MULTIFLIGHT

Creating interactive stairs through positive technology

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Abstract. This paper details a pedagogical project which calls for an improved design performance of the existing built environment through the use of smart technology and data-driven design. The project is an investigation into ways in which to improve the performance of a 'pre-selected university building' through the use of a media facade that allows for interactive experiences. Existing problems of the selected building have been identified through observation and research using a rich picture and agile approach. An underutilised staircase was selected as the focus site for a series of computational design and interactive design studies. The brief of this mini-research project aims to encourage more people to use the stairs and create a memorable experience with a technological approach through the application of a site specific interactive media installation. The project is an interactive staircase which utilises LED strips and generative sound. The project features a series of light boxes which are connected to the existing staircase balustrade. Arduino, passive infra-red sensors, and other motion detection sensors were used to allow for light and generative sound interaction with users using visual scripting tools and a generative design platform. Sensing technology was used as a real-time data-gathering device during the site analysis phase as well as an input device for the designed prototype to allow the testing of the data-driven design. This paper details the study and resultant interactive prototypes. It also discusses the exploration of performance based design ideas into design workflows and the integration of sensing tools into the design process. It concludes by identifying possible implications on using the Internet of Things concepts to facilitate the design of interactive architecture.

Keywords: Performative Design; Interactive technology; Positive technology; Internet of Things

1. Antecedent: Architecture in the Internet of Things Era

The Internet of Things (IoT) is a current development that integrates the use of sensors and network connectivity into ordinary objects in order to send and receive data that can be fed back into systems and designs targeted at improved lifestyle and commercial activities. This process has caused a significant shift in our understanding of digital tools and the use of hardware in architecture and design in the last decade. IoT integration in product design can be seen with the Coke machine project at Carnegie Mellon University in the early 1990s (The “Only” Coke Machine on the Internet) which was, arguably, the first internet connected appliance able to auto-report its inventory and whether loaded drinks were cold. Although a simple application, it showed the potential of using sensors and the internet to enhance product performance and communication with users. Over the following decades, IoT has started to be gradually integrated into design due to the introduction of open-source hardware and software. The use of sensor technology in architecture, such as the Arduino platform, is causing the creation of sophisticated assemblies (RVTR, 2009), where buildings such as the North House Prototype, built in 2009, have an improved environmental performance through “computer-automated exterior shading louvers … based on real-time interior and exterior climate sensing” (Trubiano, 2013: p. 89).

2. Retrofitting University Buildings: a minimal approach based on data

A recent study by the Australian Learning and Teaching Council (2010) proposed guidelines for retrofitting university teaching spaces. The paper, ‘*Retrofitting University Learning Spaces*’ (ALTC, 2010) explores 25 ways to help with the redevelopment of such spaces through the introduction of elements such as colour, allowing for interactivity, variation and individuality, and making ‘spaces within spaces’ (introducing hybrid spaces to enhance building performance) (ALTC, 2010).

Data in this research project is utilized as a driving force to allow for the creation of a hybrid space within a circulation space. The ‘Grand Narrative’ for this project called for improving the performance of the Red Centre, the Built Environment School at the University of New South Wales, through a series of design interventions that look at ways to improve the environmental and communication performance of existing buildings. Data was captured through a series of experiments. The integration of data-driven and interactive projects into educational spaces is relatively uncommon and the completion of this project will show insights into how it can be utilized to create a positive impact on a location and increase the visual and aural experience of the site.

There have been increasing numbers of architectural projects that integrate the use of sensors as a way of collecting data and/or utilising the resulting data and taking it into consideration in final design decisions. One example can be gathered from '*Generative Design Intervention – Creating a Computational Platform for Sensing Space*' (Alhadidi, 2013) where sensors were used as a method to track the motion of people. This helped determine the design decisions of optimal pathways that were created through a generative tool. Instead of using generative outputs to influence design decisions, MultiFLIGHT looked at generative outputs of light and sound as a major design gesture which is ever-changing to allow for interactive designs that are driven by end users. This paper explains how generative processes can create a memorable experience due to their unpredictable nature. Sound, which is often a neglected element when it comes to architecture was driven by data captured on-site that "embraces and transcends the spaces in which it occurs" (Avidar *et al.*, 2009).

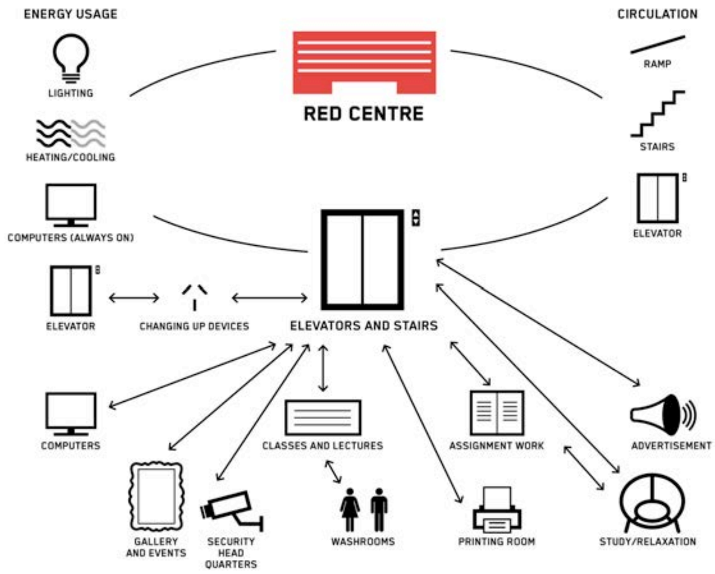

Figure 1. Rich Picture of the Red Centre.

3. Performance in Educational Spaces: Enhancing Communication Through 'Positive' Sensing Technology

Datasets through IoT are presenting an exciting opportunity to merge smart technology and physical architectural elements to achieve high degrees of communication to allow for better spatial quality. During the last decade, teaching spaces were influenced marginally by the implementation of smart devices using smart whiteboards and cloud computing as they "are an effective means [to make] learning more motivational and meaningful" (Giles & Shaw, 2011: p. 36). Smart white boards have not been as successful as anticipated in providing a positive impact to educational spaces.

The notion of designing with 'smart' technology to improve interactivity between students in teaching spaces is evident in newly retrofitted buildings, however the shift towards performative teaching spaces in older existing building stock, in reality, has not been developed due to the high cost and the need for further infrastructure to enable the installation of smart devices. Introducing sensing technology to circulation spaces within educational institutions may serve as another method to enhance the communication between students and enable neglected spaces to become actively utilised. For example, Passive Infrared Sensors (PIR sensors) can be used to gather real-time data from the existing space, which can then be used to inform and drive the design of the interactive prototype.

The creation of smart educational spaces enables the development of 'positive technology'; that is, the use of technology to improve the quality of personal experience, through increased "emotional, psychological and social well-being" (Brooks *et al.*, 2014: p. 222). Previous projects such as the Piano Staircase in Brussels (Thefuntheory, 2009) is a notable example. The stairs were used as a positive technology intervention in order to raise awareness of health issues related to lack of exercise. This experiment was successful in attracting 66% more people to take the steps than the escalator (Hansen, 2012). Although this project has had positive results in the short term, the intervention may become predictable after several visits and raises the question as to how to make an experience more variable and dynamic for the user.

4. The Investigation

The Red Centre's staircase was chosen as the location to implement the interactive intervention because it was assessed as an underutilised space. Through a series of studies, this project aimed at formulating a better understanding of how and why people move through the building. This project used the vertical circulation space as a 'blank space' that enabled a valuable opportunity to engage, stimulate and promote the use of, and engagement with the staircase by students. To this end, the staircase functioned as a canvas that allows users to adjust the built environment experience and encouraged a re-imaging of learning spaces.

4.1. DOCUMENTATION AND SITE RESEARCH: DATA CAPTURING

Documentation of the staircase was undertaken to determine any possible issues within the building. This process involved photographing the site and surrounding buildings and observing how people used the building so as to identify problems with the Red Centre and gather possible 'live' data with which to improve the immediate environment. The documentation approach used in this research was the first threshold for designing the interactive experience.

4.2. SURVEY VERSES TIME-LAPSE

In order to gain a clearer picture of the underutilisation of the staircase, a questionnaire consisting of eight questions was created and completed by students (*N*=50) to examine their perception and use of the space. From the survey it was found that there was an even split between people using the stairs and elevator in the Red Centre. The elevators were used mainly for going up three levels or higher in most cases. The survey indicated that the project could potentially motivate approximately 26% of occupants to take the stairs more often if the project provided a space for an interactive media zone consisting of lights, sound and sensors.

In addition to the survey, time-lapse photos of the Red Centre entrance were recorded from 09:00 to 17:00 over five regular teaching days. The camera was angled to view the number of people waiting for the elevator and to view how many people travelled via the staircase. This study served to verify the findings of the survey in relation to staircase utilisation.

Figure 2. Time-lapse of main circulation space from 10:30 to 13:00 on Monday.

4.3. MOVEMENT-DATA-DRIVEN-DESIGN

Smart technology refers to the incorporation of data and Internet Technology into an object or framework that enables autonomous communication within a network as nodes. One example of smart technology is the D-Tower, by Lars Spruybroek in the Netherlands. This tower reacts to information via submissions collected from a website which in turn determine its colour output and enables a dynamic and entertaining design. Within the proposed design intervention at the Red Centre, the movement of people provides a dynamic input and feedback via MUltifLIGHT, which in turn continuously adjusts the stair's performance. This data-driven feedback loop applies the use of data-mining from various mediums to create an interactive and engaging site intervention.

4.4. DESIGNING THE LIGHT AND SOUND

Architectural spaces have long been designed primarily through three-dimensional geometrical procedures that are presented and evaluated visually. However, the experience of the environment (natural or built) is one that is multisensory. Neurological evidence suggests that fidelity of aural stimuli is a significant parameter which alters an individual's perception of space and can "influence, both directly and indirectly, the mood and emotions of those who occupy or live within a space" (Blesser & Salter, 2009: p. 65).

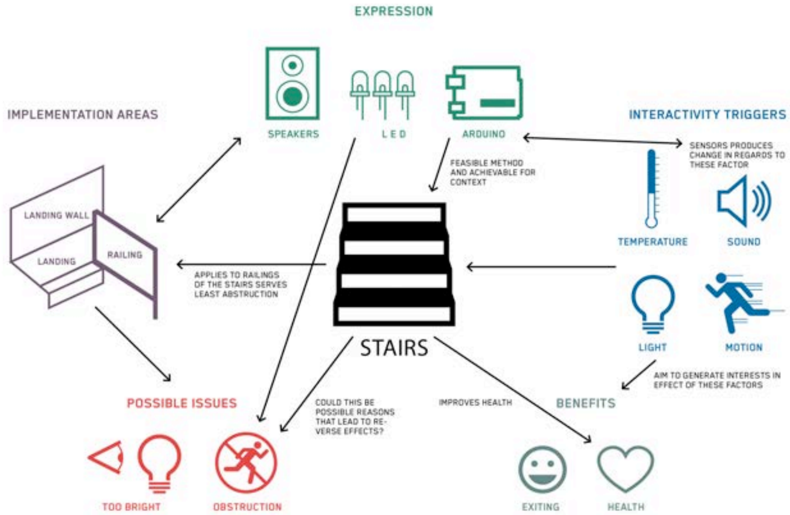

Figure 3. Rich picture of Stairs generated from the data mining exercise

Light and colour also have similar effects in relation to space as they can be used to “create focus, movement, balance, and to experience an emotional response” (Triedman, 2015: p. 200). Achieving a memorable experience relies heavily on “how novel and interesting the experience is, and the kinds of emotions that are evoked” (Koch, 2010). Using the Red Centre stairs will become a much more sensory experience which has the potential to improve the performance of the space by encouraging more people to use the stairs more often by emphasizing the visual and aural elements of architecture through the use of interactive light and sound to evoke an emotional response.

4.5. CONCEPT DEVELOPMENT

The experiments went through a number of iterations which gradually developed into a project featuring a series of acrylic boxes located on the external side of the staircase balustrade. Each box contained a number of vertical LED strips and speakers that were interactive and utilized both active and passive inputs. The interactions were divided into three categories which included passive lighting, active lighting and sound correlating with both the passive and active elements. While the light boxes were not being interacted with, coloured passive lighting generated from weather data was utilized. Active Lighting Interaction was incorporated in the design using Near Field Communication (NFC) stickers which can be activated by a series of inputs such as phones and student IDs.

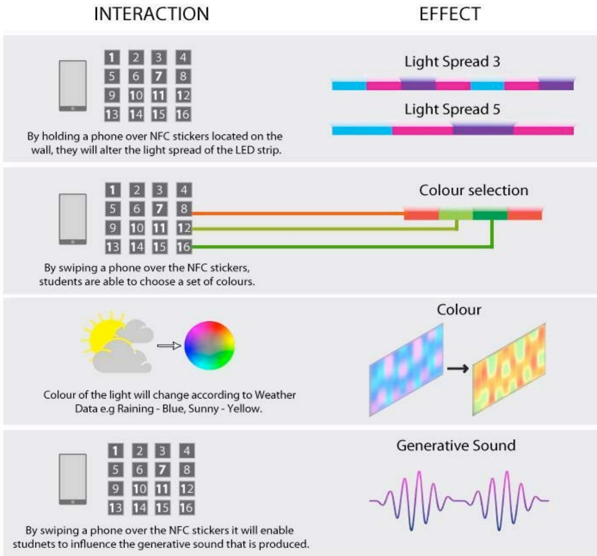

Figure 4. Diagram of interaction and effects

The NFC stickers were dispersed on different levels and generated different results from the sound and light elements. For example, level one generates slower lights and lower frequency sounds, while level five produces a different light spread and higher frequency sounds. Sound was generated from the value output from the varying arrangements of the NFC stickers, with the outputs then serving as the inputs for the musical notes in the MIDI data bank of instruments. PIR sensors located along with adjacent speakers then play sound when motion is detected at either the top or bottom of the stairs where sensors are located.

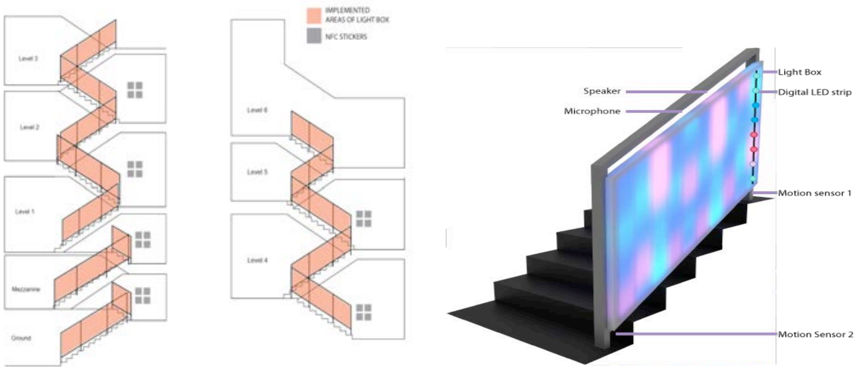

Figure 5. Section of Application Areas and Light Box Design

4.5. PROTOTYPING

IoT devices are increasing in speed and memory capacity. However, at present these small, low-powered devices still have a limited amount of memory, and some ingenuity is required to get them to perform complex operations beyond simple number crunching or simple computing. The ease and ubiquity of internet access (via Wi-Fi) and cloud computing can be used to get around these limitations, but often it is easier and provides a more robust solution to have a simple self-contained system that can run autonomously. Generative methods in programming can be utilized to create complex displays of lights and sounds. This complexity can be created out of very simple formulas, the results of which seem to the casual observer to be nondeterministic. These styles of formulae are similar to pseudo-random number generators. Given the same seed they will generate the same output each time, but that output is more ordered than a sequence of random numbers. This output of a generative formula can be used to set the individual colour of an RGB LED or play notes at certain frequencies. Consider a simple formula using bit operations like the following:

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time * ((time >> shift1 | time >> shift2) & mask & time >> shift3)
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This will produce a sequence of numbers in which each value depends on time and the resulting outputs grows and shrinks over time depending on the initial values for the shifts and marks. There are several overlapping cycles, and even when the output is examined for some time it is not obvious that it is repeating or how long the total cycle is. More dimensions of complexity can be added by altering the shifts or marks over time or as a response to user input, or even changing the formula and bit arithmetic operations within it. With a little exploration and fine-tuning the result can be complex. The code required to perform these calculation is small, fast and consumes very little memory, making it ideal for low power, low memory IoT devices. To explore the possibilities provided by a generative formula several simulators were created to explore the effect of changing the values of the shifts and marks and to see how the output could be manipulated. Simulators can be quickly coded and are a great way to explore the possibilities in a problem space. Several hardware prototypes were produced in this study, which were based on the use of LED strips with an embedded Arduino compatible chip, and an Arduino compatible board incorporating a 3G modem.

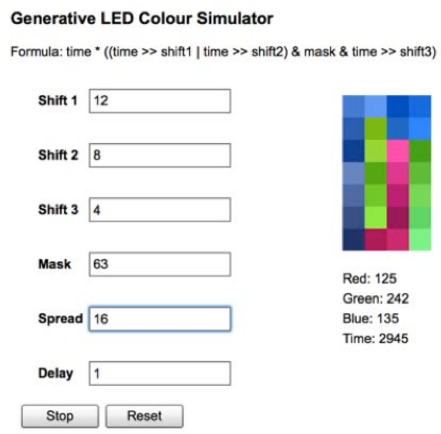

Figure 6. Diagram of Generative LED Colour Simulator

The 3G prototype was hooked up to a social network account (Twitter) to provide a simple way of controlling the generative formula. A function exposed in the cloud (as a URL) enabled the bit masks and shifts in the generative function to be changed by posting HTTP requests to this URL.

While investigating how NFC could be used to provide interaction, it was discovered that the student ID cards were NFC cards and thus provided a simple way for every student to have 'unique' interaction with MUltifLIGHT.

Figure 7. Fritzing(setup) of Arduino and Prototyping of Lightbox.

NFC stickers are cheap, easily placed and can be programmed to contain URLs and data. When an NFC-enabled phone is place near them they trigger a URL in the phone's browser. A IFTTT IoT platform (If This Then That) was used to provide the 'glue' to connect different parts together and is another tool in creating prototypes and providing other diverse inputs to the system such as weather information.

4.7. MODEL DEVELOPMENT

When developing the model there was a need to ensure that users were able to experience the interactivity without disturbing or obstructing the existing space. So the final placement was on the exterior side of the railing where the LEDs were able to shine through the glass panel of the balustrade.

4.7.1. Generative design as an ongoing solution: What makes a space memorable?

In exploring mediums for this project, light became the most convenient and effective choice, having a dramatic impact on the way the space is perceived as seen in media facades. Not only is it visually stimulating, it could be a platform for interactivity being an open and novel communications medium (Davies *et al.*, 2012), Time Square is an example of this and attracts many people because of the scale of advertising and emotive nature of the media facades. It is these emotions that help create a memorable experience. Since this project deals with interior spaces and, in the presence of occupants, one of the aims was to gather and utilise data from sensors to create outputs that responded to occupant usage. For example, motion and other environmental factors were used as data inputs to design an installation that is an ever-changing system and creates a dynamic human experience. Through this body of knowledge, it can be understood that in order to make projects of intrigue and sensory experiences, there should be a level of interactivity and interest in addition to dynamic visual mediums.

4.7.2. Generative Design and Sound: How to Make It Memorable

In exploring strategies to create immersive experience, the use of sound was introduced, having an ability to change a space as it provides users sensory information which "defines, animates and enlarges the architecture" (Avidar *et al.*, 2009). Loop.pH's 2010 Spiratomic Space installation highlighted the potential of sound and light for the user, having a weave pattern that lit up a generative pattern that changed in response to environmental factors. The unpredictable outputs became memorable from not only its dynamic system but its open and novel opportunity to involve participants. This illustrated how a memorable experience can be established by making the project responsive to people and its surrounding environment, and therefore less predictable. A harmonious connection between the lighting and the form that it is displayed on must also be established.

To apply the sound aspect of MUltifLIGHT we needed to take into consideration different factors and conduct several on-site tests to ensure the most optimal outcome. It was important to look into finalising and deciding on the appropriate decibel level that would be sufficient to be heard but not loud enough to be disruptive to people. With the available equipment, the sound was tested using a Bluetooth speaker placed on the landings. It was concluded that the most appropriate sound level was around 50–55 decibels, one to one and a half meters away from the speaker.

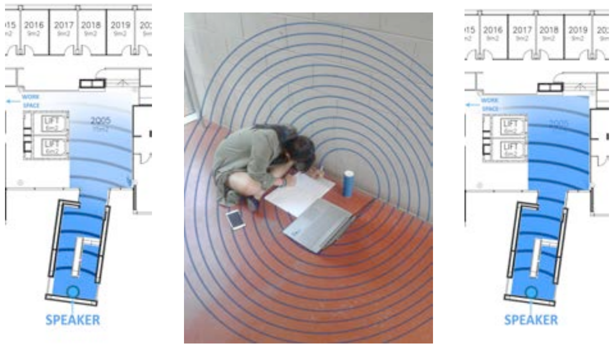

Figure 8. Diagram of Speaker Volume Level Ranging from 45–65 decibels (left to right)

5. Results and Analysis

There are many examples of the integration or use of technological application of interactive media within learning and teaching spaces; however, there are fewer cases that focus on applying media interactivity outside of these contexts. This project extends the application of interactive media to interstitial spaces, and explores how occupants can be engaged in what are often 'overlooked' spaces. This project reimagines conventional educational spaces through the utilization of 'ancillary' spaces such as circulation spaces as platforms through which to foster engagement through the purposeful application of interactive integrated technology.

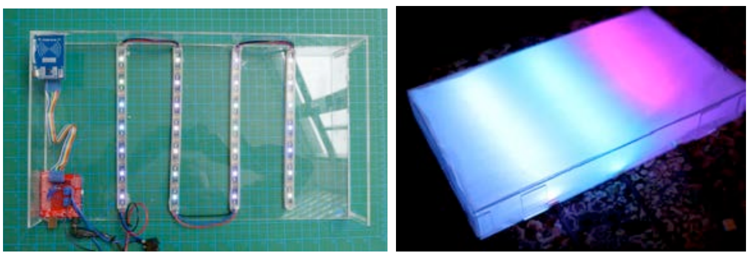

Figure 9. Lightbox Prototype for On-site Testing

6. Conclusion

MUltifLIGHT was a research project that examined the use of technological software and hardware tools as a method through which to explore the use of generative applications to create an engaging and interactive space. Through these mediums, a dynamic and interactive sensory experience was created for the occupants. There are promising potentials in the application of interactive media facades, and further research needs to be done to examine how this technology can be expanded to further enrich user experience.

The ever-increasing integration of the Internet of Things in different contexts brings with it the potential for new digital interactivity through the use of sensory tools. This research shows one of the many applications of the idea of generative responses that utilizes data gathered from occupants to produce a richer experience of the space. This project is an example of how media facades are a platform for enriching the experience of users. With the output medium of LEDs and sound being constant, the media facade is open to different inputs depending on the kind of sensors used. The type of sensor used and the interactivity involved will have to be considered against the occupant's behaviour whilst understanding limitations if the project is to be engaging. Although MUltiFLIGHT explores the use of sensors and interactivity as the means of entertainment, it touches slightly on informative purposes. With the right arrangements in hardware and software, its functionality could be extended to further applications such as data mining to understand how students utilise the building, and increased affective learning experiences.

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