terminologies for health syndromes related to the impact of digital technology towards the human body. Physical architecture is also no exception. We have witnessed the fall of physical retail businesses such as bookstores, video rental, banking and healthcare due to new digital behaviors. Architecture must cope with this paradigm shift in order to remain relevant throughout its century lifespan.

The studio project in phase two deals with the transitioning of a simple prototype that responds to a single interaction based on a single behavior of either waiting, exercising and meeting. The projects developed from these one were proposals into the definition of an augmented architecture project. Two projects are showcased here.

4.1. PARASITIC FITNESS HUB

The Parasitic Fitness Hub project transitioned from the behavior of exercising or jogging into the activities inside a fitness hub. The project proposed a modular fitness framework of activities attached to an existing building, in this case, a high-rise complex, as a parasitic architecture capable of moving and reconfiguring its units to adapt to users and its building host. Also, environmental sensor networks can be deployed inside the units to render real-time visual and audio landscapes within the space and enhance user experiences. The topic was intriguing as a project but raised many concerns about the construction and mechanics behind the mobility of units that are physically attached to a building façade (see Figure 6).
4.2. PARKOUR EXTREME PARK

The last project also transitioned from the behavior of exercising and developed the project into an extreme sports park specifically for Parkour, and created an interactive extreme sports environment where the building surfaces can be reconfigured internally and externally to accommodate the multiple levels of difficulty of the sport. The floor platform and walls are comprised of interactive units that can push in or out and reconfigure its continuous surface depending on its users. Each unit has an air pump system in a channel pushing or pulling its top cushion where it is used as a gripping object or stepping platform (see Figure 7). Customization of the obstacles can be programmed using personalized intelligent sensors combined with user behavior analysis to help shape an adaptive game (or play) setting and alternative scenarios to the players in real-time.

Figure 7. Diagram of internal spaces with three levels of difficulty and detail drawings showing the internal interactive surfaces.

5. Conclusion

Augmented architecture explores human behaviors that have changed due to digital technologies and how they impact activities and the design of spaces. In this option studio, students are required to rethink how these new behaviors impact the design of spaces in architecture as well as experiment how the design of a space with embedded digital technologies can change human behaviors purposely. The first phase of the project experimented with Arduino prototyping was a good experience to inquire human behavior changes and learn simple programming with microcontroller. Students paired up and learned from making, planning, and testing. All prototypes completed were at a satisfactory level. The second phase of the project however, transitioning from prototype design to architectural design may prove to be a challenging for students. Especially those who did well in first phase were not so successful in second. This is due to the lack of meaningful interactions within the spaces chosen and the hesitance of students to take the leap of faith into new design possibilities. Nonetheless, augmented architecture can be explored further in other aspects of computational design education and practice. Looking into novel construction applications, performative facades, kinetic building envelopes, and interactive and transformative architecture are possible future research directions for continuation of this option studio.
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