Augmented Spaces

If walls could talk

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This paper explores the development of Augmented Spaces that involve embedding within the built environment, digitally responsive recognition of human presence. Contemporary digital media provides the opportunity to enhance physical space with the property of immediate interaction, which results in a high level of user engagement and responsivenenss. Through the addition of digital media, emotional and reflective value can be added to the built form. If space is designed to be reactive, rather than passive, a dialogue can be established between the user/inhabitant and the environment. We report on the establishment and analysis of a set of prototype digital interventions in urban space that react to human presence. One is in a building threshold space; one an urban street. We describe the development of a digital particle system with two inputs; the first being the geometry that generates the particles and the second being the geometry that displaces the particles. The research goals that we report on are driven by three over-riding response criteria, Visceral, Behavioural and Reflective.

Keywords: *augmented space, reactive, synesthetic*

PROBLEM STATEMENT

Humans form meaningful connections with the built environment through the physical and social interactions within the spaces they inhabit. The built form has been "created for as long as at least three hundred thousand years, and strikingly even in the earliest and simplest forms they were interactive and multi-functional" (Alavi, et al., 2016). On a daily basis, society is in constant dialogue with the built environment. This dialogue allows us to alter the parameters of the space we occupy; by turning on a light switch, opening a window, or rearranging the furniture, we are affecting and altering our surroundings. These daily affordances give us control to create a preferred level of subjective comfort; creating physical, sensory or emotional pleasure in the spaces we occupy.

Over the last three decades, our world has become increasingly augmented by digital technology and information. In the past, technology was fixed to a particular location, and its effects were limited to specific spaces: the office, the television, the cinema. With the advancements of mobile phones, digital media is accessible throughout the day and in most inhabited locations. Pervceived through the device of a screen, the virtual world is separate from the physical environment.

This paper explores how virtual and physical interaction can be combined to develop Augmented Space and how it can be used to enhance public engagement. An interesting and relevant project is the Infinity Wall (Nexen Univercity) [1].The research examines the implications, benefits and outcomes of augmented space and aims to develop a system to create a meaningful connection between person and place in the form of a prototype system developed in response to defined performance targets.

AUGMENTED SPACE

Augmented space defines the relationship between physical environments and virtual information. As Lev Manovich writes in 'The Poetics of Augmented Space', augmented space is "the physical space overlaid with dynamically changing information" (Manovich, 2016). The concept explores how personal experience of a space can be altered and augmented through the addition of multimedia information.

Our research consequently investigates how the integration of responsive digital media into built form can enhance the level of user immersion and interaction. Biggio notes the key aim which is to develop "an interface that is able to erase itself, making the user experience more immediate" (Biggio, 2020). When describing her multimedia video installation at the Museum of Modern Art, Pipilotti Rist stated: "The basic concept is to try not to destroy or be provocative to the architecture, but to melt in" (Lavin, 2011). Our augmented space aims to be a responsive overlay to the physical architecture, becoming an integral and immediately responsive part of it.

SYNESTHETIC ARCHITECTURE

The work in this paper is focused on establishing how Synesthetic Architecture can be implemented by delivering an interactive augmented space that responds to criteria established in research investigations in recent years. The term Synesthetic Architecture was coined by the digital media artist Refik Anadol (Anadol, 2020). Anadol works with collecting site-specific data in order to generate digital data sculptures. The proposition takes inspiration from ideas on augmented space; combining physical space, and digital information with the enabling qualities of machine learning. His most well-known work, a projection onto the façade of the Walt Disney Concert Hall in Los Angeles, uses a collection of the LA philharmonics data to create digital media that presents the building's past."Synesthetic architecture, therefore, suggests that architects may enfold machine learning into building forms, not just creating but also redefining space through mixed media and interactive robotics. The age of machine intelligence will make our computers, our buildings and our cities more responsive and brain-like" (Anadol, 2020).

Equally, Sylvia Lavin uses the term 'Super Architecture' to describe the result of adding digital media to architectural form. Resulting in works that "not only superimpose themselves onto architecture but that intensify architectural effect... mingling one medium with another so that neither loses its specificity." (Lavin, 2011).

The addition of interaction to augmented space adds another layer of user engagement that will enable the user to become an active participant in the experience. The participant will become the actor rather than just the spectator, or as Augusto Boal terms them "Spect-actors" (Boal, 1985). Boal, an expert in performance and theatre, suggests that when the participant becomes a 'Spec-actor' they are applying their own agency to the experience.

Examples of projects that take such approaches includes the Nexen University 'Infinity Wall' [1]. This visualization, displayed on a 7 metre long LED screen is composed of four parts; Knock, Soaring, Combination and Climbing, each depicting a different visual language. Knock uses the language of water and fluidity, depicting a giant wave within a three-dimensional space. The design of the wall was driven by three principles; story mode, mood mode and message mode.

GUIDING PRINCIPLES IN OUR WORK

To test the ideas and principles above, in practice, different systems were developed. We adopted a core principle of Emotional Design in generating an appropriate response. Emotional Design is explored by Don Norman in his book 'Emotional Design: Why we love (or hate) everyday things'. He illustrates how understanding human emotions when designing can result in better user experiences. He describes three consequent levels of brain processing; the visceral, the behavioural and the reflective, each responding to different design interventions in different ways.

Visceral design is centered around aesthetics and grabbing the user's attention. The visceral processing level is an instinctive response, it is "about the initial impact of a product, about its appearance, touch and feel" (Norman, 2004).

The behavioural level of the brain regards how a product is used or experienced. In the specific case of our research, behavioural design is the experience of the interaction taking place. The design must function in a satisfying way to create a positive emotional experience.

The reflective level uses consciousness and thought to create the most effective emotional response. Norman describes the effects of the reflective level on design thus: "It is only at the reflective level that consciousness and the highest levels of feeling, emotions and cognition reside. It is only here that the full impact of both thought and emotions are experienced" (Norman, 2004). This thought process can be targeted to leave an impression on the viewer and enable the viewer to engage with the theoretical or thought provoking concepts of the design.

VISCERAL DESIGN - AESTHETICS, APPEARANCE AND INITIAL REACTION

Consequently the the three levels of emotional brain processing can be aligned to an augmented space design as follows:

- Visceral Design - The immediate attention grabbing impact of designed media.
- Behavioural design - The enjoyment and effectiveness of the interaction.
- Reflective design - The emotional value and speculative discussion the design enables.

These criteria are then set as the Research goals in our work, which was then respond specifically to each of the three levels of emotional design. The research was constructed to establish a response and solution for each of the nine component goals shown in Figure 1. Measuring individual user response is challenging in conventional circumstances, but with the covid situation prevailing such user feedback proves very difficult or impossible. The approach taken in this research was therefore to set the three major goals (Visceral, Behavioral and Reflective) and have three measures for each of these goals. In turn, this gave us 9 performance criteria. The research aims and achievements could then be measured against those 9 goals. So Figure 1 has the overarching criteria and the three goals within each of them, plus a final column that effectively records the achievement of each of the nine components that were established at the outset as the elements that captured the overall research objective. The table in figure 1 and was therefore the means of tracking the progress of the research.

TESTING ENVIRONMENT

The conceptual ideas in the design performance requirements established above, required specific tools and processes to achieve the desired outcome. The tools used explore the research intentions were chosen to ensure a meaningful augmented experience. The workflow of instruments that we exploited is shown in Figure 2.

The Instrument implementation took into account good practice research such as that by Nielsen [2] to ensure novice user interface design was imple-

Design Evaluation		
1.0	**Visceral Criteria**	**Completion**
1.1	The digital media should be aesthetically pleasing as well as engaging other senses such as touch and sound.	
1.2	The design should intensify and alter architectural effect.	
1.3	The design should be visually stimulating and engaging.	
2.0	**Behavioural Criteria**	
2.1	The design should include a high level of interactivity.	
2.2	The system should be easily understood without explanation.	
2.3	The design should use and manipulate real world input.	
3.0	**Reflective Criteria**	
3.1	The design should communicate the intangible qualities of space.	
3.2	The design should be presented in a thought provoking nature.	
3.3	The design should enable performative architecture.	

Figure 1
Design Evaluation Criteria based on Donald Norman's Emotional Design categories

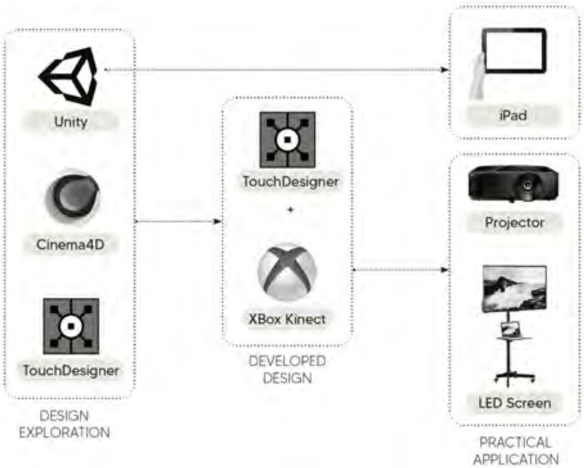


Figure 2
Workflow of Instruments employed

mented. The actual instruments can be summarised as:

Animation Software: Animation software is explored to aid the creation of visualizations which target the brain's visceral response. Cinema4D is the primary animation software used in design research. This program creates aesthetically pleasing animations that explore scale, weight and materiality.
Game Engine Software: Unity3D, a real time game engine software will be used to explore the spatial dynamics of the animations created. The Unity Augmented Reality toolkit is also used to explore the opportunities of augmented application design.
Visual Programming Software: Touch Designer is a visual programming tool which uses creative programming to manipulate real-time data into visual graphics. The software is used by a variety of creators to produce animations, interactive installations and multimedia content.
Input Sensor Devices: Microsoft's Xbox Kinect device is used to collect motion sensor data which is able to be manipulated in the visual programming software. The Kinect device is available in two versions, both of which have different capabilities. Version one and two have both been used in the design research.

Other input devices, such as microphones were used to collect and manipulate audio data.
Display Tools: Different display methods are important to explore as it will alter the overall experience of the design. Display tools that were tested include an iPad, large LED screens and data projectors.

To establish the techniques that could be aggregated to deliver the augmented space that the research needed to test, 10 mini-experiments were developed, that each contributed to achieving the nine research outcome targets mentioned above:

1. Movement and Impact
2. Virtual Impression
3. Order and Disorder
4. Fragmentation
5. Surface transformation
6. Weight and materiality
7. Surface Displacement
8. Movement and Impression
9. Sound and Reaction
10. Refelection

REACTIVE AUGMENTED SPACE

There is not enough space in this paper to show all of the more developed components that deliver

Figure 3
Displacement and Reaction

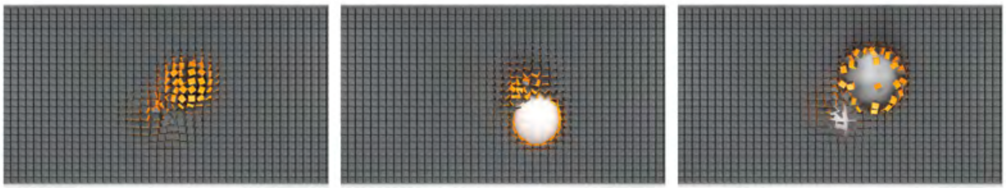
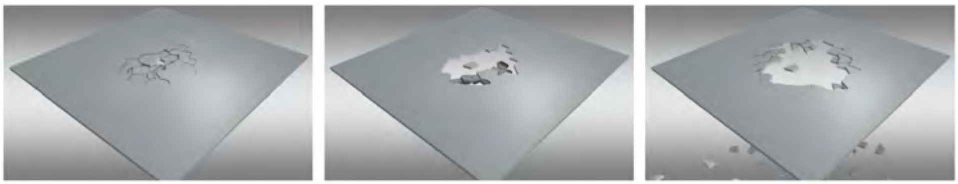


Figure 4
Voronoi Fracturing



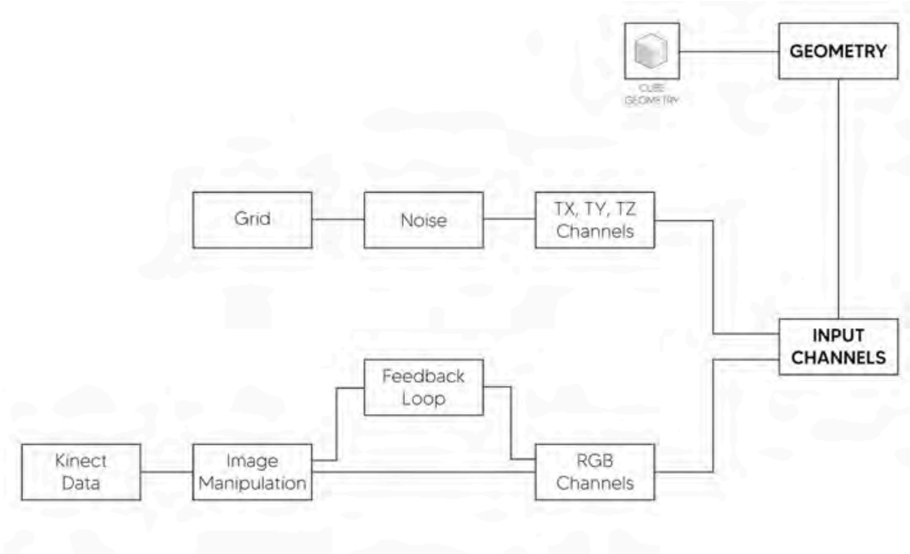


Figure 5
Body Displacer driving Network

aspects of the mini-experiments. More advanced and composite systems included Flow Emitter, Tube Instancing, Body Displacer, Hand Displacer, Body Tracking and Particle Systems. See figure 5 for an illustration of the body displays a technology network. More details on the ones not reported here, and later application of integrated systems can be found in Chan (2020). Here we focus on a particular set of performance interventions that contribute to the overall goals. Figure 5 shows the network of enabling elements that drive the system and Figure 6 shows a resulting digital visual trace response on the digital device (e.g. large digital screen).

The Body displacer is used here as an example of one of these integrated techniques that contributes to the whole project. In this exploration, Kinect data has been input to generate the RGB channels, thus reflecting the interaction in the physical environment. The tx, ty and tz co-ordinates are generated by a grid and noise displacement. The input channels affect the instanced cube geometry; as the user moves the display reflects their silhouette.

The colour input and feedback loop was the most useful successful element of this test. A feedback loop is a method in Touch Designer which creates a blur effect of the image, it effectively leaves a trace of the user's movement on the screen. In this exploration, the colour gradient and feedback are aligned. As the user moves their body leaves a trace on the screen which is represented through colour. The body's current position is represented in a blue tone and the previous positions are conveyed through purple tones (see Figure 6).

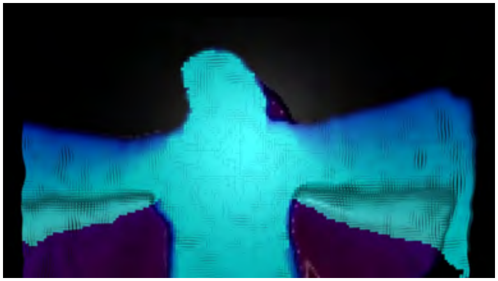


Figure 6
Resulting response when there is movement detected by the Network

Effectively the intention and the effect is that the user's body is leaving a digital trace on the virtual environment. This exploration introduces the concepts of time that is explored in Dan Graham's project, Previous Continuous Pasts (Francis and Peltzer, 2002).

Particle systems also proved to be a common fundamental core of the integrated systems. Our research development on these systems is summarised briefly here.

A Particle Node is used to create and control the parameters of a particle system simulation. Particle systems can be created in Touch Designer and can have effective aesthetic outcomes. Controllable parameters within the particle system include the number of particles, particle size, life period and mass. Forces such as wind and turbulence can be applied to displace and control the movement of the particles. The system input is composed of two parts; the geometry in which the particles are generated from and the geometry in which they are displaced by. The particles generator could be geometry such as a grid, a square or even a noise field. The displacer input is where Kinect data can be added so that the user can displace the movement of particles.

In the developed system a particle system has two inputs. The first being the geometry that generates the particles and the second being the geometry that displaces the particles.

This design development is initiated by the creation of a mechanism where the user produces the particles. The Kinect data is input into the system and is manipulated to form an outline of the user in three-dimensional world space. This outline forms the geometry which is input into the particle system as the particle generator. The animated digital image that the system land displays in response is identifiable as human form but not as a particular individual. So the person interacting to so anonymously.

The mechanism described above has multiple successful aspects. In practice the outline of the user does not appear instantly and the system captures the outline at timed intervals or when the user has been still for a certain amount of time. The individual's mark is becoming embedded into virtual space, with the visual record available for a short period of time. The particle system has external forces applied,

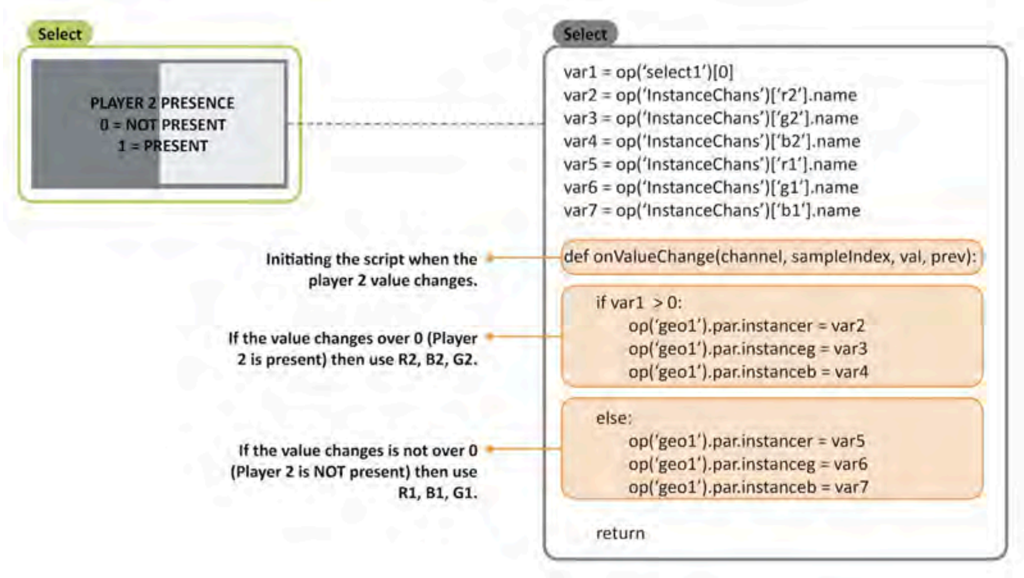


Figure 7
This shows the script structure that detects presence and responds to multiple persons being detected. The system then responds with colour changes as well as patterns of graphic response.

as time transgresses the remnants of the user's imprint slowly dissolves into digital space.

DENSITY

This development of the idea of 'density' is designed to reflect multiple human presence within the space. Density explores how the system can react when multiple users are present. Initially this development creates a relationship between the number of people to colour (see Figure 7). The code is developed so the simulating colour changes gradient depending on if there is one user present or two (see Figure 8)

Figure 8
Prototype response for multiple users

A script has been added in a similar method to the previous sound ripple development (see Figure 8). If the second player is present then the RGB parameters in the geometry node are changed to the second gradients RGB channels.

While this is a successful mechanism and visually represents a change in presence, the transition between colours is static and not conveyed in a poetic manner. Consequently this was regarded as only partially successful. So subsequently this was refined to deliver a more subtle transition has been taken, where user presence is translated to a change in saturation.

In this approach, as illustrated on the following page, the more users present, the brighter the installation becomes. Using the Kinect CHOP data, up to six people can be recognised which correlates to six different levels of brightness. There is a direct relation between presence and visual output. The wall is reacting to the human atmosphere within the space.

APPLICATION IN AN URBAN SETTING

The descriptions above show examples of how each of the components in delivering the overall system were put into place and evaluated. With the nine research goals that were described in Figure 1 met, the next task was to illustrate application in threshold spaces. One of the illustrations that we established was in the setting of the threshold to the building and the other an Urban threshold setting.

Urban activation is a topic which is well researched and explored. Unused urban spaces, such as alleyways, car parks or public parks, can encourage unwanted behaviour and compromise feelings of safety. These spaces often serve limited pragmatic purpose and lack a sense of place. In our case, this can be seen in the alleyway of Lukes Lane in Wellington CBD. The laneway it's rather anonymous and has no defining characteristic or programme; lack of lighting and sporadic occupation result in the space feeling unwelcoming and indistinct. The response to this takes its lead from the observations by Wessel and Sauda: "For such spaces to better engage people and take advantage of virtual and physical capabilities, they must be adaptive to the people in them, incorporating not just passive displays but also interactivity in a particular place as a form of socially-intelligent computing" (Wessel & Sauda, 2012).

There is therefore an opportunity to activate the laneway through the use of a digital interactive installation. The intervention sketched in Figure 9 proposes placing the interactive system within the alleyway using LED screens in the window of the adjacent building. The prototype intervention shown in Figure 10 can therefore be extended and applied at a larger scale in this location. The installation brings light to the space, enticing people to play and interact, resulting in the alley becoming populated with human activity. Through embedded digital media, the alleyway can become enlivened with social presence and light, increasing the sense of occupation.

Figure 9
Theshold location and disaggregated components of the augmented space

Figure 10
Augmented threshold space: working prototype in a building threshold

Figure 11
Augmented threshold space: Actual Urban threshold

The prototype installation for this space (see Figure 11) aims to stimulate and enliven the laneway, providing a public interface which can give the public "the ability to create and communicate meaning through their interaction with the system" (Wessel & Suada, 2012).

CONCLUDING COMMENTS

The potential for the application of digital media as a form of materiality was outlined as an opportunity and aim in the research intentions set out above. An effective digital system and physical application was explored and evaluated to test the research goals. The design research resulted in two interactive systems being developed that create visual representations in response to physical actions; as a building threshold intervention and one as an urban intervention.

The research goals were set by establishing the three core aspects of emotional response (Visceral, Behavioural, Reflective) that the urban intervention system was aimed at triggering. These responses were then turned into actual performance goals as a way of setting research targets; three for each emotional response. The research project as a whole therefore was structured as a set of cumulative and interacting experimental components. Once each component was achieved the next component could be added (and possibly previous elements refined or modified). Achieving the nine component elements was the research target that was met. Unfortunately this paper does not allow us to describe all of the interactive components and accomplishments. Response to sound was also a major component; this paper focusses on visual response.

The interactions are also recorded by the system, but body shape and movement outlines are recorded as pixellated or fragmented images that cannot be recognized. Consequently the system acts somewhat like layer of digital archaeology, recoding those who have passed and interacted with the space but recording them with anonymity preserved. So in a way the system becomes like a recorder of digital animated cave paintings, with an author who will always be anonymous.To the aspect of recording animation we have also added the recording of indistinct sound.

The creation of a digital interactive system to the set goals has provided proof of a concept that responds to criteria established by researchers such as Don Norman (2004) and reinforced by others over recent years. The practical outcomes show how in principle a real-world augmented space system, that respond to a range of research generated goals relating to positive emotional response, can be successfully implemented in built environment settings.

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