Designing digital and physical interactions for the Digital Public Space

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Abstract

Over the course of the last decade there has been a perceivable shift in the way interactions occur with digital systems with a clear preference towards touchscreen based interactions. This move can be attributed in part to the Apple's iPhone, first introduced in 2007, and whilst not the first touchscreen product, it was the first to lead to widespread adoption and use. This thesis seeks to develop new design interaction methods that recognise that we are moving away from a dominance of digital interactions with screens to one where interactions are supported by everyday things. These devices allow greater perspectives to be gained than when purely interacting by touchscreen. This is presented as an exploration of interaction methods surrounding intermediary objects that are both physical and digital in nature - phygital.

Affordances are an important part of how people interact with devices in their everyday life; it is these affordances that let us understand how to use things around us. Affordances are also present in the digital world and are an important part of how the work presented in this thesis analysed the design of the phygital objects and interactions they enabled. This thesis draws on six case studies from a diverse range of projects undertaken as part of The Creative Exchange research project. Beginning with an exploration of current touchscreen interaction methods then moving towards identifying and suggesting new interaction models. Throughout this research, key ideas will be extracted, rationalised and presented individually for each Creative Exchange project, in such a way that allows conclusions to be drawn about physical and digital interactions in the Digital Public Space.

Finally, this body of work concludes with a design manifesto which, provides a route away from strict screen interactions to one where more physical Natural User Interfaces that interact with the world. The manifesto will also serve prospective phygital interaction designers in the production of new interactions by identifying key findings such as matching affordances to the phygital objects.

Declaration

I declare that, other than where the contribution of others is specified in the list below, that this thesis is entirely my own work and has not been submitted for the award of any other degree, either at Lancaster University or elsewhere.

Daniel Burnett

Chapters 4, 6, 7, 8, 9 and 10 have sections that have been presented as research papers or chapters in books in earlier forms. As detailed below. The order of the authors represents the contributions of the authors.

Chapter 4: Interaction

This chapter includes excerpts that have been adapted and expanded from

Coulton, P; Burnett, D; Gradinar, A; Gullick, D; Murphy, E. Game design in an Internet of Things. ToDIGRA, Vol. 1, No. 3, 11.11.2014.

This paper is available in its original form here:

http://todigra.org/index.php/todigra/article/view/19

Chapter 6: Physical Objects with Digital Attributes

This chapter includes excerpts that have been adapted and expanded from

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Chapter 7: Physical Actions representing physical/virtual presence

This chapter includes excerpts that have been adapted and expanded from

Lochrie, M; Burnett, D; Coulton, P: Using NFC Check-ins to Crowd Curate Music Preferences. Proceedings of 5th International Workshop on Near Field Communication

Available in its original form here:

http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6482442

And

Burnett, D; Lochrie, M; Coulton, P: "CheckinDJ" using check-ins to crowdsource music preferences. MindTrek '12 Proceeding of the 16th International Academic MindTrek Conference. New York: ACM, p. 51-54.

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Chapter 8: Physical representing Digital

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Chapter 9: Digital/Physical representing Physical/Digital

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Burnett, D; Coulton, P; Murphy, E; Race, N. Designing Mobile Augmented Reality interfaces for locative games and playful experiences. Proceedings of Digital Games Research Conference 2014. Digital Games Research Association – DiGRA 2014.

This paper is available in its original form here:

http://www.research.lancs.ac.uk/portal/services/downloadRegister/60738086/DiGRA_Scarecrows_Full_paper.pdf

And

Coulton, P., Race, N. & Burnett, D. Scarecrows, robots and time machines. DE 2013: Open Digital

This paper is available in its original form here:

http://www.research.lancs.ac.uk/portal/services/downloadRegister/43417193/Scarecrows_Robots_and_Time_Machines.doc

Chapter 10: Digital representing Physical

This chapter includes excerpts that have been adapted and expanded from Coulton, P; Jacobs, R; Burnett, D; Gradinar, A; Watkins, M; Howarth, C. Designing data driven persuasive games to address wicked problems such as climate change. AcademicMindTrek '14 Proceedings of the 18th International Academic MindTrek Conference: Media Business, Management, Content & Services. New York: ACM, p. 185-191

This paper is available in its original form here:
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3. Introduction

The work in this thesis is primarily built upon three projects developed as part of the AHRC funded Knowledge Exchange Hub, The Creative Exchange[1] (CX) and three independent research projects. CX is a collective effort between Lancaster University, The Royal College of Art and Newcastle University, to work on improving collaboration between the creative industry and academics. A further remit was to develop a new form of PhD to help cultivate academics more attuned to working with the creative industries. In total 21 students were recruited and this thesis represents one students experience of this new PhD program. The purpose of this work is to produce a design manifesto that will guide the future creation of Phygital interactions.

The central theme linking all six projects described in this thesis considers the design of Physical/Digital or 'Phygital' interactions within the Digital Public Space (DPS). The Digital Public Space is a term coined by the BBC's Tony Ageh in 2010 (Ageh, 2010) to refer to the archived content held by groups or institutions to be made publically available for use for free and non-commercial purposes. Since then, this definition has been investigated with each researcher within CX looking at it from their own perspective, and in the case of this research the focus has been the creation of interactions that help enable the public's access to this data. In particular, this research seeks to develop new design interaction methods that recognise that we are moving away from a dominance of digital interactions with screens to one where interactions are supported by everyday things, Phygital interactions. The term Phygital here is used to emphasise "that these are not simply devices with some embedded digital functionality, but are actually connected devices whose functionality and operation is designed to exist simultaneously in both digital and physical space" (Coulton, et al., 2014). The research will consider digital and physical interactions as a spectrum along with direct and indirect to

[1] http://www.thecreativeexchange.org

create a map of these interactions, as it is often easier for people without intimate knowledge about a specific subject (Plaisant, 2004) to understand that dataset through a more interactive, curated and connected experience. Promoted through concepts such as Ubiquitous Computing (Weiser, 1993) or the Internet of Things (IoT) which have arguably personified the notion of phygital. It is through this lens that a design manifesto will be created, intended to help individuals to focus future design efforts for phygital interactions.

3.1. The Creative Exchange

The CX programme has funded forty-nine different projects over the course of its four-year lifetime from 2012 to 2016. Each CX Project brought together academics and creative industry stakeholders to work collaboratively. Each CX Project was developed for CX through one of three ways;

- A CX lab, where academics and those working in the creative industries came together and developed ideas based on a topic. The 'starter' topics were developed by an initial CX consultation with the creative industries. The ideas were then explored through generative processes using a selection of different prototyping methods.
- The Creative Lounge, which was a more informal process where people were brought together with differing skill sets and are allowed to free form ideas based upon any topic they felt related the Digital Public Space.
- Companies could also come to CX with an idea or area of interest and if applicable CX facilitated interaction with an academics also interested in the area.

The next step in creating a CX Project was to produce a project proposal that detailed: the outline of the aims for project and what might be achieved; who were the partners on the project; if applicable what outside expertise was be required; and finally what skills the partners collectively brought along. This step allowed the CX management board to assess the project and decide as to its viability against the criteria of: Value for money, Novelty, Innovation, Relevance, Potential impact and Feasibility.

If a CX Project successfully gained approval from the board, it then proceeded to the next stage where a form contract was signed by the partners in which they agreed upon the process of the project, how the funding will be spent, and how IP will be dealt with. Typically, the IP of the project belongs to the project proposers and not CX although Creative Commons options was suggested as the preferred option to allow others to expand upon the research.

The timeline of a CX Project up until this point was approximately three months, and it is from this point that the actual project itself could now begin. Running for approximately three to six months, each project has a different timeline but they all begin with a Kick-Off meeting, where all project partners came together to agree the process and goals of the project and to assign individual responsibilities. At the end of this meeting the project has officially begun and with several meetings scheduled to track progress everyone can proceed along their intended journeys.

The completion of any CX Project was marked by the completion of another document asking all involved to collate the successes and any failures that have come from the project along with what it meant to their on-going business/practice once the project has ended. These responses were pooled and, in some cases, exit interviews were conducted to help to realise the value of the knowledge exchange that had occurred over the course of the project.

The Creative Exchange's main aim was the production of a new style of PhD and this thesis is a product of this aim. The new style of PhD gives the opportunity for the student to work with industry partners on their projects. This means that while the students are involved in the process of designing the project but not the original idea, the main aims of the project are decided upon by the industry partner and lead academic. Differing from the typical style of doctoral research wherein the student leads the research in their chosen direction. This is the reason why this thesis is driven by a collection of diverse projects, these projects are further discussed in chapters 8, 10 and 11.

As the projects origins are with the SMEs, it is for the PhD students to find areas of the projects that fit with their research question. In the case of this thesis, looking at the interactions and the design of the objects is key. Whereas for the project these may have been merely incidental in the pursuit of an overall final output. It is worth noting that at the start of each project all parties were encouraged to articulate what outputs would be their priority to ensure projects addressed all expectations

The thesis is structured such that each project, CX or not is contained within its own chapter, in the next chapter background on what is meant by interactions will be discussed followed by a chapter explaining the methodology which the thesis and associated research projects will adhere to. Starting with Chapter 6 the individual Projects will be examined towards answering the Research Question posed by this thesis namely how to Design digital and physical interactions for the Digital Public Space.

4. Interaction

4.1. Background

With the plethora of new devices emerging which are increasingly connected to the digital world means people are interacting more and more through both digital and physical interfaces. This trend is arguably being driven by notions such as Ubiquitous Computing (Weiser, 1993) and The Internet of Things (Council, 2008). It is the contention of this thesis that much more design consideration needs to be given towards the experience of users when interacting these devices (Burnett, et al., 2012). In the following chapters a range of projects will be considered that address a range of different physical/digital interactions applicable to the central notion of the research project which is the Digital Public Space (DPS) that go beyond current interactions where the finger-touchscreen is arguably the primary method of input. Because of the nature of the individual CX Projects, each of the subsequent data chapters effectively stand alone in relation to the associated theory and research methods, before overall reflections are provided at the end of the thesis. However, in the following sections I will give the grounding to the arguments presented in these later chapters to provide an understanding of the central issues that drove this research.

4.2. Interactions

In terms of general interaction design there are many ways that it has been presented but in this thesis the sketch by Bill Verplank, recreated in Figure 1 (Verplank, 2009) will be used as the basis for discussion.

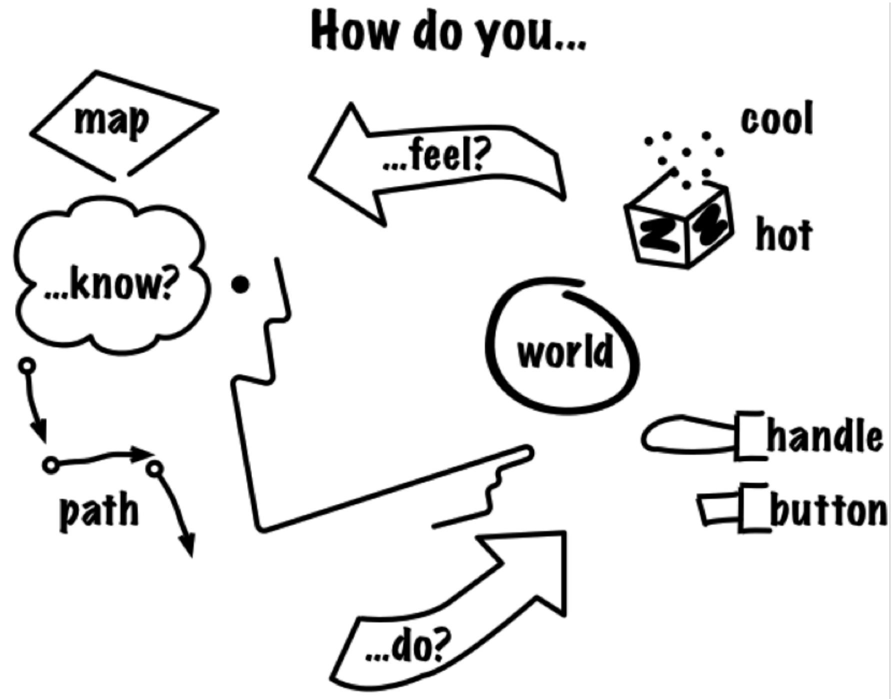

Figure 1: Interaction Design as defined by Verplank

Verplank frames interaction design as a designer answering the three questions: How do you do? How do you feel? How do you know? (Verplank, 2009). Starting with 'doing', Verplank distils this to a consideration of whether the interaction is continuous or discrete (represented by the handle and button respectively in the sketch) and while both of these are applicable, and available, in the design of phygital interactions this must be extended to also consider that they are likely to be implemented as a combination of real or virtual interactions. Designers must therefore, consider carefully how such interactions are used and combined so that it 'makes sense' to the player.

In terms of how the user 'feels', while he considers this in relation to users' physical senses Verplank presents it in relation to the medium through which the interaction is presented to the user. This draws upon the work of Marshal McLuhan and his definition of media as "any technology that ... creates extensions of the human body and senses" (McLuhan, et al., 1996). McLuhan categorized media in terms of 'hot' and 'cool', whereby a hot medium, such as print, is one that dominates one particular sense absorbing our attention and leaving little room for participation, while a cool media (sometimes described as fuzzy) that engages across our senses leaves space for participation (McLuhan, et al., 1967). When McLuhan wrote this original definition, he considered television as a cool medium although nowadays it would more likely be considered towards the hot end of the spectrum when compared to games. This illustrates that the hot and cold definitions are, as McLuhan intended, not static but dynamic concepts. Arguably the Internet doesn't really fit into McLuhan's definition as it both encourages participation but it also commands our attention and often dominates our senses. As the phygital interactions under consideration would be expected to expand the interaction across the users' senses they are likely to appear at the cool end of the spectrum. In relation to the overall design of phygital interactions, cool features are likely to attract and engage whereas hot features can be used to provide very specific activities, such as help, and designers would normally be expected to consider a combination of these within their design. For example, an interactive character toy could be used to voice the hints and tips of a game, specific combinations of interactions with the toy could unlock special powers, or using the toy in a certain physical location might unlock special locations within the game.

The final question of 'how we know' is illustrated by Verplank as paths and maps and he argues that often the best overall interaction design utilizes a combination of both (Verplank, 2009). This categorization is derived from Kevin Lynch's work in his 1960 book, *'The Image of the City'*, which studied how people developed an understanding of the layout of a city. Paths are primarily step–by- step instructions that guide the user through an interaction and it is generally regarded as the easiest form of interaction as the user only needs to know one step at a time (path knowledge). Paths are commonly used in situations that require immediate action by users who are likely to be experiencing the required interaction for the first time (i.e. emergency door release) or in game tutorials. Maps essentially represent knowledge obtained through the interface affordances that help users construct coherent mental models from which new tasks and uses can be inferred. The knowledge maps build on affordances through the interactions performed by the users in multiple scenarios using objects and systems that provide similar interactions. Thus, the interaction design of phygital interactions requires designers to not only fully understand the virtual aspects the affordances they are perhaps used to, but also to extend these to include the affordances that are associated with physical objects to ensure their overall design does not cause confusion for the user. It is therefore important to consider the concept of affordance in more detail and will do so in the following section.

4.3. Affordances

Throughout this body of work, much will be discussed about the affordance, both physical and their virtual counterparts. Affordance is a concept brought about by Gibson (Gibson, 1977) and is a way to describe the way objects values and meanings can be related to how people see them. His work was later furthered by Norman (Norman, 1999) who looked into the way affordances can be grouped into either real or perceived affordances providing a method that could also be used to distinguish the properties of real and virtual objects. When designing real objects, designers have control over both real and perceived affordances whereas when dealing with virtual objects on displays there is really only the perceived affordance available to the designer as the physical affordance is typically prescribed by the computer system itself (Norman, 1999). As much of what was built in the pursuit of completing the projects is a mixture of both physical artefacts and virtual applications taking this information into account while designing the interactions is critical to the creation something that will be understandable to the potential users.

4.4. Internet of Things

IoT devices are objects that are connected to the Internet and perform some form of function such as being readable, recognizable, locatable, addressable and or controllable via the Internet (Council, 2008). These devices provide a unique method of interacting with the digital world through physical objects. Perhaps a perfect example of this is the Philips HUE lights, these lights are configurable via an app on a mobile device or through an Application Programming Interface (API) that can be programmed to perform functions based on several different events, either remotely from the Internet or locally controlled by some configured action. For example, one of the projects discussed allows these lights to be controlled in response to a broadcast programme. The system created allows users or broadcasters to set certain colours to apply to specific people or characters on screen, creating a curated real world environment that complements the story of the programme.

There has also been an increase in devices that are connected to the internet, for example the Nest thermostat and the iKettle, that provide both physical and digital interaction to the user to perform their basic functionality. However, many of the aspects of their additional activity is opaque to the user as these devices also gather every piece of information they can from arrays of sensors built within them and relay this to some central repository. These devices through their prevalence enable algorithms to predict patterns in our behaviour and adapt to our lifestyles. After a week of ‘training the Nest thermostat learns when you are active and when you need your heating to be on in order to get to your preferred temperature. These devices as thus promoted, not only simplify our routines, but offer the additional benefits of improved efficiency and, therefore, cost savings.

There are also devices such as the Chromecast or the Kindle FireTV that allow the streaming of media from phones or computers from anywhere. This part of the internet of things also learns our behaviours but primarily through the content that is browsed through or played.

Many IoT devices start their development through the application of rapid-prototyping hardware. These technologies were principally developed for the maker or ‘hacker’ community that embraced products such as the Arduino, or the RaspberryPi to create cheap and small devices that can be embedded in spaces where a typical computers’ power and size would be overkill. The Arduino uses a very simple micro-controller to run programs that can interact with different sensors, such as temperature, humidity, light, proximity and Near Field Communication (NFC) technology. This gives a wide range of potential interactions that can be moulded to suit the situation but the Arduino is hampered by its slow processing speed and lack of threaded processes. The RaspberryPi created by the RaspberryPi Foundation overcame some of these limitations by creating a credit card sized computer that is much faster and capable of using monitors and speakers to create a more computer like experience. These 'hacking' technologies are used to great extent within the projects discussed later and thus there are strong associations with the internet of things.

4.5. Phygital Objects

Whilst IoT principally prioritises data collected from the object this research is more concerned with interacting with the objects themselves and therefore the term Phygital objects is used to consider objects that support interaction not only in the physical but also in the digital space. This new generation of objects again allows for interesting interactions to be designed to augment the way people experience the DPS. These objects bridge the physical and digital affordances and so as previously discussed when designing both must be considered and crafted to create a suitable user experience.

Another consideration to keep in mind while designing these objects is the idea of 'cultural conventions' (Norman, 1999), which suggests that users' conventional interpretations of how they interact with an object should be taken into account. These conventions were split by Norman into three distinct areas; logical, physical and cultural constraints. Logical constraints are informed by the way users expect these interactions to proceed. Such as in the video game Rockband[2] users can deduce that the "Guitar" controller is used in much the same way an actual guitar is played. Physical constraints link to the actual object and its limitations such as in Skylanders[3] where the Portal which is an NFC reader, can only

[2] http://www.rockband4.com/

[3] https://www.skylanders.com/uk/en

detect tags within a range of centimetres. And finally, cultural constraints are those that are shared by a cultural group for example in a micro culture the myriad of rules different families have referring to the use of Free parking in the game of Monopoly each has their own rule. (Coulton, et al., 2014).

The interaction in Rockband with the guitar is a form of Mimetic interfaces as coined by Jesper Juul (Juul, 2009), such interactions require that users perform actions similar to those of the actual physical interaction one would actually perform. Thereby making it obvious the way in which the device is to be used. These mimetic interfaces have a lot in common with Natural User Interactions (NUI) defined by Wigdor and Wixon (Wigdor & Wixon, 2011) as "natural refers to the user's behaviour and feeling during the experience rather than being the product of some organic process" and while they suggest that these NUIs should not be mimetic it has been suggested (Burnett, et al., 2012) that they be a subset of NUI. These interfaces can be a simple way of putting users at ease by providing a familiar interaction that they can identify, however producing something that has the same physical characteristics but completely different interactions could dissuade the user from using the device or object and so care must be taken when designing familiar objects for people to interact with.

The design of any phygital object therefore must follow a myriad of ideas from multiple disciplines to ensure that users feel secure in their operation of the object. As designing these objects is the primary focus of this thesis these considerations must be taken into account to produce an artefact that people will be willing to use and understand the interaction method without requiring an instruction booklet to deduce. These ideas will then be collated at the end for the creation of a Design Manifesto.

Phygital objects present a new area of design research, one where objects can contain sensors or be used to convey information in subtle or novel ways. These objects unlike IoT devices need not be Internet connected and so have uses in places where the Internet doesn't currently reach. These Phygital objects bridge the gap between the Digital and the Physical, allowing people to interact not simply through the use of a finger on a touch screen but instead through a much wider range of interactions which address a wider range of human senses. This opens up new avenues for designers to look into when first designing an object or space, these Phygital objects will allow users to interact with the Physical and Digital worlds in ways they never have been able to before.

With new design options also come new design challenges and Phygital objects are no different in this respect. While these devices open doors that are new to the world they are also new to designers, who must learn a new skillset in deciding when the use of a Phygital object could help their design rather than hinder it. Along with the physical design of the object there is also the underlying architecture that must be understood to produce a working Phygital. As these objects rely upon digital infrastrucutres a commensurate amount of knowledge of electronics and programming will also be required. However, these skills will not be new to the next generation of designers, while we have seen the rise of the Arduino and Makerspaces this generation will learn from an early age how these technologies work and will be instrumental in the design of future Phygital objects. Along with the object itself, issues will need to be addressed with the interaction choices that are enabled with said object. As mentioned previously while there is scope for disrupting common interaction methods, confusing people from the outset is unlikely to lead to a well understood and utilised Phygital object.

The design manifesto discussed earlier will be used by this and the next generation of designers when looking at the world and how to create these new interactions. This manifesto will lay the groundwork from which they can expand upon and form their own unique methods and ideas of design and creation. They are intended to provide a frame that challenges them to go beyond preconceived notions of what is 'good' product design or 'good' interface design to see how these areas can be combined in new and interesting ways.

4.6. Related Research

Because of the operation of the CX PhD and particular nature of each project that was undertaken the related research is included within the chapters associated with each project. This is intended to provide clarity for the reader in that the relevant related research is associated directly with the project to which it applies and also because as the forthcoming methodology will describe the research was performed through emergent iterative cycles of creation and reflection. This means that the understanding of what was the relevant research was developed as part of the practice.

5. Methodology

5.1. Introduction

The CX approach suggests that each CX Project forms its own case study for research into a particular area but that the overall outcomes contribute to an understanding of to the CX's primary focus; "Digital Public Space (DPS): Anyone, anywhere, anytime can access explore and create with digital content". Using this as a starting point the main aim is to produce a design manifesto that could be used by researchers and designers in the future to aid in the design of Phygital devices for use in the DPS. The methodology described in this chapter emerged in response to goals and operation of CX and provides an understanding how the researcher approached the specific projects and ultimately the creation of such a manifesto.

5.2. Big and Little R

The research conducted, is primarily focussed within the sphere of design research in the context of the Arts and Humanities. It is therefore important to understand how research using design can be applied to generate rigorous knowledge outputs.

While design research can take many forms, Frayling attempted to provide some clarity in his 1993 paper (Frayling, 1993) in which he discussed the difference between the "Big R" and "Little R" and went on to split design research into three distinct areas; *"Research through art and design", "Research into art and design"* and *"Research for art and design".*

Frayling expands upon his notions "Big R" and "Little R", however the origin of his definitions drew from the Oxford English Dictionary and in the way the word 'research' was used. In his original definitions "Big R" refers to research where the knowledge generated is new to the field of study, and "Little R" refers to the act of searching for existing knowledge/things.

By applying these three distinct areas Frayling came to a point where they each took on their own meanings;

- Research for Art and Design: Where the end product is the final artefact, where any learning or knowledge gained is contained within that artefact.
- Research through Art and Design: Where a rigorous method is applied to test and create something, this can be shown through action research where the research diary and the accompanying report both help to communicate the results of the work. The end product in this case is not just the artefact as in Research for Art and Design but the knowledge base that sits beside it in an accessible form that allows others to follow.
- Research into Art and Design: Looking at the history or the theory behind topics within Art and Design. The end product here is the analysis of the topics researched and how it can be applied/used to understand what has come before it.

Following Fraylings' work several other researchers have described and iterated upon Research through Design in an attempt to improve or to further specify the areas in which the methodology can apply. Under names such as "Project Grounded Research", where Findeli (Findeli, 1999) swaps the meaning from Fraylings "*for"* and "*through". Or* "Research Oriented Design" where Fallman (Fallman, 2007) makes the distinction between Design-Oriented Research and Research-Oriented Design where these are "Research for Art and Design" and "Research through Art and Design" respectively, though Fallman did not cite Frayling in his paper the descriptions match quite succinctly.

After considering these contributions and others (Zimmerman, et al., 2007) (Gaver, 2012) a conclusion was reached that while each may add some particular nuance to the descriptions that Frayling first coined they do not however substantively alter what he originally wrote. Therefore, in this thesis it will be Fraylings' original definition of Research through Design that should be considered in relation to the CX projects.

Using an example, that will be expanded upon later in this thesis in Chapter 10, the Project “Cold Sun” was a collaborative effort between Lancaster University, Mudlark (A Game-Interaction company) and Anglia Ruskin University, intended to provide a way to address Climate change in a way that people could relate to through the use of a branching storyline and the inclusion of real world weather within the game world.

The “Big R” in this project was the approach taken to designing the game and the way in which the eventual testers responded to the output which corresponds to the definition of Research through Design. Thus for the “Big R” the game artefact itself was not overly important except as an example of the design process. That being said the game was completed to a much higher standard than might be expected from a typical academic research prototype. While showing high quality visuals and graphics to the players helped with immersion it was not necessary to go to such lengths to evaluate the design premise. The reason the game came to such a fully realised state was that from the Project Partner Mudlark perspective it needed to be of a quality to be used as a showcase of their capabilities to future clients. This aspect of development was thus “Little R”, and by taking the existing knowledge of game design and applying it, it was possible to create a realised game that could be presented to the wider public.

In and of itself Research through Design is not enough to provide a working methodology for the research that has been produced. If all projects were conducted in the same manner, then perhaps it would suffice. However, the outputs and the methods used to achieve them vary wildly from project to project so it also useful to consider the notion of applying a Grounded Approach.

5.3. Grounded Approach

A Grounded Approach comes from Grounded theory which is a methodology in which the theory comes as a result of the research and not as a precursor to it. “Theory evolves during actual research, and it does this through continuous interplay between analysis and data collection.” (Strauss & Corbin, 1990). In the case of this thesis it is the way in which the projects are approached is “Grounded” in that their focus was explorative research rather than to answer specific questions.

Though ideally in grounded research the researcher should come to the research with a blank state of mind however, in practice this is impractical. By starting with a loose overarching theory or a general idea of what the theory should be a set of experiments can be formulated to test this theory and garner results which can be used to further refine the research question and come to a logical conclusion point.

Typically Grounded theory progresses through several stages before coming to its conclusion; first is the collection of data, while at the same time writing notes about the data collection process. After this comes the coding phase where the data is grouped into areas of similar themes, these are then compared with a focus on the data and become more abstract with the categories changing to handle the newly included codes, the categories are now refined and integrated into the emerging core. The theory then comes from this core and is described by its scope and modifiability. Finally the writing up stage, this is where the theory is put into practice and the writer must convey its use to the reader (Heath & Cowley, 2004).

An alternative method to this is provided by Strauss and Corbin, (Strauss & Corbin, 1990) where they suggest that an initial open coding of the data through an analytical technique, followed by Axial coding, where the categories are combined down into clusters, these categories are then further developed through the coding and the identification of a core category until a theory is fully described (Birks & Mills, 2011).

While it is preferential and it is strived towards that any researcher bias is left behind before starting a study, there is no way to guarantee this and so it can be hard to determine the validity of any work actually performed due to this. Though sometimes the researchers own bias or subjectivity may bring about good insights it is still preferable to have checks in the research method where the researcher needs to examine the theories that are being pulled from the data and confirm that it is not just their own bias that is bringing them to these conclusions (Gasson, 2003).

Using Grounded Theory as inspiration, a grounded approach suggests the researcher obtains detailed data from the project and the experiences of the those involved to reflect upon the overall aims of CX.

A grounded approach on its own however is not enough to produce the outputs that are required by CX although it does allow the researcher to reflect upon their own position within the research process. To reflect on the actuality of CX a more iterative process is required where upon changes to individual parts of projects can be tweaked and then measured to determine the best possible outcome. This is what the following discussion of Action Research seeks to provide.

5.4. Action Research

Research in academia can often seem to be seen as out of touch with the real world, therefore Action Research proposes that research theories should be put into practice in real situations to see if they still hold water outside of a lab environment. (Avison, et al., 1999) . Action Research as defined by (Cohen & Manion, 1994) as "a small-scale intervention in the functioning of the real world and a close examination of the effects of such an intervention". In other words, if the research doesn't stand when put into practice in these real world solutions the theory is modified to take on the new ideas and the process begins again. The entire process can keep on with these iterations ad-infinitum in order to apply the research to a wider range of situations.

Action research is all about the improvement of practices or artefacts, and is performed in a field where the researcher is an 'insider' (McNiff & Whitehead, 2011), typically action research is based around questions about how the researcher can help or what they can change. These questions are applied to what the researcher already knows about that area and includes themselves as one of the participants in the study, as opposed to 'outsider' questions which are where the researcher removes themselves from the group and puts the question to that group.

The main use case of Action Research is to identify an area of improvement, come up with a potential solution trial this solution and then use responses and observations to improve upon the solution and trial it again. Repeating this until you have a workable solution.

Action research has many advantages, primarily that it involves looking at real people in real situations, the results of which can be immediately noted and acted upon allowing the theory to evolve naturally as the research progresses fitting with the grounded approach. The quick turnaround from this methodology would help significantly with projects in CX owing to the fact that when working with companies that expect quick results and fast prototypes this system will allow for that.

There is no required equipment or knowledge needed in order to perform experiments based in Action Research, just the wish to be involved and take the work further. This obviously reduces costs and training time required to bring researchers up to speed with the current state of affairs within a given field of research and so allows for much longer to be spent planning and devising ways to improve upon the current situation.

Yet another advantage is that the researcher typically has a vested interest in the research not purely from a research point of view but actually wants to improve things for both themselves and others like them, this means that researchers will typically have more insight into the area than is usual as they are participants as well as the conductors of the research. While this can contradict the typical Grounded Theory approach where a researcher would come to a project without any biases, this is why checks are used as previously discussed to confirm it is not these biases that is leading to the conclusions drawn.

A disadvantage to Action Research is that it cannot be used to perform comparative tests or to show cause and effect relationships (McNiff & Whitehead, 2011). Meaning that through the use of this method it would not be possible to draw a comparison of which product better suited the needs of the user as it is constantly iterated upon. Instead two stages of action research would be produced with the second based heavily on what was learned from the first and then perform the comparison upon the two separate outputs.

Also with the researcher being so deeply ingrained in the research question and group it may be hard for the researcher be objective about the situation. However, as the researcher in this methodology does not exist in a vacuum and in fact has fellow researchers all with their own aims and objectives, it is plausible that the outputs will not favour one researcher too heavily.

Through this consideration of Action Research, it is easy to see that it is tightly entwined with the CX process even before the projects have begun, in the way in which the project proposals are quickly iterated upon by the group to achieve a workable proposal for the research project.

5.5. Agile Software Development

Through all of the projects described within there is at least one common feature shared across all of them, that is the software that is used on/in each of the artefacts. Developing the software to run on each of these artefacts was essential to their operation and their eventual success, so it was crucial to the project and its partners that they have access to the software as quickly as possible. This is where the mantra of Agile Software Development comes into play. What began with just seventeen people in 2001 has spread to an entire movement of software development.

Agile development came from a group of developers that found issue with the current de facto method applied to software development, the Waterfall method.

The principles behind the Waterfall method are best described through use of a diagram see Figure 2.

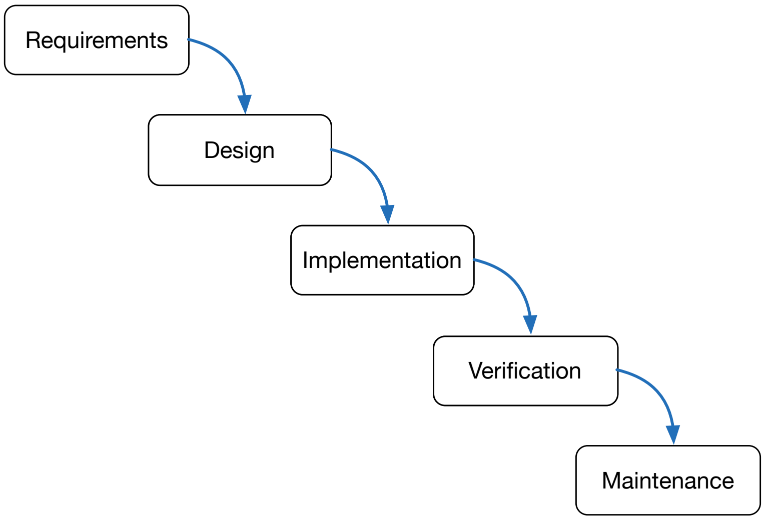

Figure 2: Waterfall Programming Diagram

This is a very prescriptive method that requires the developers to take each step in turn and only progress to the next step after completion of the previous steps. With a known specific outcome this method can ensure that due care and attention is applied at each stage so that the final piece of software is fit for purpose. However, this linear structure limits the rate at which developers can innovate and test their new ideas or strategies as there is no specified place for self-reflection or a point at which to reassess the current requirements and if what is being built is fit for purpose. This is where the Agile method comes in.

The Agile movement encompasses twelve[4] separate ideals that should be followed when working with clients or partners for the betterment of the software that is produced. They can be summarised thusly:

- Work with the client/partner daily
- Deliver working software early and often
- Reflect and then iterate on the project often

[4] http://www.agilemanifesto.org/principles.html

To further show the development cycle for the Agile method, the below image shows that where the traditional waterfall method lacks the opportunity to reflect and change with changing requirements or technologies, the Agile method takes this in stride and in fact encourages frequent cycles of reflection and iteration.

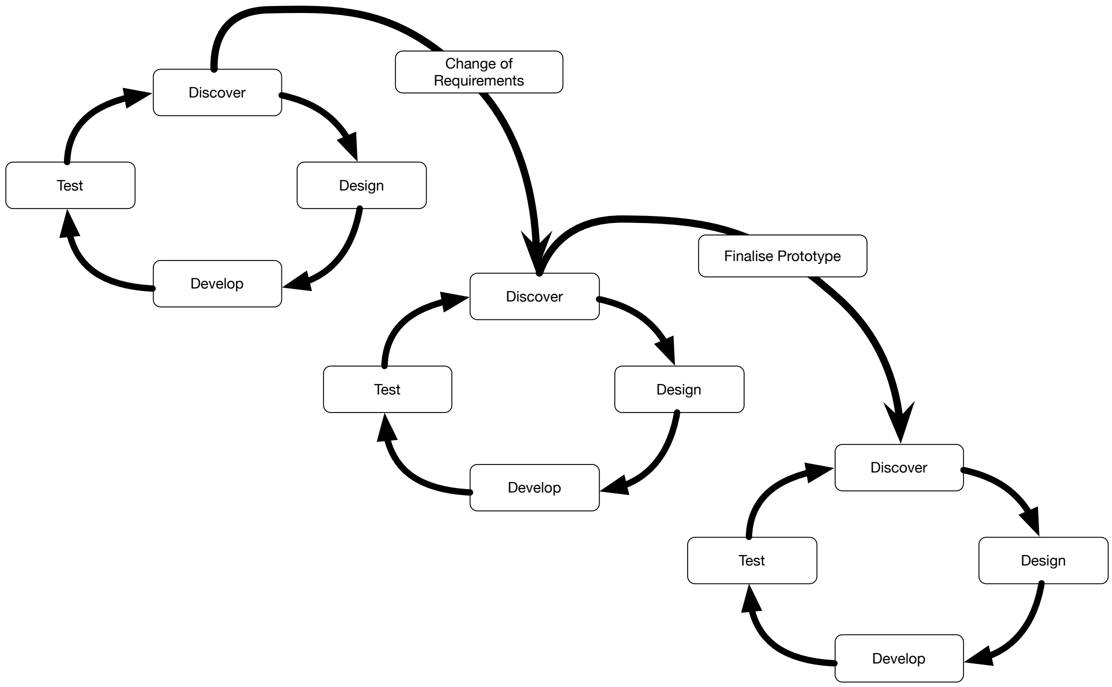

Figure 3: Agile Development Cycle

Using the same project as before for an example, Cold Sun, while working with Mudlark in order to show progress with the development of the game the Agile Methodology was followed. This happened in several ways, primarily by keeping in daily contact by using the Basecamp[5] tool. This allowed for immediate feedback anytime a new software update was released, along with the sharing of documents and the tracking of outcomes. As a tool it was invaluable in evaluating each step and working towards the final product.

[5] http://basecamp.com

5.6. Summary

The major form of research presented within this thesis will be Research through Design, with perspectives derived from Grounded Theory, Action Research, and Agile Development. This allows the research to act within the complexity of doing a PhD within the context of CX. Such Creative Design practices have recently become a consideration of Computer Science conferences (Gaver, n.d.) and has sparked a conversation about how this form of research can be transformed to give the field more rigor. But as Gaver points out, this could have a negative effect causing the field to become less agile and less creative. By allowing the artefact to develop as an outcome of the research and by noting the perspectives of the previously described methodologies meant it was possible to begin projects without specific research question pre-formed and simply work with the partner organisation for the betterment of the final output. Whilst such an approach had its drawbacks in that there was no guaranteed turnaround time for the research to reach a salient point. However, as each project has a finite resource pool and there is always another project in the pipeline they inevitably built on each other to help form the overall design manifesto.

5.7. Conclusion

From what has been discussed, the methodology that was followed while performing the Research through Design in each project could be considered a child of both Action Research, Grounded Theory, and Agile Development. It moves along a reflective trajectory of, initial proposal, first prototype, revisions, second prototype, revisions and so forth until such a point where the project artefacts satisfy not only the researcher but the other stakeholders. A illustrative example of which can be seen in Figure 4.. Using this approach creates the opportunity to use rapid prototyping and agile programming to quickly build multiple iterations in order to test and query the produced artefacts.

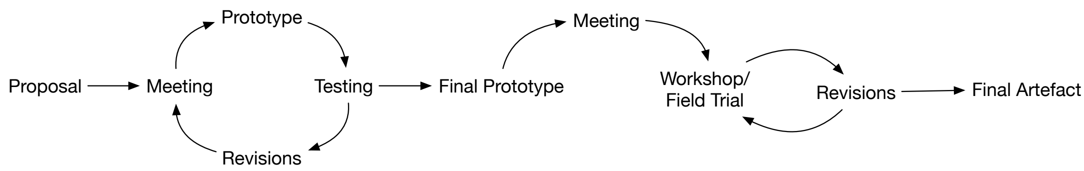

Figure 4: Methodological Approach

While the overall methodology for the thesis will remains the same, the methods applied to each individual project will vary due to the very nature that they are all different and require individual approaches. Thus particular methods are detailed in the relevant chapters. Before starting this exploration into specific CX projects a scoping project is presented that provided some of the initial understandings design of physical/digital interactions that influenced the researcher in those later performed under the auspices of CX.

6. Physical Objects with Digital Attributes

6.1. Introduction

Whilst the project presented within this chapter was conducted prior to The Creative Exchange projects being initiated, it has important implications for the way in which the rest of the research was approached and therefore should be considered as an influence on the subsequent projects.

This research was concerned with the creation of physical game pieces that could be used for games running on commercial capacitive touch screen tablets. As such the game pieces can be considered a form of Tangible User Interface (TUI). TUIs can be defined as providing a physical form of digital information and facilitates the direct manipulation of the associated bits (Ishii, 2008). However, as the game pieces are located within the game space on the screen of the tablet they can also be considered a form of Augmented Virtuality (AV) as the conform to its general definition of physical objects that are dynamically integrated into, and can interact with, the virtual world in real-time (Drascic & Milgram, 1996). Although it is outside the Milgrams original vision relating to the mixing of visual images from the real object within the virtual world on a display (Drascic & Milgram, 1996), as demonstrated by projects such as Augurscope (Schnädelbach, et al., 2002), the physical location of the piece on the screen achieves a comparable effect. In terms of AV games there are few specific examples relating to games as the majority of research relates to Augmented Reality (AR) (Bernades Jr, et al., 2008) and Table Top AR in particular (Kato, et al., 2000). Indeed many of the desired features for TUI design in AR (Kato, et al., 2000) are applicable to AV. In particular, the features of:

- The form of objects should encourage and support spatial manipulation (Kato, et al., 2000);
- Object affordances should match the physical constraints of the object to the requirements of the task (Kato, et al., 2000).

It is worth considering the concept of affordance in more detail as affordances that the game pieces offer differ from what can be achieved with virtual components. As this research enables the creation of physical games pieces this means designers must take into account both the real and perceived affordance of the object itself in its relation to the game. An additional consideration for would-be game piece designers is that the particular implementation of the game pieces presented in this research are representative of what Jesper Juul (Juul, 2009) describes as mimetic interfaces in relation to casual games like Wii Sports and Guitar Hero. These games require players to perform actions that closely resemble the physical activity required by the avatar on the screen. These interfaces make games easier for players less familiar with the more 'traditional' configuration of game controllers utilizing buttons and joysticks to pick up and play casual games. As Juul describes, the requirement for players to strum the guitar controller in Guitar Hero requires no explanation as most would be familiar with the image of a music artist playing a guitar (Juul, 2009). Whilst this prior knowledge may make learning the game easier, it also means that if the game challenges these expectations it is likely to put players off. Therefore, designers must ensure they consider carefully any likely affordances the physical pieces might relay to players.

Whilst mimetic interfaces might suggest they are the same as Natural User Interfaces (NUI) the definition offered by Wigdor and Wixon (Wigdor & Wixon, 2011) "natural refers to the user's behaviour and feeling during the experience rather than being the product of some organic process" and indeed suggest a natural experience "is NOT best achieved through mimicry". However, it is suggested that mimetic interfaces would be a subset of the broader area of NUI. In terms of the research presented in this project, while the particular implementation presented is a mimetic interface the expectation is that its general applicability would be through NUI.

An interesting extension to this classification debate is the emergence game interfaces using real world artefacts as game interfaces such as the game *Rocksmith* from Ubisoft. The game comes with a cable that allows players to plug their own guitar into an Xbox 360®, PlayStation®3 or PC. In addition to the expected song tutor activity the system also provides a 'Guitarcade' of mini games that are designed to practise specific techniques. For example, a 'Space Invaders' style that for practising fret placement shown in Figure 5. In some ways these games invert the NUI premise as arguably the natural interface for many of the mini games is the traditional style game controller.

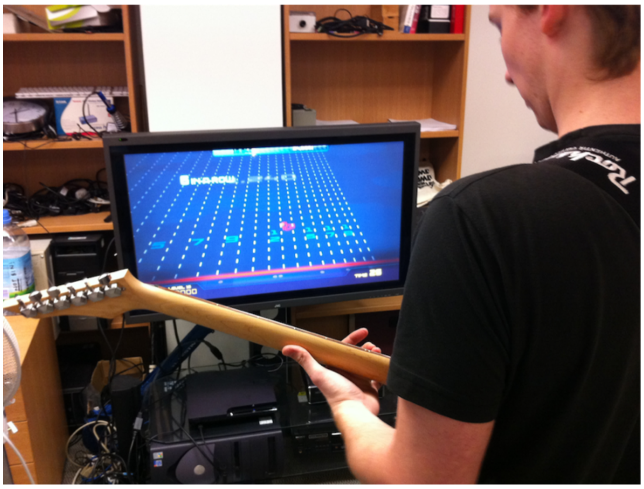

Figure 5: Rocksmith game using 'real' guitar as the interface

In terms of using physical game pieces to augment virtual games much of the research has been concerned with augmenting table top games (Magerkurth, et al., 2004) (Hinske & Langheinrich, 2008) (Mandryk & and Maranan, 2002) whereas a recent commercial game *Skylanders: Spyro's Adventure* from Activision augments a traditional role play adventure game for all the main consoles . A player is provided with a 'portal' (RFID reader which connects to the console via USB or Bluetooth) and RFID enabled game pieces as shown in Figure 6. The game pieces are either character avatars that can be swapped on the portal to change the player's current in-game character (character movement is through the standard console controller) and spell and potions to provide enhance character performance. The other interesting aspect is that the majority of the game pieces are sold separately to the game and it is therefore adopting aspects of physical card collection games first presented in *Magic: The Gathering*[6].

[6] http://www.wizards.com

Figure 6: Skylanders game pieces

The game presented in this research takes its inspiration from the Air Hockey game that appeared in arcades in the early 70's and the classic Atari video game *Pong* which also appeared at this time. In terms of comparable research projects the closest would be AR^2 Hockey (Ohshima, et al., 1998) which utilized 'mallets' augmented with fiducial markers that are tracked by a head mounted camera worn by each player. This allows the game to be projected relative to each player's viewpoint and the position of the mallets through head mounted displays. Apart from the obvious complexity of the display mechanism the requirement to have the fiducial markers in constant view constrains the player in the way the can operate the mallet. In the following sections a game is presented that overcomes both the complex system and limitations on the player whilst providing novel and engaging game play.

6.2. Analysis of Touch Interaction

The game pieces presented in this research take advantage of the technology behind the multi-touch input of the iPad rather than create new gesture interactions (Buxton, et al., 1985). Whereas resistive touch screens require physical pressure to be applied to create a touch event, capacitive touch screens such as those seen on the iPad exploit the electrical properties of the human body through mutual or self-capacitance. Therefore, any game pieces produced must allow the conductance from the player fingers to pass through them to the surface of the iPad. This is achieved by using a conductive material for the games pieces along with conductive cloth on their base to mimic the touch points as illustrated in Figure 7. Such a configuration allows the game pieces to be designed in relation to the aesthetics of the game and the touch point control system to be considered separately.

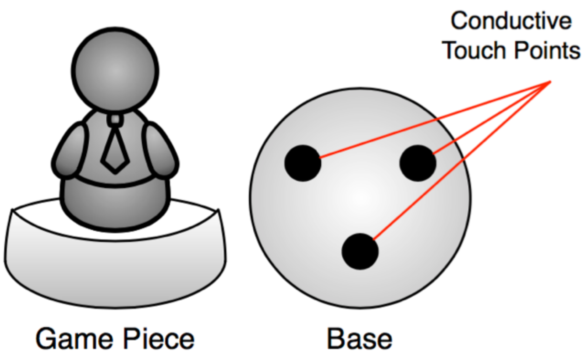

Figure 7: Physical game piece

This passive approach differs from the recent work presented by Yu et al (Yu, et al., 2011) who propose active objects for tangible interfaces that modulate touch points at frequencies they suggest are beyond what is likely from human users but still detectable by the device. This they offer as a solution that overcomes some of the design limitations which follow from the forthcoming analysis. However, although Yu et al present no users studies they state that because of speed required by the device to detect this frequency modulation “this limits the use to static objects” (Yu, et al., 2011) and as such would drastically limit its applicability for many games genres and would suggest it would be better suited to augmented toys (Hinske, et al., n.d.) (Marco, et al., n.d.). Therefore, the following paragraphs present an analysis of the touch information and control available on the iPad and the possibilities for passive game piece detection. It is worth noting that while the values are specific to the iPad the attributes affecting the design of the game pieces will be universal to touch based phones and tablets. Touch events on an iPod touch or iPad are detected and handled by iOS. From the hardware's point of view, when a user touches the screen it recognises an elliptical touch point and calculates the co-ordinate of where it thinks the user was trying to touch (Apple, n.d.). The obvious initial question if designing touch points for the base of the game pieces is *what size points can the device detect?* Generally when creating systems where fingers are used a generally accepted guide for the size acceptable targets is that they should be no smaller than the smallest average finger pad, typically a 1cm diameter is used (Saffer, 2008). Through experimentation using conductive cloth of different diameters and a bespoke application it was confirmed the minimum size on the iPhone, iPad, and iPod Touch is 5mm in diameter. This smaller size means that when targets are placed in close proximity, as observed on the iOS keyboard techniques such as iceberg tips and adaptive targets need to be employed (Saffer, 2008).

The next design question that follows is *how many independent touch points can be used and tracked simultaneously?* Again using a specifically developed application shown in Figure 8 it was confirmed that the iPhone and iPod touch are able to detect and track five points simultaneously whereas the iPad can handle eleven. Whilst the maximum number of touch points provides a bound for game piece design it is all important to understand *what happens when the number of touch points is exceeded?* as the user may touch the screen with their fingers or add extra games pieces. When the iPad is saturated with touches, iOS passes a set of all of the currently tracked touch points to a cancelling routine. From this point on iOS no longer informs the application of any changes in state relating to the touches that were already in action on screen. However, iOS does appear to continue tracking touches until they end and these have been termed ‘zombie touches’. A zombie-touch refers to a touch that is still tracked by iOS but the application believes to be dead. Whilst there are at least the maximum number of supported touches on the screen in the zombie state iOS will not register any new touches on the screen. A new touch point is unable to replace a zombie-touch and will not be passed to the running application. It appears that the effects of a zombie touch can only be remedied by the removal of that touch point from the screen. Therefore, any game piece designed must be considerate not only of how many touch points it uses but the games must be designed to prevent the accidental creation of zombie touch points by allowing for a ‘touch-buffer’ in case of user errors.

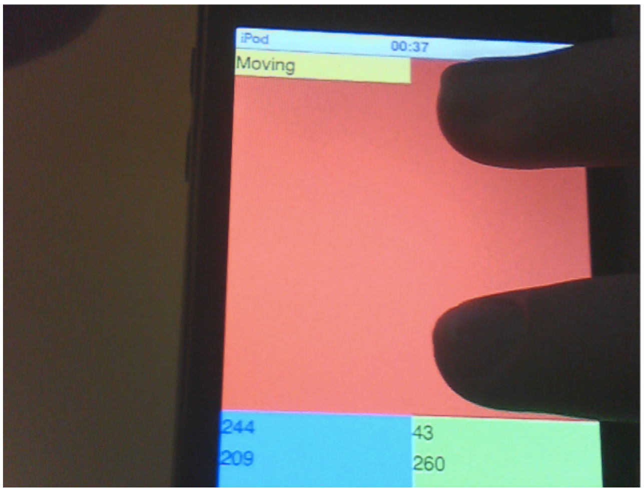

Figure 8: Multi-touch tracking

Having defined the minimum size and maximum number of touch points available the next question that will affect the design of the game pieces is *what is the minimum separation between touch points?* Adopting a similar experimental approach to the previous questions a program was created which calculates the distance between the centres of two touch points where the points are the minimum 5mm diameter previously discussed. These experiments indicated a limit of approximately 70 pixels before iOS effectively 'merges' touch points and treats them as one individual touch point. Intuitively this value is believable as it is also approximate to the point at which it becomes difficult to bring your fingers together in close proximity without touching. This suggests that the touch point detection in the iOS is designed to exploit this physical limitation when evaluating touch points on screen.

The value is defined in pixels as this is the easiest way to obtain the it through iOS although this needs to be converted measurement for construction of the game pieces. Traditionally screen sizes for phones and tablets are defined by the number of horizontal and vertical pixels and the pixel density is normally given as Pixels Per Inch (PPI). The values for the iPad are shown in Table 1 which also includes a number of other tablets to illustrate the variation between them. Using this information, the distance between centre points can be calculated as 14mm.

Device	Diagonal	Pixels	PPI
iPhone 3GS	3.5”	320x480	163
iPhone 4,4S	3.5”	640x960	326
iPad, iPad2	9.7”	1024x768	132
Dell Streak	5”	800x480	187
Motorola Xoom 2	8.2”	1280x720	149
Samsung Galaxy Tab	10.1”	1280x800	149
Blackberry Playbook	7”	1024x600	170

Table 1: Tablet screen specifications

With the acquired information as to how the pad handles touch points and the resulting physical limitations games pieces can now be designed and in the following sections the creation of a game and pieces will be presented along with a user evaluation.

6.3. Game Piece Design

Even with the constraints previously defined it is still possible to create a range of game piece such as:

- Real sliders used to control powers levels or speed;
- Knobs for use as dials or rotational control;
- Individual game figures for board games such as Monopoly.

However, as previously discussed it was decided to create a game based on the arcade game Air Hockey and the Atari classic video game Pong. In both games the player controls a mallet and competes against another player controlling a second mallet (in Pong this could be a computer controlled opponent) on the opposing side of the game area. Players use the mallets to hit a puck back and forth aiming to get the puck in to their opponent’s goal and earn points. The game ends when a player reaches a pre-determined number of points. The game created in this research, dubbed Pong+, is designed to be played with the iPad horizontal and using physical game pieces as mallets as per Air Hockey but with the virtual assets and game-play akin to Pong. Placing this particular implementation into context its can be regarded a fully embodied dynamic spatial tangible interface (Ullmer & Ishii, 2000) and overcomes the limitations previously discussed research on active objects (Yu, et al., 2011) that only supports static interfaces.

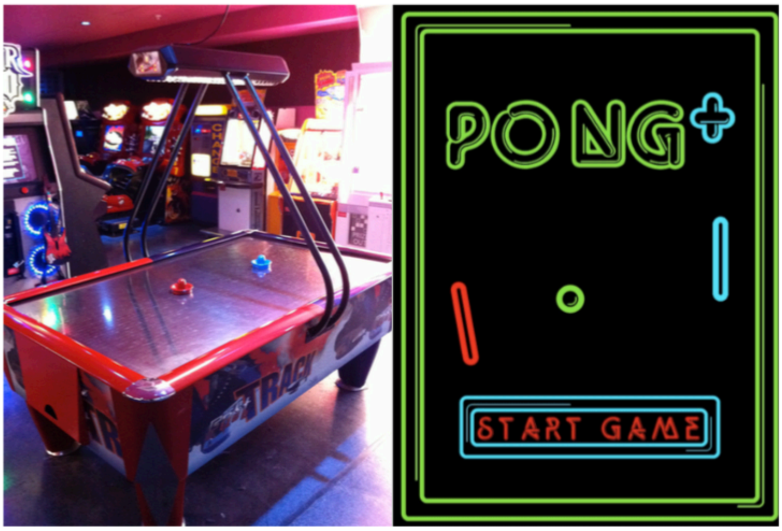

Figure 9: Arcade Air Hockey (left) and Pong+ (right)

The prototype game pieces, shown in Figure 10, were implemented using a metal mallet that had two touch points on its base made from pieces of conductive cloth and attached using conductive glue. The touch points thus both protected the screen and provide the unique reference points through which the mallet could be identified by the software.

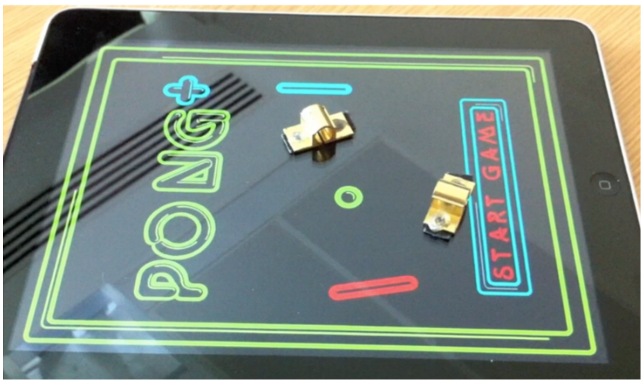

Figure 10: Game mallets

A fully functional game was created in Objective C and having two touch points per mallet allowed them to be treated as a continuous block within the program thus providing enhanced game play in that players can angle the mallet to control the direction of the puck as illustrated in Figure 11. This also means that the mallets and their operation satisfy our initial design criteria of having a form that supports spatial manipulation and the mallet affordances match the physical constraints of the object to the requirements of the task.

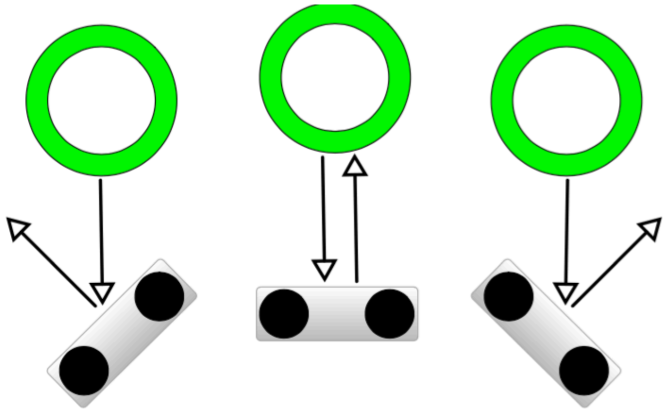

Figure 11: Angle of mallet allows control direction of puck

6.4. Game Piece Evaluation

In order to test the value of the game pieces to the game a user evaluation was conducted at Lancaster University with 8 unique pairs of users whose ages ranged between 11 and 50 (average 28) of which 9 were male and 7 were female. Two versions of the game were created for the user evaluations one that used the physical mallets and in the other the players used a finger to control a virtual mallet. Note that the virtual mallet was made circular so that the game could be played with a single finger and hence avoid introducing too much complexity. Additionally, the finger version placed dynamic mallet images under the finger but in all other respects the games were identical. Each test consisted of a player being asked to play two games of each version of each game. The order in which the two versions of the game were played was switched between subsequent pairs to avoid bias and each evaluation was conducted out of sight of other potential players.

As the main premise of using physical game pieces is that they by providing both physical and perceived affordances they offer a more intuitive interface for the player. Therefore, the test players were not provided with instructions in how to operate they game prior to play. The aim was that the players would therefore have to deduce the operation from the affordances presented to them. The players were asked to speak out loud their observations during the evaluations and these were videoed for later analysis. The following paragraphs represent results of the analysis of these user evaluations.

One clear effect of the different affordances presented by the physical mallets was at the start of the game. In both versions the player was required to tap the puck to initiate the game but in all the games where the players started with physical mallets they all tried to start the game by pushing the puck showing that the affordances in this case did not match the expected affordances of the player. This is illustrated in Figure 12 where the arrow shows the players movement and was much commented for example:

"the start is confusing should start by pushing like proper air hockey"

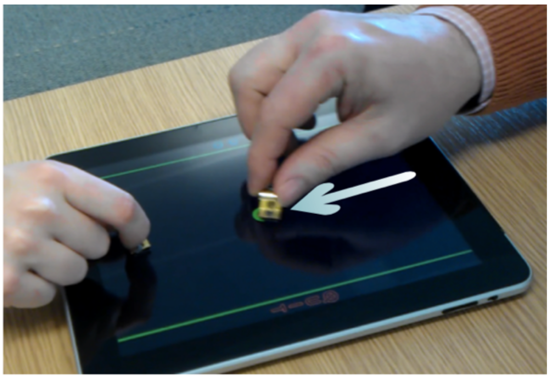

Figure 12: Players attempting to 'push' puck to start game

It was very noticeable that for the virtual mallet version the players simply pressed the screen repeatedly to try and start the game and then fairly quickly the puck. In one case where players had started with virtual mallets they still initially attempted to start the game by pushing the puck when they switched to the physical mallets.

This desire to push with the physical mallets was also readily apparent during the actual game play. During the physical games players grasped the mallet and moved all around the game area effectively balancing their hand on the mallet as seen in Figure 12 whereas in virtual games players tended to rest their wrist on the table and simply move the mallet from side to side essentially stroking the surface of the iPad as illustrated in Figure 13.

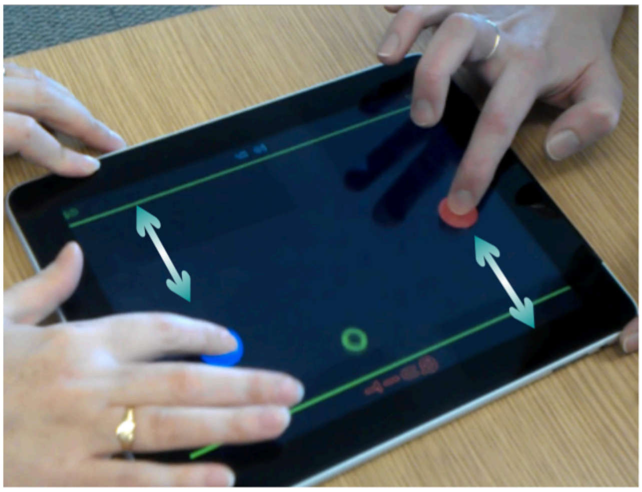

Figure 13: Players using virtual mallets

This difference in playing style resulted in a common comment by players that physics of the physical game needed to be altered to allow players to push the puck along the table with the physical mallets.

"The game needs to let you push better with paddle"

"Feels like you should be pushing the puck with the mallet"

In reality both versions used the same basic pong like collision detection which was not optimised for this type of interaction, yet none of the players perceived this as an issue when playing the virtual game.

Another issue raised by two of the players was they felt there should be some virtual presence of the physical mallet to provide feedback that their touch was registered.

The final observation of this user evaluation related to two players using the virtual mallets complaining that the puck was often obscured by their hand.

Examining the video footage revealed that it was related to the finger the players used to control the mallet whilst the majority of the players used their index fingers, as illustrated by the players in Figure 9, these players often used their middle finger which resulted in this issue.

Overall it was clear from the evaluations that even on this relatively simple game the physical and perceived affordances offered by the physical game pieces were significantly different than virtual ones and from the very enthusiastic reception by all the players offers some novel for touch screen game play.

The next stage of the research produced 3D printed mallets as seen in Figure 16, that look exactly like those supplied in for air hockey and to build in movement recording so that heat maps can be plotted of screen use to more closely ascertain the significance of the physical affordance to movement style within the game.

6.5. Extending Touch Interaction

In the previous analysis of the touch point information only the open parts of the iOS SDK, in other words features accessible to the general programmer. However, there are hidden features within iOS that are accessible through jail-broken devices that are often revealing in terms of the future features. Examining the closed parts of the iOS SDK reveals it is possible to obtain an approximation of the diameter of the current interaction point using a hidden method. This feature opens the possibility of extending the design options for game pieces to include varying the diameter touch points. To evaluate this, feature the Xcode debugger was used in conjunction with an iPhone and conductive pads cut to various sizes. The sizes of the touch points were displayed in the debugger when the pads were touched to the surface of the iPhone as shown in Figure 14.

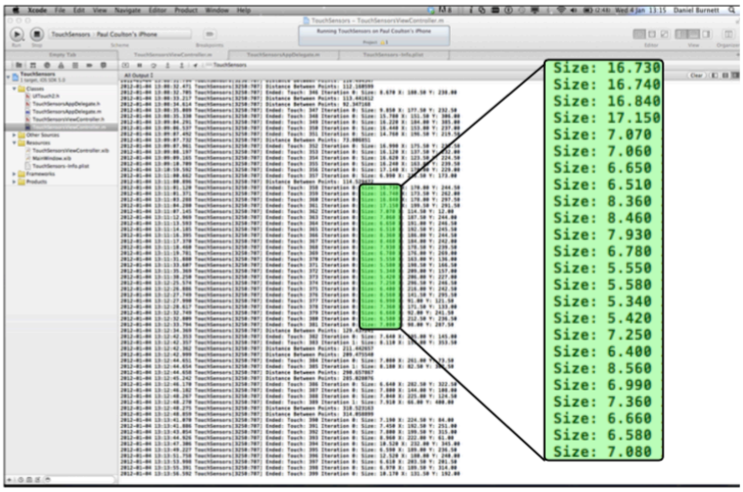

Figure 14: Debugger display showing the size of touch event

The results indicate that minimum touch size remains 5mm diameter and the iOS was able to accurately and consistently detect changes in diameter of 1mm.

However, producing touch pads with such a tolerance maybe difficult in practice given the materials available and using a tolerance of 2mm maybe more practical. The increase in possible combinations facilitated by sizes presents the possibility of creating a system akin to a 2D barcode using touch points as illustrated in Figure 15. Further, future versions of the operating system may allow access to the raw touch point data whereby the concept could them be extended further by manipulating the shapes of the touch points.

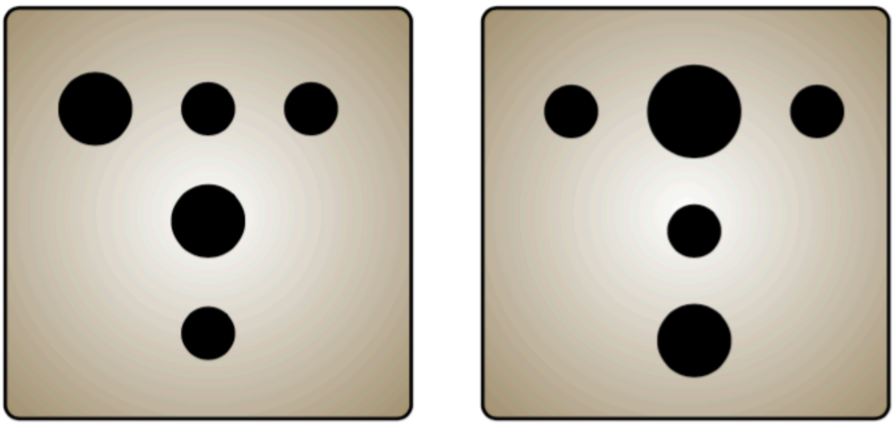

Figure 15: Possible 2D touch points ‘barcodes’

Also within the undocumented features of iOS there is a method named pathPressure which one would assume gives some sort of feedback as to the pressure exerted on the screen however at the current time it always returns a zero value. If pressure is to become available, it suggests either the screen will incorporate some new technology or the system would estimate pressure from the size of the touch point i.e. as a user presses harder a greater amount of their fingertip comes in contact with the screen. In either case this would offer little in extending the options for game piece design.

With the current limit of 10 touch points on many tablets, this places a restriction on the number of recognizable objects that can be detected at any one time. However, with future hardware, this may be extended allowing for a greater number of objects to be recognized simultaneously.

6.6. Discussion

Whilst touch screen devices have been readily accepted as an increasingly important element of the games industry it is also acknowledged that the interface not optimal for all game genres and some game interfaces struggle to create the perceived affordances necessary to produce intuitive game play. The purpose of this research ascertains the benefits of using physical game pieces on touch based devices in terms of both physical affordances.

The analysis of the capacitive touch system for the iPad provided not only the specific values which affect the physical limitations for the design of game pieces for this device but provide guidance on the information required when creating such pieces on any capacitive touch based tablet or phone. The solution offered also overcomes the problem associated with proposed active systems in that the pieces are not only much simpler to manufacture (an issue given the low-price point mobile games command) they can also be used dynamically within a game. Given that mobile games are generally sold at low price point. Further the analysis of features currently hidden within operating systems indicate that these limitations can be extended to increase the flexibility when designing game pieces and if this is coupled with more touch points and/or access to raw touch data, it would enable the support of games requiring a large number of pieces such as chess.

To evaluate both the validity of the design guide for game pieces and the effect on players a version of Air Hockey was created in which physical or virtual mallets can be used. The results of user evaluation clearly show that the materiality and the resulting affordances of the physical game pieces produce clear differences in both in perceived expectation of how the game should operate and the physical way it is played due to it affecting the users' natural wrist position. Thus the game pieces are not merely novelty physical versions of virtual objects they offer new interaction possibilities and design challenges when used within games.

Overall this research demonstrates that while commercial touch based phones and tablets are now dominating the computing landscape there is still the opportunity to innovate around their interaction by creating novel physical games pieces and toys.

6.7. Conclusion

As previously mentioned this project came before CX, but it still has implications to how the design of these phygital hybrid objects are created. With the amalgamation of the two inputs of the digital screen and the physical mallet, people often felt that the digital aspects of the game should act in a more physical way. This affordance seems to have evolved from the production of the physical mallet, players that started with just the touch version understood that there had to be a button press before the game started, whereas users that started with the mallet version expected the game to behave as real air hockey does. This is an important consideration to take into account when creating these hybrid objects when a common physical interaction of this type already exists, changing the status quo can lead to confusion and a break in immersion. So, what seemed inconsequential at the outset actually became quite the focus of attention from the players from a negative stand point. Whilst this was not addressed in later versions the addition of 3D printed mallets as seen in Figure 16 did help users understand what was required of them at an earlier juncture. This suggests that the form of the mallet had an impact on the way people perceived the game.

Figure 16: 3D Printed Air Hockey Mallets

The idea to create 2D barcodes that allow the reading of the capacitive points to identify objects has since been implemented by a group focussed on creating serious games for education (Dos Santos, et al., n.d.). Showing that there is potential for these interactions to move on and create more meaningful interfaces, that don't rely on a simple finger mechanic.

So, towards the manifesto the ideas that can be extracted are not revolutionary but are important. Where affordances exist in the physical world, the phygital object, if it serves the same purpose, must match the affordances in the phygital realm and careful consideration should be given to which affordances can be removed.

7. Physical Actions representing physical/virtual presence

7.1. Introduction

A second project that ran prior to CX that has influenced the subsequent CX research was a platform that allowed people to customise the space they inhabit by democratising a music jukebox system. The idea being that as more people entered into a space the system would tally those peoples' musical tastes and then tailor the music playlist to suit the majority of people within the space. This project while being conducted before CX still worked on the principles of the Digital Public Space, as it afforded new ways of interacting with repositories of content which in this case was Spotify and Facebook. It also followed the same trajectory as CX projects, using agile programming methods and rapid prototyping to quickly and deftly create multiple iterations improving at each stage on the last.

Unlike CX projects however, there was no creative industry partner but the research was conducted with then PhD student Dr. Mark Lochrie and Prof. Paul Coulton. During the course of this project I was responsible for the hardware and the software that ran the service, with Mark responsible for the web front-end.

7.2. Background

In the last decade, large sections of society have been spending increasing amounts of time socializing online through sensor rich mobile devices (Lenhart, et al., 2010). This phenomenon is primarily driven through popular social networks such as Facebook, Twitter and Foursquare, which encourages their users to broadcast their activities by updating, tagging, (re) tweeting and now checking-in to venues. Many venues are already embracing the Foursquare community by enticing customers to 'check-in' achieved through many social mediums and also by the inclusion of such advertisements in window displays. More recently, venues are seeking new ways to engage people in the atmosphere of a location by seeking to change the 'mood' of that location through techniques such as ambient media. Where ambient media, is media that surrounds and encompasses users while changing the environment in subtle ways to alter the mood of a social space using audio and visual techniques (Wisneski, 1999). Whilst it has been shown that for people to notice a change in an ambient display a severe change from a high intensity to a low intensity or vice versa is required, people notice subtler changes in ambient sound (Wisneski, 1999).

While ambient media music or sounds may be more attractive in terms of user response, it is possible to integrate the visual by using audio visualizers, and video cues on a large screen informing users of changes in influence. However, one way in which ambient media could be transformed is by the inclusion of crowdsourced data.

Over the years, local councils and communities have sought to change and improve upon the areas that are in their vicinity. However at least from the communities' point of view these changes are peripheral or tokenistic (Arnstein, 1969). New methods for individuals to voice their opinions about public spaces are now coming to light with the ubiquitous mobile devices (Weiser, 1993), allowing people to post these comments as and when they come to mind (Lam, et al., 2011). But what about if people only want to personalize the space whilst they are in it? This research considers how to create a system whereby people collectively change and influence public spaces for a limited time, and what affect it has on the community inhabiting this space. In particular, it will effectively enable a crowd curated Jukebox within a venue. The term jukebox was first used in the United States during the 1940s describing a music-playing device that is controlled by someone selecting songs to be played thus changing the environments ambience. Users navigate through a list of songs/albums and are able to select a song to be played by inserting money (traditionally, coin operated). This selection is added to a playlist of already chosen songs. However, we are seeing fewer public venues offering their patrons the use of such Jukeboxes due the high rental costs associated with the machines and maintenance, not to mentioned the increasing use of music players controlled by the venue staff.

Over recent years there has been a rise in location aware mobile applications, which use Global Positioning System (GPS) to determine one's location. Twitter and Facebook both provide the functionality to tag tweets/updates with geo locations, but this is arguably not their main functionality. Whereas, Foursquare' entire social network is built around users sharing their location through a game-like activity whereby users are awarded points, badges and mayor ships for checking-in to venues. A small minority of venues are offering patrons special offers, deals and unique experiences for those who check-in or are the current mayor of the venue. However, this can easily be exploited, as the inaccuracies of GPS mean that a players' physical presence isn't required to check into and unscrupulous players can gain such offers without previously 'stepping through the front door' (Nandwani, et al., 2011). This could be one of the reasons that many venues aren't seen to be using this approach for attracting patrons. Hence, some form of physical check-in system is required so that companies can truly engage with their clientele and NFC has been proposed as a solution.

NFC enables the passing of information wirelessly from a 'tag' or device with an active NFC chip to a reader connected to one of the aforementioned products, this information can simply be any number of different data and can potentially be used to many different results. The primary method most people interact with this technology in day-to-day life is through access cards such as the Oyster card or perhaps their payment cards at a store. Even mobile phones now have the ability to mimic a card opening up interactions to an even greater number of users. But that is not the extent to which this technology can be used, by storing a Unique Resource Identifier (URI) for example you could create a method for directing an NFC reader into loading content from anywhere in the DPS. The technology has been used to great effect in the realm of gaming on video game consoles through games such as "Skylanders" by Activision (Burnett, et al., 2012), as discussed previously.

In this project, the aim was to bring back control of the venue Jukebox to its patrons and provide an extra incentive to physically visit and check-in to a location. Although the use of NFC as a method to control music has been proposed previously for producing music (Tuikka, n.d.) (monobanda, n.d.) to choosing individual songs via RFID tags (Anon., n.d.) it has not been used to crowdsource opinion. Therefore, a platform was developed to support users' physical check-in where they can help crowd curate the music genres being played in public spaces and hence named it 'CheckinDJ' (Burnett & Lochrie, 2012) which fuses the two main characteristics of the system.

7.3. System Overview

CheckinDJ allows users to interact by a simple touch of their RFID enabled object over the CheckinDJ controller; the system provides users with real-time feedback to provide notifications of their interactions. An additional argument for adopting a new social music player experience has been conceived from observing peoples' interactions with traditional jukeboxes. Typically, it is a single person that usually operates said machine, whereby people tend to spend a long time choosing their songs to play, the issue with this is that others wanting to interact have to wait or miss out. Therefore, one key feature of CheckinDJ was to provide the user with a minimalistic interface that people interact with by touching their RFID object over its sensor as seen in Figure 17, hence the system can accommodate multiple users checking-in in quick succession. There are four main characteristics to the system; a simple web interface to register interest and assign music genre preferences, a RFID equipped unit, a database backend to log all interactions with the device; including user accounts, songs played with playlist associated, who is checked-in and leader boards accompanying the use of the system and also a Spotify application to collate songs associated with the chosen genre of music.

Figure 17: Photograph of the CheckinDJ Jukebox demo

In order for the system to work, the service relies upon several major components. First of which, is the interaction, where users communicate with the device using a contactless protocol. This is achieved by implementation an Arduino board connected to an Ethernet shield, which combined connects to an NFC module. The NFC module is required to read the NFC objects. Users can utilize any 13.56MHz RFID tag in order to communicate with the CheckinDJ jukebox.

Those wishing to interface with the jukebox are required to register prior to using the system. The registration process involves users linking their RFID enabled objects' unique ID number along with their personal information such as username, password and three genre preferences. This will assign each user an influence value of '1' (It is this influence value that effects the playing order of the music genres), therefore when they check-in their genres would increase in the leader board by 1. Users can increase their influence by authenticating their social network accounts with the service. The user who is the mayor of the venue on Foursquare has a greater influence on the system, so when they check-in their preferences are increased by 10. The whole registration process for the system is designed to require as little effort possible from the users' perspective; one reason for this was because sometimes people may wish to register at the venue, as opposed to before entering the venue, where they would be able to do it at their convenience.

Designing the system to allow the inclusion of peoples existing social network accounts (Twitter, Facebook and Foursquare) is an attempt to increase the flow of social information disseminated around all networks, therefore it could be said that such systems are services built upon existing social platforms. This has obvious benefits, one being the project gaining a greater awareness online, but also for the venue where the music played consumes the public space.

As the system was developed without the use of an external display, the Arduino is programmed to give users feedback in the form of lighting sequences of a group of LEDs, this is used to indicate what stage the device is currently in operation, for example it shows an amber LED while checking the card (to indicate to the user that something is happening) which then changes to green depending on the notification delivered back from the server, this typically would imply that the transaction has been successful, therefore the users preferences have been added to the system and obviously red to inform the user that something has held up the process. All the routines for notifying the user were available on the CheckinDJ website (Burnett & Lochrie, 2012).

A backend comprising of a relational database and server-side scripting, form the basis of the system. The backend server collates all of the users' preferences that have been added in the last 30 minutes and then returns the highest rated of these to the music playing system, which proceeds to remove all but the current and next track to be played from its current playlist and then adds 10 songs of the highest rated genre to the playlist. The system also maintains a log of all songs that have been played so that users can download a play log of what has been played at the venue. Users can either touch their NFC equipped mobile phone against the CheckinDJ jukebox, scan a QR code or browse an online catalogue on the systems website (Burnett & Lochrie, 2012), to view current and previous play logs.

The system also facilitates the sharing of multimedia information as users can easily download the current playlist from the system by tapping their mobile phone against the jukebox this downloads a Really Simple Syndication (RSS) feed to the user's handset (Burnett & Lochrie, 2012). To monitor how users', use the system every time they attempt to influence the system it will be recorded whether successful or not, hopefully this will reveal how people perceive the ability to influence and whether they have strong feelings towards wanting their own preferences to be played. An overview of the system process for checking in is shown in Figure 18.

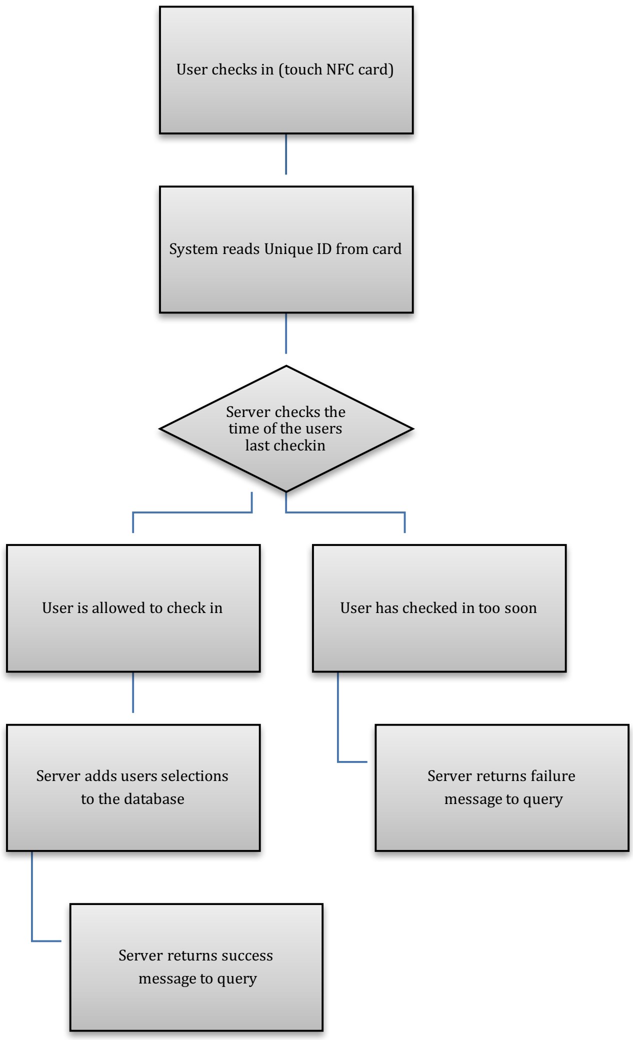

Figure 18: Checkin System Flow

In order to maintain a playlist, the music system polls the server for the highest rated genre every 20 seconds, in this way the system can react quickly to the changes in the collective users group. Likewise, every time the playlist or track changes the server is notified and updates the current playlist so that users can keep track of when their music will be playing. To ensure a variety of songs are played, the system takes the genre of highest rank and then searches for a group of 50 artists within that genre. From these 50 artists a single artist is then picked at random and a new search for all of their tracks is then performed and a random track is then selected from here. This is repeated 10 times to fill the playlist. If the genre changes before the currently playing track finishes however this playlist will be destroyed and a new playlist with the new genre will be created. Simply checking-in will not get your music played, there will have to be a majority of people wanting to listen to that particular genre for it to be played this is the idea behind crowdsourcing, by giving control to all users they have to work together to get their music played. A CheckinDJ Twitter account was set up to serve two main purposes; to broadcast tweets of the current song playing and its genre its associated with it and a Spotify URI to hear the current playlist that is being played at the specific venues location, this allows others who aren't physically at the venue to experience the same music wherever they are (people would be able to listen on their computer and mobile phones with Spotify installed). The web interface, which can be displayed on mobile devices to large screen installations, allows people to follow what's going on at the venue. People can see who has checked-in, what's playing now, the current playlist (Chen, et al., n.d.), genre leader board, any meta narratives of inter dialogues between users and there are also methods to share media information with others. This process is shown in Figure 19.

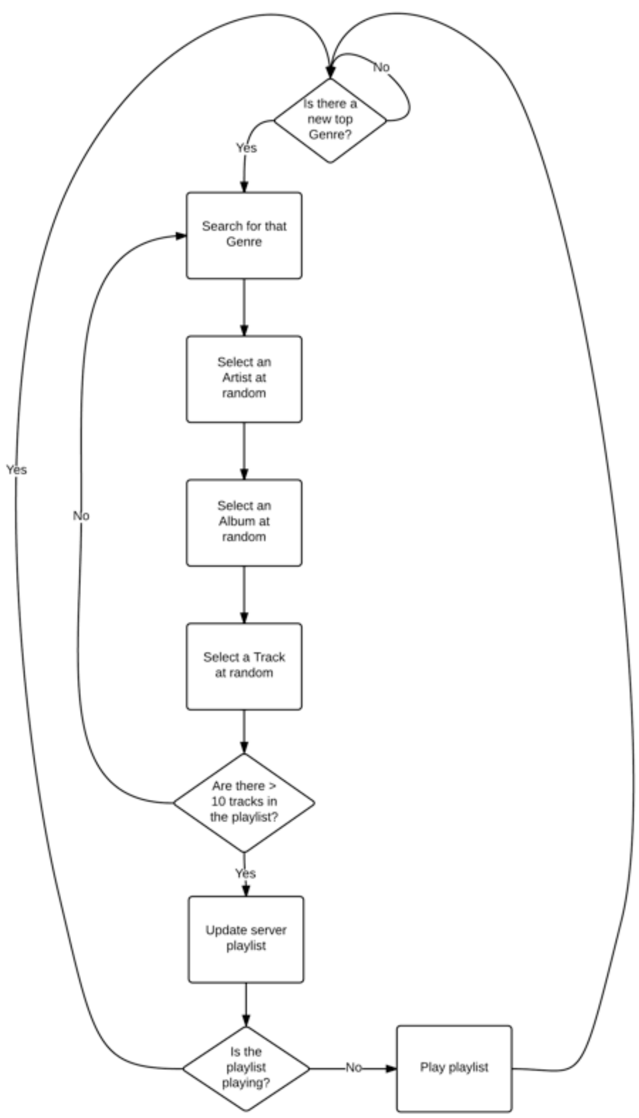

Figure 19: Playlist Generation Algorithm

One way of engaging people with the system is through the competitive element of checking-in. Players compete in order to get their music played, this is achieved by a flashing notification on the web interface that shows people that something major has happened or the subtle change in music will alert people to potentially trigger a rush of check-ins to keep their music style playing. Further to this, when a user checks-in their avatar will show up informing others that this person is currently at this venue, but also as that person checks-in their genres are added to the leader board, this influence is demonstrated by showing that users avatar next to the genre title, potentially sparking new social interactions as people learn more about the strangers around them. Users are also provided the functionality to vote on tracks that have been played at the venue (Koskela, et al., 2010), (Koskela, et al., 2009), (Paek, et al., 2004), (Scheible & Ojala, 2005), by doing so this adds to the camaraderie aspect of collaboration in such social spaces. The system is then able to create a leader board based on what songs are the most played in the venue versus what the users like, to which has a greater impact showing what music people actually prefer as opposed to most played. Not only is the vote recorded with the CheckinDJ system but can also be distributed on social networks (Googles' +1, Facebooks' Like and Twitters' Re-tweet, Hashtags). By allowing users to extend the discussions away from the venue, this promotes a meta dialogue running alongside the system, which is useful for times when the venue is closed or when the CheckinDJ jukebox isn't in operation.

7.4. First Prototype Evaluation

The jukebox was in use in one of the bars on the Lancaster University campus for a period of approximately two months, predominantly used by a closed student-testing group. People could register their interest using their library card number and then the system interfaces with the Universities IT services and facilities in order to obtain that students RFID number associated with their library card number. This allows users to register online without the need to use scanning technology to read that cards RFID number. This decreases the difficulty associated with facilitating new users to the CheckinDJ jukebox system. It became apparent during the early stages of beta testing the jukebox in a real world environment, that users were seeking extra feedback in the form of a display beyond the sequence of flashing LED's. Users indicated that they wanted to know the effect they had on the system, so they could visually see the effect take place. Which is why the authors decided to extend the web interface to fit the purpose of a large screen.

The idea of community influenced public spaces, has been found to be an interesting way of perceiving the impact the individual can have upon the group consciousness and the way that they use the space afforded to them.

7.5. CheckinDJ Second Prototype Design

As previously mentioned users of the closed beta indicated a preference for using of an external display to provide extra feedback. In version 2 of CheckinDJ a change of system architecture was implemented to utilize the power and performance from a Raspberry PI, which provides the ability to output video using the High-Definition Multimedia Interface (HDMI) output. Utilizing the HDMI port provides the system with the functionality to output to many video devices. By doing so the users could generate their own visual content by designing their own visualizations to play alongside the music, therefore increasing the association with their presence, thus extending the impact of personalizing the public space. Another motivation to adopt the Raspberry PI in version 2, allows the system to be built into one unit, as currently the Spotify application is running on separate hardware. Currently only one unit of the CheckinDJ is deployed to the venue, if multiple units were required the Arduino unit would still be useful as only one unit needs the ability to play the music and output the video. Another use of all the logged data could be to extend the gaming element of CheckinDJ. People tend to visit public spaces in groups, therefore the system could enhance its reward system by rewarding users who come in regularly with extra influence on the music choices, first time users could get an initial boost to allow them to see their impact more readily, groups of users that regularly check-in together could gain a rolling multiplier, 1x for the first person 2x for the second etc. Obviously these are but a few of the options available to us for engaging users with more exciting and rewarding features.

7.6. CheckinDJ Version 2 Trial & Evaluation

7.6.1. Trial

The new jukebox was trialled at an organized event held on Wednesday 26th September 2012 from 5pm onwards, the trial was held at Lancaster University's Live at LICA's Nuffield Theatre venue. With the advancements of version two of the system, the trial was open to anyone on campus to pop by and take part in the study (the study lacked the usual student demographic, as it was completed out of term time). The authors placed advertisement posters around particular areas of the campus; the idea behind this was to attempt to advertise the study to a wider demographic audience. Some of the testers were informed of what the study was about prior to visiting the venue; therefore, those testers registered interest through the online portal (thus setting up an account with their library card number) (Burnett & Lochrie, 2012). The visitors that came in on the off chance were required to create accounts on the day. It is not essential for users to register with their social media accounts, although they are influenced to do so, as one of the main competitive elements of the system is to recognize social media relationships between people. The system uses the Universities IT services and facilities in order to obtain the NFC identification number associated with the participants' library card number Figure 20. This decreases the difficulty associated with introducing new users to the CheckinDJ jukebox system. The trial saw 41 users register their interest of which 18 people attended the event during the 2-hour period. The participants were age between 19 and 60 years old and 66% of those who attended the event were male. A simple questionnaire was provided to each participant to indicate what their impressions were of the system. The main purpose of the questionnaire was to seek if those changes made to the system from version one to two were influential and to obtain feelings towards the system in enhancing the social experience.

Figure 20: Photo of user Checking in to CheckinDJ

The photograph in Figure 20 demonstrates how users interact with the system.

7.6.2. Gathering of Data

By providing the questionnaires to people who attended the event, the authors were able to capture anonymous reflections towards the system, although the general consensus was positive there were some people who found the idea behind playing music to bring people together confusing. Some comments from the evening were:

"It introduces new songs and I can find hidden gems"

"It will provide a wide and varied music styles anywhere it's used. Good idea"

"I don't really see how this would benefit such events. Music tastes are quite niche. Ice breakers and networking events are surely purposed to bring people together through common ground rather than unique differences"

"Not sure if there was a crowd of people standing around the jukebox, with the size of the system I'm not sure if everyone will be able to see it."

"It would well in a conference setting or even fresher's week."

As one of the aims was to see if the inclusion of a small LCD screen to accompany the system would provide users with sufficient information thirteen people found the LCD screen provided information enough information when checking-in through displaying the current genre, song playing and who was checked in. It was also important to explore how long people congregated in front of the system, as the main aim of the system is to provide quick and easy music selections without taking people away from their social setting. The conclusions of this was that the majority of people gathered at the CheckinDJ box for 0 – 45 seconds, this combined with the previous question proved that people found the screen to provide the correct length of information without requiring users to spend too much time waiting for the information they required. 88% of participants thought that

CheckinDJ could be used to enhance networking events or a forms of ice breakers. One of the main characteristics of the system was to design simple interfaces for people to interact with for both the online portal and the physical object. 21% of participants found the online registration of CheckinDJ to be a little confusing. The common theme throughout the confusion was the linking of social media accounts and the reasons behind selecting the genres of music weren't clear.

"Maybe too many genres to pick from."

"There seems to be a lot of information prior to registration, but once registered, the system doesn't really say what to do."

As the objective of the system is to enhance the ambience of the social environment, the relies on users linking CheckinDJ to their social media accounts, 39% of participants did link their social accounts to the system, however the 61% of those who didn't either didn't understand the benefit of linking their social networks to the system or didn't use such services. One participant really wanted to be involved in the study so much so that she borrowed a friends' library card (as this was the only NFC enabled object she could get her hold of), she commented that had she been using her own library card she would have linked her social media accounts with her CheckinDJ account.

"I wasn't using my own library card but if I was using mine I would have tweeted and Facebooked."

As the system was in an open beta stage some of the components weren't fully integrated or enabled at this point, this was obvious when revealing the results of the questionnaire 44% of users understood the gaming element of CheckinDJ however this was one the areas which wasn't fully integrated at this point. Although the purpose of the system is to minimize to requirements to include a large display, some participants thought highly of accompanying the system with a large display due to the size of CheckinDJ and if used in a nosy environment observing information from afar would be essential as they would rather do this than having to move close to the system to obtain the information they required.

"Yes - we are all nosy. Also a large what's playing display so I can shazam it"

To finalise the questionnaire, the authors asked participants to rate the enjoyment be selecting a value from a scale of 1 to 5 (1 being low and 5 being high), the general consensus of people rated the system as 4, as they could see the potential and would seek to use when deployed in a more relaxed environment (similar to where traditional jukeboxes are).

7.6.3. Evaluation and Improvements for Version 3

As previously mentioned CheckinDJ logs a history of user interaction data, the primary use for this is to extend the gaming element of CheckinDJ further to look into social relationships and really pursue to social gaming element that can be derived from such system. To do this the systems influence on linking social media accounts would need to be explored further, as it would be integral to utilize CheckinDJ as social gaming platform. Providing the aforementioned functionality to vote on tracks that have been played at the venue adds to the camaraderie aspect of collaboration in such social spaces. Using this data could then be used to determine which genres and songs are the most popular during different times of the day, demonstrating a greater impact of what music people actually prefer as appose to most played. Besides the current system, the project explored using an Android application to allow users to register their own NFC tags, however as the amount of NFC enabled mobile devices is still quite in its infancy, an Android application on pre-set up devices to enable users to register at the venue with the system was considered. However initial studies showed, that users were less likely to share their social network account data on a device that was not their own. When NFC becomes as popular as other sensors like Bluetooth, Wi-Fi, Accelerometers etc., there would be possibilities to integrate such devices further into the system. Utilizing the mobile device as a method of integration or as a P2P network was considered, however current Android devices (the most popular wide spread commercial Operating System (OS) to integrate NFC into their systems) does not support such communication to take place. The way in which the Android OS is set up, is to use the device as a reader and writer to NFC tags and not to use the mobile device as a tag itself.

7.7. CheckinDJ Third Prototype Design

The third and currently final version of CheckinDJ was built on the platform that had successfully hosted the previous trial, but also included other features that people had mentioned in their comments about the previous system. To improve the sign-up process an Android tablet was used to register users, simply by tapping any NFC enabled card to the reverse of the tablet and then choosing their three favourite genres as seen in Figure 21. In this version of the software users were able to add their social media logins for Facebook or Twitter and each acted as a multiplier for their preferences.

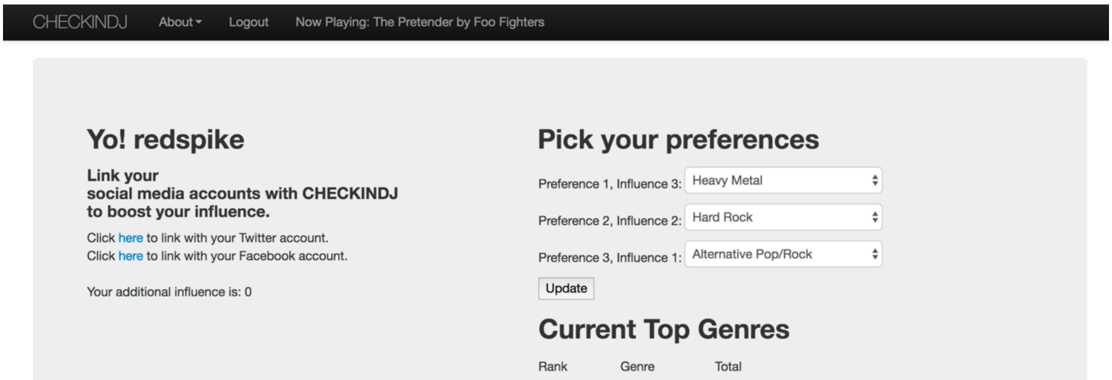

Figure 21: Display Users Saw on Swiping NFC Card

Preferences were also no longer afforded equal weighting, but rather the top preference had a weighting of 3 with the bottom preference a weighting of 1. This was done to ensure one person would not have too much control over the music selection as it was supposed to be a crowdsourced democratised system. So a user with their Facebook account connected would have preference weightings of 6,5,4 respectively. Other changes for this test were to also remove the ability to log in to the website for users, the website would still display current information but users would only be identified in a manner such as “DJXX” where XX is replaced by a number. The previous conversations from the other trials had shown that the control of preferences and the login system was too convoluted for users to get to grips with initially and so by streamlining the process it was hoped to promote user engagement.

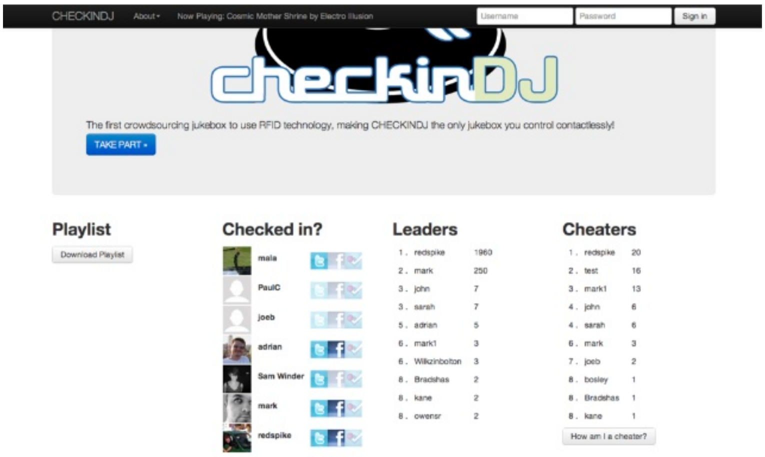

Figure 22: Online Portal for CheckinDJ

7.8. CheckinDJ Version 3 Trial & Evaluation

7.8.1. Trial

For this version of the CheckinDJ system, the locale was changed back to its original setting of a Bar on the Lancaster University Campus. This event was a one-night affair and ran from 7:30pm (The Bars opening time) until 11:00pm (The Bars closing time). During this time, 21 unique users checked in to the system and registered their cards, these users proceeded to checkin 155 times over the course of the three-and-a-half-hour period an average of 44 checkins per hour, approximately twice an hour per user.

The users had a wide range of music preferences and this created an interesting mechanic within the bar where people would watch for other users going to check in, which then caused a flurry of other users to follow suit. As users were able to checkin once every 10 minutes this became a predictable flow as people vied to get their genre to be the top choice.

During the trial the project team were taking notes on emergent behaviour and were approached by one of the patrons to request a change in the music. Following a brief explanation, it was understood that the reason for this was that their favourite genre was not available on the system. Therefore, in order to accommodate the new user a change to the genre list was made. After a few attempts to get the music choice to swing to their preferences, the user then started to request that their friends change their preferences in order to make their choice the most popular and thus control the music. This gamification of the system was not foreseen by the team but was an interesting observation that the user was that passionate about their music choice that they wanted to attempt to "cheat" the system for their control. This user then sparked another behaviour as other groups noticed what was happening and then grouped together to change their preferences to attempt to regain control. With one user at a time checking in with multiple cards, as soon as one user moved the other group would follow and queue in order to checkin as soon as possible after them. This battle continued until the end of the evening at which point the users all requested for another night with the system in the bar. For the team this was seen as a great achievement and a good sign that the system was on the correct path.

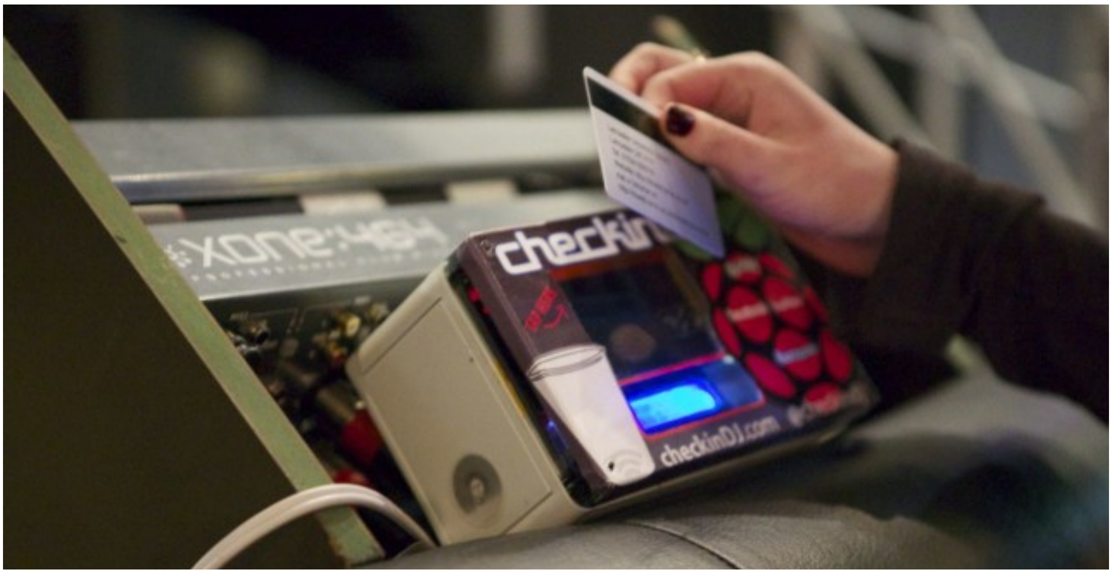

Figure 23: User Checking In with CheckinDJ

7.8.2. Evaluation

Overall the trial of the new sign up system and the public bar setting seemed to engender usage of the system. Peoples' opinions of version 3 of CheckinDJ were very positive and were quite excited for the return of the system for the next evening. As this trial was a one off and it was not possible to run for an extended period this could not be performed, however in the future a similar system could be employed to control music in venues.

Peoples' interactions with the device accelerated with each use, compared to the previous version there was perceived to be a much flatter learning curve between entering the venue and checking in to the system. This change was seen as good evidence of the system having improved from its first version. The simplified registration system saw users frequently interacting with it and changing their preferences on the move. It seems that given the increase in power of newer generation Android tablets, that moving the platform forward it would be better to concentrate on an Android version of the CheckinDJ Platform, as it would be quicker and easier to deploy as well as having all the inherent capabilities that come with it.

7.9. Discussion

The process of creating a Crowdsourced Jukebox has moved through several iterations each taking the previous versions shortcomings and then improving on them, in the same cycle as described in the methodology chapter only without the input from an overarching project team. This meant that the project while able to move quickly from prototype to prototype it did reduce the influx of new ideas, potentially causing stagnation within the project. As it stands there are options for taking the project further and there has been interest from a number of parties that would like to include the system in their stores/businesses, however due to licencing issues it would not be possible with the current system that uses Spotify.

Since working with creative industry partners and other academic institutions, the first-hand experience of working in a group to bring ideas to life has shown the difference that comes by not working in a purely academic vacuum. Not to say that research cannot come from this place, but that from a design perspective without the external provocation it is easy to remain in a safe space of research.

7.10. Conclusion

From the perspective of the thesis, this project looked at the ways in which people interact with digital objects to change the physical world around them, and found that people enjoy the ability to personalise the spaces they inhabit. The project also brought forward key ideas for the interactions that these objects should have, where the first version failed with its limited feedback ability, the second tried to rectify with a screen but didn't convey to the users what was happening, it wasn't until the third version that people truly understood what was happening and got to grips with the system with the tablet that they saw as the main point of interaction. In the future this could be expanded into differing methods of the community influencing their space such as changing light colours or influencing the state of windows or curtains to their preference.

8. Physical representing Digital

8.1. Introduction

This chapter will look at the CX project 'The Physical Playlist', a project was born out of one of the initial workshops run by the Lancaster CX group titled, 'Making the Digital Physical'. Based at The Lowry in Salford, this was a bringing together of researchers from industry and from academia along with creative sector workers. It was here that the idea for a sharable, physical playlist was conceived. A group led by Ian Forrester of the BBC R&D[7] department were the creators of this project, also involved were MakieLab[8] a company that creates bespoke 3D printed dolls and of course the Lancaster research team, this time led by Joel Porter another of the CX PhD Candidates.

The roles in the project were defined by Joel, who took lead in keeping the project on track, and I was made responsible for the model design, electronics and the code for the RaspberryPi/Arduino and I was helped with this by Adrian Gradinar who would also lead development of the Android application.

The inspiration for the project was the shared mix-tape which had an emotional and physical connection for people that digitally shared content often lacks. This connection comes from the fact that objects or artefacts often symbolize something more than their intrinsic value, and this is often preserved over the years. Our personal associations with objects often gain subjective meaning based on the memories and nostalgia that exists about them, although such memories are generally hidden and intangible (Csikszentmihalyi & Halton, 1981). Where once time was spent decorating the cover of the mix-tape[9] and carefully cultivating the tracks

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[7] http://www.bbc.co.uk/rd

[8] https://mymakie.com/

[9] A mix-tape is the name given to any compilation of songs recorded onto any audio format although it is primarily associated with the compact audiocassette.

and possibly taking upwards of an hour to make, it now takes mere seconds with digital services such as Spotify, where on average nine playlists are created each second[10]. Between the mix-tape and Spotify came the writeable CD but they came too late, or too close, to the emergence of the mp3 to become a shareable treasured object akin to the mix-tape. The project presented in this research resulted in the creation of a system, The Physical Playlist, that can be used to explore users experience of a physical shareable personalized object that has digital content embedded within it. Thus the project differs from those that have used objects as a means of storing memories, such as Memory Boxes (Frohlich & Murphy, 2000) or Stevens et al's Living Memory Box (Stevens, et al., 2003), as the object itself primarily represents the embodiment of the time and effort the creator took to personalize the gift thus making it more meaningful than a purely digital playlist.

8.2. Initial Meeting

The core idea going into the first meeting of the group after the project had been agreed to by the CX board was to create an object similar to the Mix-tape that would be able to play back new digital media. Different ideas were put forward, that suggested how a shareable playlist could be created while considering the need to make it portable leading suggestions to the idea that it would help if it were something wearable. As the project was to be created collaboratively a similar research through design approach as used throughout this thesis would be adopted, because it would allow all parties to reflect upon the design in an agile and emergent manner.

This initial meeting was used to bring together the collective ideas of the group and to rationalise them into a coherent plan. Coming out of the meeting the main requirements were set out for the project. These were,

- That the created artefact must be physical
- Should have some way of visually recognising where the playlist is up to.

[10] https://press.spotify.com/uk/information/

- The playlist should be built into a customisable item.
- The playlist should play in the order the creator prescribed
- That there should be no interaction needed with the player itself other than to turn it on.

From a project stand point, it was also felt that the code output and the device itself should be made open source, so that anyone with the wish to either build or alter the device for themselves could do so.

8.3. Design Requirements Research

Working through each of the requirements, beginning with the necessity of the player to be a physical moving device, several options were proposed. Firstly, a fruit bowl style player that worked by recognising the object in some way no matter how it was placed into the bowl, the bowl or its associated mechanism would revolve around in order to achieve this and the position of the mechanism would show the playlists position. Another option proposed was to be some form of vertical movement platform where the platform moved down the object and identified each part of the object as it moved and translated those pieces into playlist items. The third idea positioned the object on a Vinyl Record through which the arm of the record player would move across, identifying the parts of the object as it swept through it. Finally, the idea of repurposing an old computer scanner mechanism that would scan the object in a horizontal plane was proposed, and would feedback the position of the playlist based on how far through it had scanned.

Before being able to compare and contrast the proposals it was important to define what form the object would take. As the group had already concluded that the object could be some form of wearable object, the Lancaster group began by looking at common everyday items that people wear, in order to identify good candidates for what the form could be. People in general have many different habits for what they wear on any given day, it was important for the group to consider all possible users and therefore not exclude people from the outset. There were ideas floated that suggested customisable watch straps, though it was pointed out that not all people wear a watch. Necklaces were considered but felt that it could be quite a bulky item for someone to wear around their neck. NFC rings already existed and could be repurposed for the project however they offered limited personalisation ability and would be difficult to show the progress of the playlist. The group eventually settled on the idea of a customisable bracelet, where individual playlist items could be treated as charms and customised individually.

The proposed ideas were then scored for their practicality, feasibility and how well they met the requirements.

The first idea of the Fruit bowl with a revolving reader at first was thought to be an elegant solution, however while working the idea through within the group several issues came up that would either substantially delay or change the central themes of the project. For example, the revolving reader could be made to spiral around the bowl, however the order in which it would discover the playlist could not be guaranteed. It was also felt that creating this mechanism which would be a great artefact when finished would be quite labour intensive to build and within the short time frame of the project, this was not a feasible suggestion. A different spin on this was proposed such that the jewellery would be recognised as it fell into the bowl through some sort of reading device, this would be quicker to build as the reading device would be static, however it would now not show some form of playlist position in a meaningful way.

The vertical movement platform from initial discussions and designs quickly became a favourite as it allowed for the reading of the playlist in a set order, had a physical presence and could show the position of the playlist. An example mechanism was quickly sketched out showing the movement of the device; A central threaded rod would be rotated through a set of gears which would raise or lower a platform that was guided vertically by two supporting rods. This design in contrast to the last would allow for a much faster route to testing as the mechanism was not as complicated and could easily be customised to create an artefact with both function and form.

The use of a record playing mechanism to create the player would decrease the build time by a great deal, however it would increase the amount of time that would be needed to be spent creating the mechanism/code that would control the record player arm so it would be able to recognise each part of the jewellery. The length of this process was evaluated to take longer than the previous example without added benefit to test the initial idea.

Finally using the flatbed scanner mechanism would perhaps be the fastest route to testing the idea, however it would severely limit the options for customising the final product were the idea to proceed.

Artefact Type	*Design*	*Feasibility*	*Practicality*	*Features Met*	*Total*
Bowl Type	5/5	2/5	3/5	2/3	12/18
Vertical Movement	3/5	5/5	4/5	3/3	15/18
Record Player	4/5	3/5	3/5	3/3	13/18
Flatbed Scanner	2/5	5/5	4/5	3/3	14/18

Table 2: Evaluation of Artefact Options

The vertical reading system was decided upon and although other options were close in score, the project timeline wouldn't allow for the building of several options so the team had to move forward. A method for storing data within the jewellery was required, for the intended use, the team collectively came to the decision that NFC would be the most suitable medium for storing the data on the jewellery and then relaying the data to the reader. This conclusion came about after discussing what would be required of the storage device. The main point of which was that it would need to store a Unique Resource Identifier (URI) along with some way of describing the type of track that was to be played as this data would only be a small number of characters these could easily be stored within an NFC tag. After deciding upon NFC tags as the bearer of the playlist, a method of personalizing the tags and then reading them back to play the associated media would have to be created. The tags chosen needed to be relatively small and robust, in the end a 14mm laundry tag was settled upon. Given its resilient nature and small footprint it was ideal for the application, as the jewellery it is attached to may be worn out and about in diverse environments.

In order to allow these tags to be removable and orderable, some method of attaching the individual components together to make a bracelet, however it had to be possible to create using the resources at hand, i.e. a Laser Cutter or 3D printer. Several options were considered; using a ball and socket joint that could rotate around and be coupled/decoupled to create a bracelet where the tag would be removable by a simple receptacle with a guide on one side and a peg on the other to attach to the bracelet, or using the same receptacle push it through a fabric bracelet with corresponding holes cut out or bracelets that held tags within their structure.

To increase the speed at which a prototype could be developed, the simple fabric bracelet was settled upon.

Using Research through Design and Action Research principles, fast prototyping would be used to create a quick mock-up of the initial idea for both the reader and the jewellery. This stage of the research would involve using rapid prototyping technologies such as the Laser Cutter and 3D printer.

8.4. First Round of Prototyping

8.4.1. Physical Prototyping

For the initial prototype, a quick sketch was drawn out within the Lancaster research group and can be seen in Figure 24, this rough sketch was converted into a vector based drawing on a computer that could be sent to the laser cutter which then cut through a piece of Perspex to create the components of the base and moving platform. Constructing the base from its component parts was a simple method of guiding the pieces together in the correct order and using bolts to secure them in place.

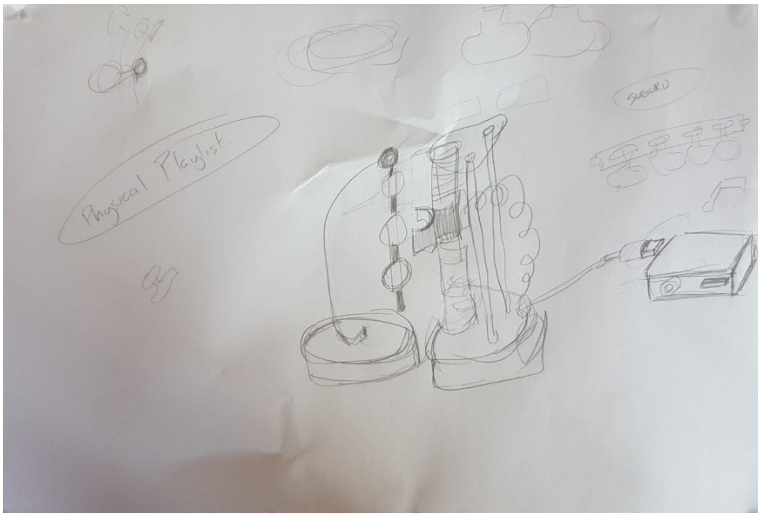

Figure 24: Sketch of Original Physical Playlist Design

A length of threaded rod was sourced and cut to length along with two hollow Perspex tubes that could then be placed into the base of the reader. It was here that the first issue with the prototype design was discovered. The depth through which the plastic and metal rods were allowed to travel through the top of the base was not deep enough to let them stand and so a new solution was sought where the rods would travel deeper into the base by creating a plastic washer inside the base that would guide the rods and hold them in place.

With that issue resolved in this prototype, a platform was cut out and had a threaded nut fitted into it that would allow the platform to travel along the threaded rod, this was placed onto the threaded rod and base. A motor and set of cogs were connected to test the prototype at this stage. While the motor was able to rotate the rod, the whole structure was unstable due to the placement of the bolts holding the base together, this was mitigated at this stage by affixing rubber feet to each corner of the base. With the base no longer rocking with the movement of the motor, it was noted that the rods were slowly moving their way out of their places. In order to solve this, two plastic washers were cut out that had the same inner diameter as the outer diameter of the rod but a greater surface area that were then glued to the top of the player. This stabilised the rods at the base, but the top was still unstable. At this point the solution was to cut out the same shape that supports the rods at the base and this time place it at the top with the same modifications that were made to the base including the washers. Finally, the platform could move without causing the player to become unstable this setup can be seen in Figure 25.

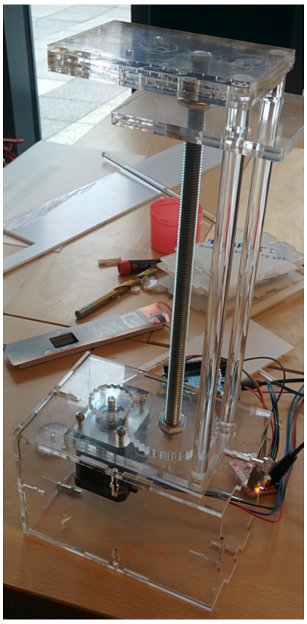

Figure 25: First Prototype

8.4.2. Software Prototyping

Using an Arduino and a stepper motor, control software was written that allowed the Arduino to rotate the rod at different speeds in order to move forward or backward through the playlist. At this stage another issue was pointed out, the problem being how to know when you were at the end or the beginning. The answer is fairly simple and the process has been used many times across several products, Limit switches. These switches notify the control software when the platform reaches a certain point, allowing the software to then reverse the direction of the platform.

The next stage was to connect the Arduino up to the NFC reader that would allow the selection of different media from the bracelets. Several ideas were floated including building our own antenna which would be highly customisable but difficult to make to look neat. Using an NFC breakout board, a development board that includes more options over the type of NFC tag that can be used or an NFC board that can only read a small number of tags but is self-contained and is compact. The decision made by the group was to use the smaller board and to then pick tags that would work with it as it would speed up development times.

Once the first version of the control software was up and running, a playback system was now required to show what the NFC reader had read. This was to be run on a RaspberryPi and as one of the playback formats was to be Spotify and having access to software that had previously been used with CheckinDJ it was decided it would be quickest to develop the software stack on top. In order to use the Arduino with the RaspberryPi there had to be a method of transferring information from one to the other. The Arduino has the ability to output information via Serial Communication, the process of sending one bit at a time in a stream over a communication channel in this case USB at a certain speed or baud rate. However serial communication can be prone to errors so it was necessary to create a protocol that could enclose the data to be transported in a way that could differentiate erroneous data. To that end a format of enclosing the data within Chevrons “<” and ”>”, therefore any other data could be ignored.

With the protocol and method of communication decided upon, all that was left for a viable prototype was to enable the playing of the media. This was done using open source software from GitHub called Youtube-dl and getiPlayer along with the Spotify software previously developed. With the code in a reasonable prototype state, it was decided that the next stage was to take the prototype whole to a meeting with the entire project group. While there were still issues to resolve having preliminarily tested the device it was at a stage where moving forward without the rest of the group would go against the process that had been decided upon.

8.4.3. Bracelet Prototyping

A collection of simple fabric bracelets were sourced and holes cut into them using a Laser cutter, allowing a receptacle to be pushed through the bracelet and held in place on the other side. This resulted in the definition of a widget to hold the requisite tag and after a number of design iterations in order to get the proportions correct and to make the design strong enough to receive the NFC tag without breaking shown in Figure 26, a widget was produced that fulfilled this purpose.

Figure 26: From Left to Right Widget Prototypes to Final

With the NFC tags suitably housed the next step was to create a means to turn this individual item into a playlist. A simple bracelet was chosen as shown in Figure 27 below, as each widget could then be customized to produce something akin to a charm bracelet.

Figure 27: Initial Prototype Bracelet

8.5. Prototype Evaluation Meeting

The working group came together to discuss the current working model, and how it could be improved, both in form and function, in order to produce an artefact that was capable of being tested with diverse groups.

While the group were happy with the overall function of the device it was agreed that there were still bugs that needed to be worked out and that the current form, while functional was not ideal. A 3D case for the player was discussed at this stage that would enclose the entire device, a decision was made to invite a 3D designer to join the group to create such a design but in the meantime the group agreed to a second version of much the same form but with extra design features, colours and rounded shapes in order to enhance the overall aesthetic of the device.

The group also brought to attention the need for some form of shaped "hanger" for the bracelet to be suspended from. This would facilitate the easy changing of the bracelet and its placement in front of the NFC reader.

The discussion moved towards the software and it was agreed that there needed to be some form of display that explained what was occurring. As an example, while demonstrating I was explaining that at certain stages while nothing was playing on screen the video was buffering in the background, so something as simple as showing "Buffering" on screen was suggested. As people are already comfortable with the term and would understand that something is occurring.

During the explanation of the software and its different stages, it was pointed out that the reader device would be of more use to potential other projects if there was some sort of method of controlling the movement of the platform via commands sent back through the same Serial connection used to pass the URI data. There was also worry that the device was too difficult to setup and get going, so a method of automating the start-up was also required.

Overall the group felt the project was moving in the right direction but that there was still work to do, especially if the device was to be put into the wild for user testing.

8.6. Second Round of Prototyping and Interface Design

8.6.1. Physical Prototyping V2

Starting back at the beginning, but not wanting to change the design too radically due to time constraints the redesign started with the base. Taking notes from the first version, there were several issues to resolve;

- The balance of the device
- The wiring
- Shape of the platform
- Shape of the device

To combat the balance issues, the placement of the screws that hold the device together was changed. By moving from a design with one screw placement on the base to three, it created a flat and balanced base.

Fixing the wiring require removing the breadboard from the circuit and a slight circuit redesign. But this simplification created a much neater interior to the device that with its transparency was sorely needed.

8.6.2. Software Prototyping V2

In order to allow for the changes discussed during the meeting, the Arduino code was the place to start as all changes would follow through from that point to the next. Discussions within the Lancaster group identified the most useful controls that would improve the devices portability to other projects down the line. The controls to be added were:

- Start – Rewind to first position and then proceed from there.
- Speed – Change the rate at which the platform moves.
- Stop – Stop and wait in current position until the next command.
- Fast Forward – Accelerate the movement of the platform and stop at the bottom.
- Scan – Scan for a tag at the current position.

- Delay – Delay the movement of the platform for a certain number of seconds.

To make this work a method of parsing the messages had to be created that could deal with the errors that can come through on a Serial connection as was done with the Pi software previously. This method then had to be called whenever a message was sent and the command dealt with before processing any of the rest of the control system.

With the changes implemented on the Arduino side the changes had to propagate to the raspberry pi for it to be compatible with the new software. As the Serial connection was already in existence in the software on the raspberry pi, it was trivial to add the ability to send commands in the opposite direction.

It was at this stage that the "rewind" rate was recorded, the time taken was compared with the time it takes a ninety-minute cassette to rewind and the platform speed calibrated so that it matched the rate of the cassette rewind.

Finally, other alterations were made to the software to increase its stability and then to change the operating system to start the application automatically on start-up.

8.6.3. Interface Design

The first prototype meeting also brought up the fact that there was no way of knowing what was occurring until the video or song began playing. This led to a conversation/design meeting of the Lancaster group to discuss the best method for displaying some form of interface that would allow the end user to understand what was happening and provide feedback.

A quick mock-up was created that showed a large drawing of a cassette tape, with the title bar blanked out so that text could be overlaid on the image to display the different states of the machine such as "Buffering: Youtube track", "Playing: Spotify Track" or "Rewinding", this can be seen in Figure 28.

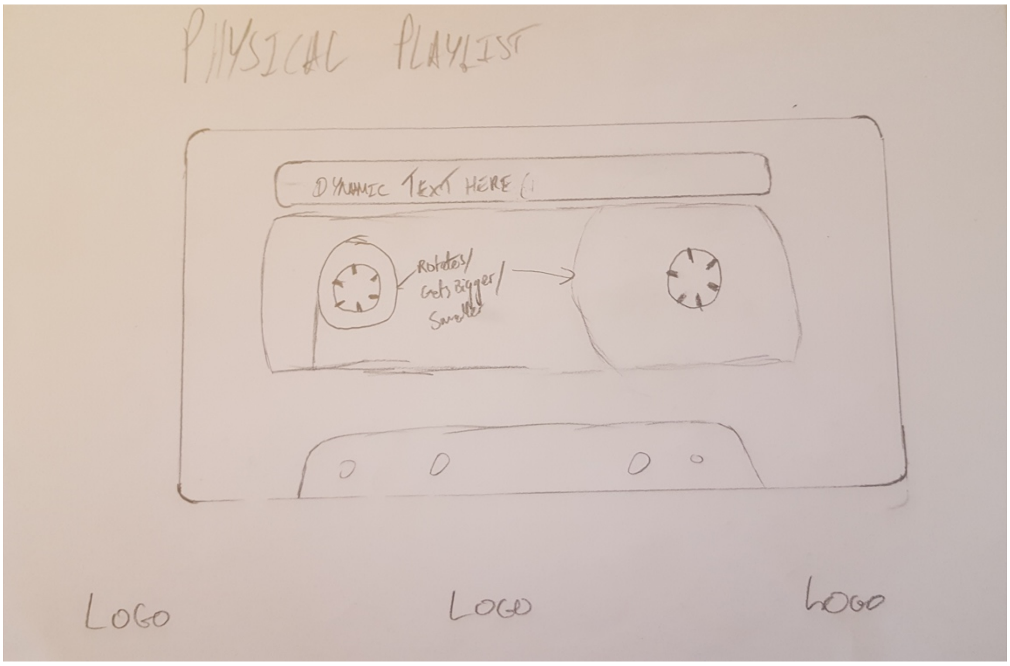

Figure 28: GUI Sketch

Along with the dynamic text, it was thought that the tape reels growing and shrinking in a way akin to how cassette tapes change as they are played.

All of this had to be written into the code for the application using GTK which is a framework for creating Graphical User Interfaces (GUIs). The interface in this format while relatively simple as the majority is static, with the exception of the dynamic text and the movement of the wheels. The text overlay was created using a Fixed layout and positioned with absolute coordinates. The creation of the animation for the rotating wheels was more difficult and two different methods were tried and tested. The first was to create a High resolution GIF (Animated Image Format), which was displayed on the screen under the text. The issue with this was that regardless of the resolution the output was created in the display on the screen was jagged and not up to standard. The next was to have a looping movie playing in the background. However, the issue with this method was that CPU usage was too high and slowed the rest of the application to a crawl, obviously this was unsustainable. A unanimous decision was that it would be better to have a high quality static image over a medium quality animated image that could harm the applications ability to perform its usual tasks.

8.7. Mobile Application Development

So that the creation of playlists and so bracelets could be streamlined the CX member Adrian Gradinar took the lead in the building and deployment of an Android platform application. This application could be used to write and rewrite the NFC tags on the bracelet. The “App” had a simple interface where one could fill in a search box with what they wanted to find and then simply select the service that they wished to search on, be that iPlayer, Spotify or YouTube. Later changed to only include YouTube and iPlayer due to licence restrictions. The “App” made it easy to explain to the users the interaction that was required to write onto the bracelet and after a quick demonstration most users could perform the task again without help from the development team.

The reason for only supporting Android is two-fold; one, that the platform is popular and at the time had a market share of around 80% (Edwards, 2014) and two that the platform allowed the open use of its NFC capability something that Apple still do not allow on their iOS products.

8.8. Final Evaluation Team Meeting

With the project at a stage where playlists could be created, customised and played back, the team felt it was the right time to bring everyone back together to go through the project and decide on how best to proceed from this point.

In attendance at the meeting were the BBC representative Ian Forrester and Jasmine Cox who is a part of the BBC R&D user experience group. From Lancaster, the team lead Joel Porter, Adrian Gradinar, Prof. Paul Coulton and myself. The team discussed the project and how it dealt with the original criteria that were presented right back at the first meeting.

The main requirements as set out for the project were,

That the created artefact must be physical and must have moving parts that show where in the playlist you were. The movement of the player was a key consideration of this project and the discussion led to the conclusion that while not ready for full scale production and sale, the prototype met the requirements set out and did so in a relatively simple manner. Comments were made on the overall design of the player object, and due to the success of the project at the Mozfest workshop Prof. Coulton suggested applying for further funding from The Creative Exchange in the form of a field trial grant to pay for a 3D redesign of the player by product designers.

The playlist should be built into a customisable wearable item, such as a bracelet or necklace. When creating the bracelet for the first prototype, the main consideration was to have a bracelet that would be easily customisable by the end user and while that objective was successfully completed, it did however leave the project without a clear design narrative that one could easily recognize that someone was wearing a bracelet. There were also comments that while functional the bracelets were not aesthetically pleasing and that perhaps the field trial funding could extend to the design of new bracelets for the player as well.

The playlist should play in the order of the elements of the piece of jewellery so that the playlist is experienced the way the creator had intended. As part of the way that the hardware and the software was designed, there is no other way for the player to play the songs. The player will only play each track on a playlist once, save for a user consistently pressing the lower limit switch to reset the player, which will allow it to start over from the beginning.

No interaction needed with the player itself other than to turn it on. After the previous discussions over how awkward the setup of the player was, the entire software side was restructured so that the player starts up and configures itself without user input apart from having to plug it in and attach the reader by USB port.

The code output and the device itself should be made open source. At this stage it was felt mainly for sake of the readability of the code that it would not be made open source at this time but further down the line when it had been cleaned it would be.

Overall the project partners felt that having had good reviews of the project when it has been in the wild and the report from the masters' students' evaluation that they were happy to sign off on the project, but would be applying for further funds to enable the creation of a final display quality design that could form the basis of a product.

8.9. Workshops and in The Wild Testing

8.9.1. Mozfest 2014

The customizable physical shareable and a bespoke media content player were taken to Mozfest 2014 for preliminary evaluation where participants were invited to create and play their own bracelets. At the end of the exercise 24 of the participants completed a simple visual tool to indicate how they currently share data and how likely they are to share that data in the future with different peer groups. The tool was designed to encourage comment and debate and enabled the researchers not only to ascertain that the users were able to create and play the produced objects easily it also drew information from the users which suggested that in the future they would be more likely to share a larger amount of personal information with friends and family if it were embedded in a physical object compared to current social network platforms.

In terms of the acceptance of slow technology perhaps surprisingly the younger participants enjoyed that they couldn't skip a track and had to listen in order whereas the older participants wanted to rush through and get to the next part faster. This buoyed the development team in the decisions so far, as for the younger generation they seemed to really like the idea that a friend would have to listen to their compilation in its complete form. Whereas for the older generation it acted as a provocation and got them reminiscing and contemplating the way in which media is consumed.

8.9.2. Masters Design Students Workshop

To test the projects robustness and general usage, the second prototype and the associated application were handed over to an independent Masters student project for evaluation. The student took on the project from the vantage that the physical playlist as a whole was ready for mass production and sale, as this was not the case with it still being in a prototype stage the opinions posited by the paper do not always truly reflect the correct state of the project, but do point in the direction that the project should move should it become financially and practically possible to take the project and make it market ready.

The workshop results that were shared with the project team showed promise in that as part of the workshop the participants were invited to design and create their own bracelets/playlists. The participants apparently took great care and attention over the curation and creation of their playlists and the decoration of the bracelets and many already had a recipient in mind for the playlists while creating it.

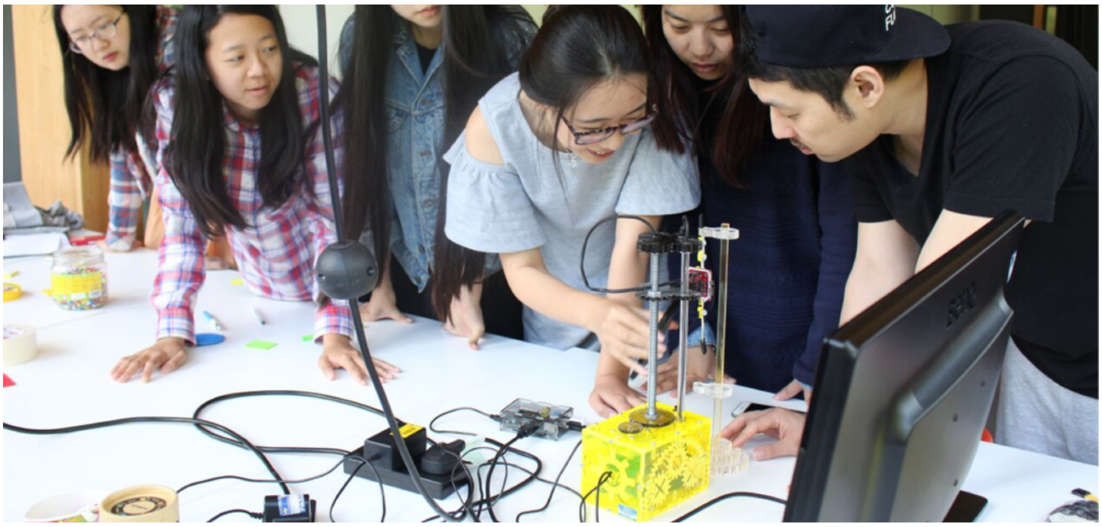

Figure 29: Workshop Participants Investigating the Player

The participants were introduced to the project without fanfare or instruction and asked what they thought the Physical Playlist Player was. This was performed to determine if there were any clues in its design that could point to what it might do. Out of the responses gathered from the participants only one correctly deduced its use. Others gave responses such as ‘electric generator’ or ‘printer’. As the project would be a brand new product without a direct competitor in the field it is understandable that first-hand knowledge of how to use or what the physical playlist is, does not exist in the common parlance. That being said once users understood it’s utility they were able to use the player to play back their playlists and create new ones easily. The masters’ student suggests that this is due to the perceived affordances of the object not being the correct affordances for how to use the object. Upon examination of the method of how this was tested, which was that the player was presented to the participants as an individual object disconnected from any screen or output device, the reasons for the confusion become clear. The understanding of an object out of context is not trivial however the learning curve that has been seen from other experiences such as at Mozfest have suggested that actually while the innate understanding of how to interact with the device does not exist, once given the explanation that each NFC tag can represent any song or video people quickly pick up on the workings of the device. Though what the workshop did point out is that whilst interesting from a design/prototyping perspective, the actual inner workings of the device can distract from its function and that perhaps by hiding this and allowing the user to see the device as a whole, with a bracelet in position and playing a playlist would show the appropriate affordances.

8.10. Final Player and Bracelet

8.10.1. Final Player and Bracelet Design

As discussed previously, 3D designers were commissioned to create designs for new bracelets and a new housing for the player to bring it more in line with a production piece. Joel Porter took the lead in finding a designer for the new bracelets, while Prof. Paul Coulton suggested another PhD student to create the design of the housing. Both of these design stages involved all members of the team, with specifications and drawings being constantly disseminated and shared between members.

During the design stages several prototypes were printed and sent from the bracelet designers and by working closely with the housing designer several small scale models were able to be tested using the departments 3D printer. It was through these prototypes that it was determined that several of the options just weren't suited to the purpose that they were meant for. The bracelets had issues with breaking or being unable to hold the NFC tags without snapping their retention brackets. The housing model had similar troubles, but due to working in the same building as the designer in this case much more rapid progress was able to be made. The first issue to come to light was that the design of the ovoid structure, while attractive did not allow for much stability, which was a worry as the motor that would be held within could potentially cause the structure to wobble.

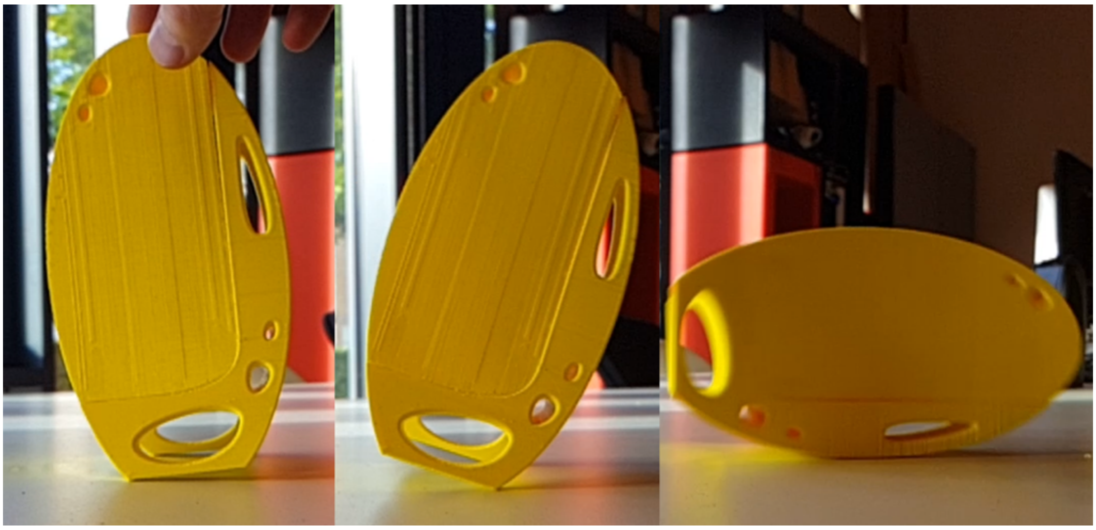

Figure 30: Slow Motion Stills of 1st 3D Prototype

By printing a small quarter scale version of the housing out this was exemplified by the slightest of movements from its centre of gravity causing it to rock and eventually tip over. This was rectified by adding a small lip to the back of the design, so that with the added weight of the motor and assembly inside the housing would no longer fall over. This was tested again by printing a slightly larger version, this time at 47% scale.

Following the rounds of revisions based on experience from the design of the earlier prototypes and the test printings, designs were ready to be finalised and sent to be printed. The bracelets would be able to be printed in house at the designer's studios, however the scale of the housing only allowed us to print up to 47% in house. Which would not be able to scan a bracelet that would fit around an adults' wrist. In order to print the housing, it was therefore necessary to find a commercial 3D printing company able to print at the scale required. After contacting several different companies and discussing with them the size of the print and the qualities of the materials that would be required from them, the only one company was found that could handle the scale, material and timeframe requirements. Laser Prototype Europe (LPE)[11] were contracted to fulfil the printing order, following discussions with their engineers and technicians about the proposed prints, several issues were identified within the models that had been created for the housing. They noted that several points of the model were thinner than 1.0mm and that it would be possible to go for a better finish and use a stronger material at a better price point.

It is worth pointing out that while these are being called final designs, they are not being produced in the manner that they would if the project were to reach full scale manufacturing. However, as the cost to set up full scale manufacturing of the model would be so exorbitant it made sense to have the model 3D printed.

[11] http://www.laserproto.com/

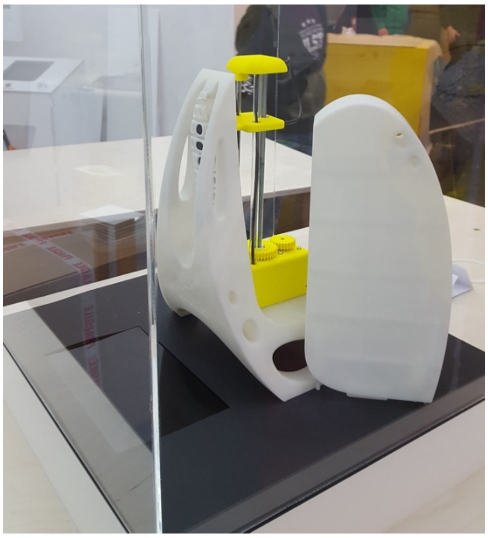

Figure 31: Final 3D Design of The Player

The final model is shown in in its display case at FACT Liverpool for the CX Final Show. The interior was redesigned to fit in with the new sweeping design, great care was taken to design the wiring such that connections as much as possible are hidden, with internal cable routing for the limit switches and for the NFC reader allowing smoother lines and more secure wiring solution.

8.10.2. Final Player and Bracelet Evaluation

The final build of the player and bracelets created a state where the project is in a position to be displayed for the purposes of The Creative Exchange, however there are a few issues that remain with the latest version. The chief amongst them is that the movement mechanism jams sporadically, as this was never an issue with the original model it does appear that some of the changes of the newer design have brought about this issue. Any future designs would have to take note of this, so as not to cause similar issues down the line. Another issue only discovered when in the final assembly of the unit is that the NFC reader is unable to read through the plastic to the depth of the position of the bracelet. This was not expected as the NFC reader is typically capable of reading at a distance of 6cm through thorough testing prior to the original build. The distance between the reader and the NFC tag in the bracelet when hung in the player is ~ 5cm. The solution to this is not apparent but may require cutting larger holes into the plastic as moving the bracelet backwards further into the model seemed to have no effect. While these are issues that need to be accounted for in any future designs, they are purely part of the process involved in prototyping any new type of hardware which are in line with the processes set out in the way that CX projects are approached.

Figure 32: Final Player with Final Bracelet Hanging in Place

Figure 33: Final Player with Final Black Bracelet

8.11. Discussion

Whilst the original mix tapes offered elements of personalization from the sleeve of the case to the cassette itself, the flexibility of the potential objects that can be combined to form a physical playlist is considerably greater as they can take almost any form. Further, as the playlist is digitally enabled they can also be made to use other information, for instance they could be made so that they could only be played on a specific day, such as a birthday, or at a specific time, or when the weather is warm and sunny, thus allowing the creator to produce a very unique personalized experience. The media used within the playlist is also not limited to those which have already been chosen, with little modification to the software on the RaspberryPi and the Android phone, other sources could be used such as Vimeo or potentially Netflix.

The adoption rates when the player has been in residence in the BBC kitchen, at Mozfest, at the Masters workshop and at the CX Showcase event, show that the attraction to the novelty and the decorative aspects of the project offer something that is not currently available on the market. While that was not the intention of the project at its outset, it is a welcome outcome that may allow the project to move on further in the future. As was shown in the case study performed in 2006 by Nokia on one of the earlier smartphone systems that the ability to customise and curate one's phone is very important, a trend that has only continued into the android and apple ecosystems. (Häkkilä & Chatfield, 2006). This personalisation level is just not available in the digital media world, you may be able to curate the list and decorate the page on which the playlist appears, but there is something intrinsic in the act of curating a physical object as a gift that has more of a connection to others than a purely digital form (Petrelli & Whittaker, 2010). As the paper discusses it's not that people view them as completely irrelevant it's more that they feel that the physical object has more of a presence than the infrequently accessed digital equivalent.

It is believed that the advent of 3D printing coupled with readily available means of embedding digital content in any number of custom physical objects has enormous potential in creating new ways of sharing and this project offers a glimpse of the potential of this.

8.12. Conclusion

The project from the CX perspective was a success as it brought together the BBC and Lancaster University in a collaborative project that has gone on to foster relationships and has enabled both sides to gain and transfer knowledge in a space that allows for innovation and creation.

Figure 34: Workshop Participants Playlist Bracelets

From the perspective of this thesis it has given insight into the way that people perceive the digital and the physical, while the original design of the bracelets and their customisation options were minimalistic, at all events where people were given the opportunity to create their own bracelets and the objects that adorn them the perception of the objects were those of glee and interest. A large number of the bracelets have been produced and given out as gifts to those who produce them, even though they lack the ability to play the media stored on their bracelets away from the player itself. This personalisation of objects that store digital data is likely to be a big move in the coming years, while storing data on your devices is convenient it doesn't offer any information to the holder of the object of what is stored inside while a simple customisation would allow people to personalise objects which then may hold more of a personal attachment to (Petrelli & Whittaker, 2010).

It is important then to understand that the customisation of these digital objects has a great impact on the perception of the users and having this in mind while designing the objects for use will serve the objects well through high adoption rates.

9. Digital/Physical representing Physical/Digital

9.1. Introduction

The origins of this project date back to 2003 when the villagers of Wray, who had been campaigning for broadband to be made available to their community without much success, approached Lancaster University for help. In 2004 a new research project that involved the university and the community building a new wireless mesh test-bed within the village was initiated.

The project has had a considerable impact, not only in terms of academic research output but, more importantly, in terms of its social and personal impact. It has enabled approximately 100 rural businesses to get online and provided 230 families with free internet access after years of campaigning for a connection. It was the first project to be developed by the RuralConnect Living Lab and has facilitated the investigation and understanding of the 'real world, real time' impact of numerous interventions.

This particular project was initiated as part of the EPSRC's 'Telling the Tale of Engagement' and in the spirit of the original project it achieves this through two novel design interventions that form part of the village's main cultural event, an annual scarecrow festival that takes place in May. The interventions are an interactive digitally enhanced scarecrow, which will participate in the festival, and a novel mobile augmented reality (AR) application to allow visitors to experience both the current and past scarecrow festivals in a playful way. In this project the design and development of the mobile AR application known as the 'scARrecrow Time Machine' and the interactive digital scarecrow known as "ScareBot" will be considered.

While not a formal CX Project, ScareBot and the scARecrow Time Machine App were both supported by CX and followed the same trajectory and were ultimately adopted by CX as it showcased the potential outputs for other projects. In this case the team consisted of members from a singular university, a great deal of influence came from the village of Wray, both in the form of designs for the ScareBot from the children of Wray's Primary School and from the community leader who helped the group understand the reasons for the scarecrow festival and had great knowledge of the surrounding area for the AR application.

The two parts that make up the overall project are both aimed at different audiences, while the ScareBot will be primarily used in a static fashion, being presented at events and the Wray Scarecrow Festival the App will be able to be used by any and all people regardless of location.

9.2. Background

AR is a term often used simply to describe the augmentation of real world objects and environments with virtual data, although the more specific description used within the research literature is the registration of computer generated graphical information on the users' view of the real/physical world (Wagner & Schmalstieg, 2006). This places AR on the virtuality continuum (Milgram & Kishino, 1994) , which is a continuous scale ranging between the completely virtual, and the completely real, reality. The space between the two limits is generally referred to as mixed reality and AR represents a particular point on that continuum. Ronald Azuma provided the first clear definition of AR systems (Azuma, 1997) as exhibiting the following characteristics:

1. combining the real and the virtual;
2. interactive in real time;
3. and registered in three-dimensions (3D).

Mobile AR provides this functionality but without confining the users' operation to a particular location and is generally further sub-divided as either Wearable AR or Handheld AR. Wearable AR utilizes Head Mounted Displays (HMD) to provide an immersive view. Whereas in Handheld AR a device (typically a mobile phone) is used as a 'magic lens' through which an alternate non-immersive perspective on the world is provided (Copic Pucihar & Coulton, 2013). Handheld AR has generally been viewed as more practical for wide-scale adoption than Wearable AR as mobile phones supporting the required sensors are so widespread, and HMDs have been criticized for limiting the field of view, comfort, and inducing motion sickness. Despite proliferation of Handheld AR, the launch by Google of the Googles Glasses and by Microsoft of the HoloLens means that it is not yet known which incarnation of mobile AR will ultimately dominate. Whatever the type of AR the processing pipeline for AR applications is:

1. Get video frame from the camera.
2. Estimate position and orientation of the camera.
3. Render the virtual objects onto camera view.
4. Render UI to process the user input.
5. Update the application, then repeat.

The significant difference in the implementation, and consequently their operation, comes in the estimation of the position and orientation of the camera that is generally referred to as pose. Sensor based pose estimation approaches take advantage of increasing numbers of sensors such as Global Positioning System (GPS), accelerometers, magnetometers (digital compass), and recently gyroscopes on commercial mobile phones. Combining the readings obtained from such sensors allow the position and orientation of the phone camera to be estimated (Kähäri & Murphy, 2006) in relation to 3D space. Such systems are relatively easy to implement and are the basis of many of the AR browsers currently in the app stores such as Layar[12] and Wikitude[13]. The main issue with sensor based techniques is that the use of GPS limits the approach to outdoors and the accuracy can be highly variable due to spatial scattering which will ultimately impact on the contextual sensitivity of the applications developed (Bamford, et al., 2008). The simplest and most widespread of the vision techniques involves the use of two dimensional (2D) fiducial markers to provide a pose estimate relative to the environment (Wagner & Schmalstieg, 2007). The problem with this approach is that the narrow field-of-view

[12] https://www.layar.com

[13] http://www.wikitude.com

of many mobile phones cameras can cause significant issues when tracking markers in a real world environment and when coupled with the practicality of covering the world with such markers limits the possibilities of how easily it can be deployed. The alternate approach is natural feature tracking which uses natural occurring features within the environment to produce the reference plane (Klein & Murray, 2007). However, this comes at the expense of high device processing which is always an issue when implementing mobile AR (Wagner & Schmalstieg, 2009). Whilst there have been a number of systems developed using natural feature tracking on mobile devices (Wagner, et al., 2008), (Klein & Murray, 2009), many have required apriori knowledge of the environment to create a reference map. Recent research has shown that Simultaneous Localization and Mapping (SLAM) techniques, originally developed for robot navigation, can be successfully applied to natural feature tracking and positional estimation (Davison, et al., 2007), to create a more dynamic system. However, there is some way to go in adapting these techniques such that they can be implemented on current mobile phones. In relation to this research the discussion will be limited to projects that have utilized Handheld AR for outdoor use. Although many early applications combined PDAs with external sensors it is only relatively recently that cameras, GPS, and compass (magnetometer) have been combined within a single devices and that the Mobile Augmented Reality Applications (MARA) project from Nokia (Kähäri & Murphy, 2006) that coupled the required sensors directly to the phone, most closely matches what can be achieved on current devices. Applications using point of interest (POI) data is probably one of the most commonly occurring themes in mobile but in the case of this project the playful history tours of most relevance are REXplorer, that used phones to create a gesture based POI tour (Ballagas, et al., 2007), and Guided by Voices which was an audio tour featuring wizards and trolls (Lyons, et al., 2000). In terms of playful augmented reality tours, TimeWarp created for Cologne is the most relevant (Herbst, et al., 2008), although it used HMDs and users suffered a number of technical issues which means it was never released publicly. In relation to the design of the interfaces all used traditional maps as the primary navigational aid. In terms of Handheld AR experiences released in the wild, the augmented reality game Free All

Monsters (Coulton, et al., 2010) is of most relevance as it coupled POI information with a game design that drew upon the family friendly experience of Geocaching to promote exploration and social walking. However, only the early prototype of Free All Monsters provided solely AR navigation (Coulton, et al., 2010) and this was rather simple use a hot, warm, cold icons to give a relative distance without direction as there was no compass available on the device used at that time.

9.3. scARcrowTimeMachine

9.3.1. Development

The emergence of the Internet and networked media has opened cracks within the chronological representations of time allowing memories and stories to seep back through to the present. The aim of this application is to exploit this effect by allowing visitors to select a festival year to experience and then displaying scarecrow images from that year at the relevant locations as they move through the villages, thus, allowing them to traverse both time and space.

Figure 35: ScARecrow Time Machine App Screenshots

As the application created in this project is to be used outdoors in the village where the buildings are generally well spaced and not above two stories in height, a sensor based system was deemed most appropriate. In terms of the application design it was decided that only an AR view would be provided and not combined with a traditional map view as in many AR POI applications. This was done in order to evaluate the design challenges that must be considered if AR navigation becomes commonplace for pedestrians through either phones or AR glasses. One of the design challenges is to provide a sense of depth (distance) within the AR view. To this end, a number of common art techniques for adding perspective to 2D visualisations have been utilised as shown in Figure 35(b) and together these go beyond the primary use of size and scale in the majority of geo-spatial AR applications.

One of the design challenges is to provide a sense of depth (distance) within the AR view. The grid provides linear perspective by creating a vanishing point, which is enhanced by adjusting the size and scale of the scarecrow icons that also utilise atmospheric perspective by adjusting their transparency. To avoid clutter within the AR view the scarecrow icons traverse along three horizontal lines that represent distance ranges as the phone is rotated. The only distance shown is that from the user to the closest scarecrow, which is shown by a different coloured icon. When the user gets within five metres of the position the icon changes to a fully-fledged scarecrow and the photo button is activated as shown in Figure 35 (c). The photo view is also an AR view, shown in Figure 35(d), and shows the name of the scarecrow, its builder, the year it was made, alongside a photo of the scarecrow. The image is deliberately set to one side to allow the user to take a photo that could include themselves, their family or friends, or indeed the current scarecrow alongside the image. These users' photos are stored in the list view, shown in Figure 35(e), which is accessible from the main screen and provides a history of the users' interaction shown in Figure 35(f). As an important aspect of the project is 'tell the story' of the project to a wide audience the application can also be used outside of Wray. The application uses a geo-fence around the village so that if a user is inside the fence the scarecrows are shown in the actual location where they appeared, otherwise they are randomly distributed around the users' location. To enable the villagers to update the application to include scarecrows in future years a simple image management portal is provided that allows new images to be uploaded along with all the relevant context information (name of scarecrow, location, date of creation).

9.3.2. Evaluation

To investigate whether users are able to successfully navigate using the AR only navigation to find the scarecrows a user study was undertaken. It was decided create a specific version of the application in which five scarecrows were distributed at specific locations. The study involved ten users over a period of five days at Lancaster University and they were aged between 21 and 50 of which 70% were male. Note that while the names of the scarecrows were changed from person to person the five GPS coordinates remained the same. The users were asked to use the iOS application to guide them towards each of the scarecrows using the instructions provided within the application. The instructions stated that the closest scarecrow is represented as green on the screen and the distance to this scarecrow is shown below the scarecrow overlay. Each user began their walk from the same place but were left free to choose which order they collected the scarecrows. In the background the application recorded the users GPS position, their direction bearing, time, and the capture of a particular scarecrow at the frame rate of the application. Note that each user was followed during the test but no interaction or help was given. To evaluate the details of the users' navigation the data captures, use of space-time paths was adopted (Coulton, et al., 2008) as they illustrate how a person navigates their way through a spatial-temporal environment and are thus well suited to the evaluation of location based systems (Coulton, et al., 2008). The physical area is reduced to a two-dimensional plane with these dimensions representing a person's top-down position (e.g., longitude and latitude). Time is represented by the vertical axis. These three dimensions combine to form a world representing a specific portion of space and time. The path of a stationary individual will appear as a vertical line between the starting and ending times at a specific location. If an individual move between two geographical locations at a constant velocity, the graph will show a line with a fixed trajectory that joins the start and end points. The slower an individual travels, the greater the lines vertical gradient. Therefore, the vertical gradient of the plot is inversely proportional to the user's ground based velocity.

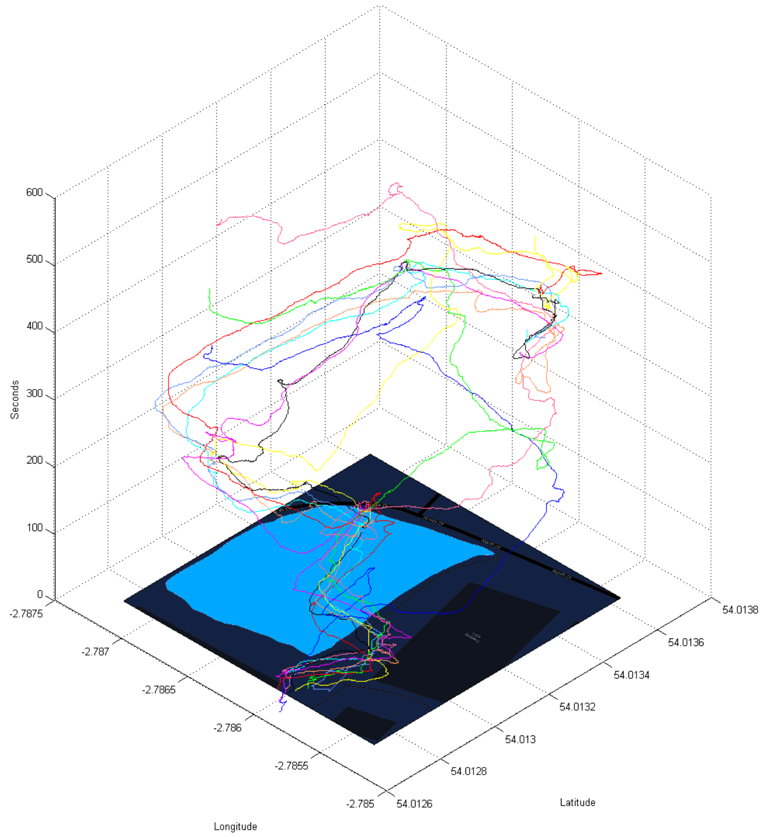

Figure 36: Space-Time Paths for All Users

Figure 36 shows the space-time paths for all the users in the study with each user represented by a different colour, this map illustrates how different people interpreted the AR map and what the best route to the next scarecrow was. A map of the area is shown on the base of the plot with buildings shown in dark blue. The large light blue area indicates a woodland through which an un-surfaced path ran which is not shown on the map. Using such plots, it was easy to establish that whilst 70% of the users spotted the scarecrows in the same order the route through they took was often very different. To illustrate this more clearly Figure 37 shows separate space-time paths for four different users. In these figures the green line is the route, and the red labels are the names of the scarecrows at the point at which they were spotted. Note that the top two paths show two users who collected the scarecrows in the same order but took a different route in particular whilst one user decide to take the shortest path through the woodland the other decided to take the paved route which went round the woodland. The other two plots represent two of the users who collected the scarecrows in a different order. Whilst it may seem strange the users took a completely different routes if they all started from the same point and all five positions of the scarecrows was fixed it is most likely due to the fact that these users performed the activity on different days when would be different as the GPS satellites would be in very different positions causing differences in the spatial scattering (Bamford, et al., 2008) which affects the accuracy of the positional information.

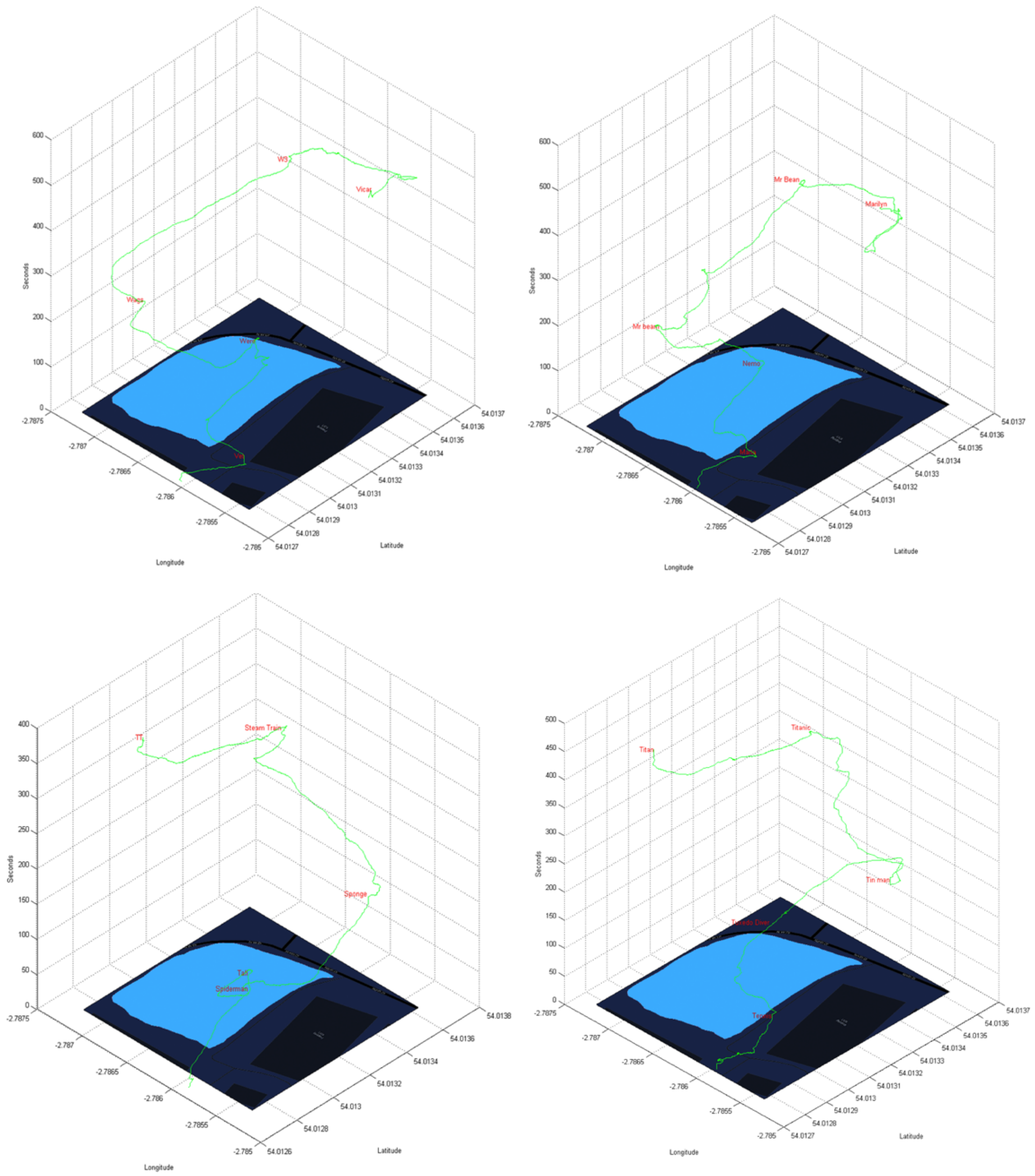

Figure 37: Space-Time paths for Four Different Users

Whilst the GPS data provides part of the navigational information from the users the bearing information provides an insight into how easily the users were able to navigate through the space using only this AR view. Figure 38 shows the space-time path of one user that has been augmented with bearing information. In this figure, the red numbers represent occasions where the user has turned through an angle greater than 40 degrees in any one second and blue text represents the location of the Scarecrow. Note that 40 degrees was chosen as it allows us to only consider points outside the average deviation observed from all the user data.

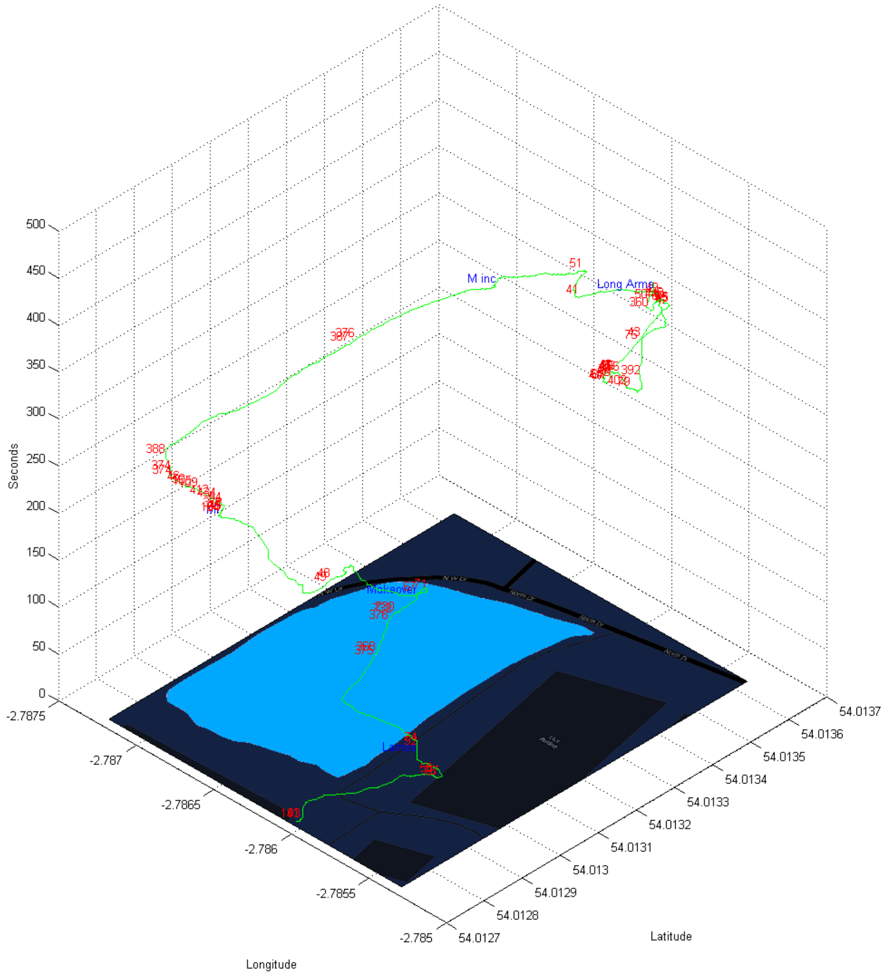

Figure 38: Space-Time Including Points of Significant Bearing Change

From this it was apparent that these points appear to be clustered around the positions at which the users get close to the scarecrows and immediately afterwards. This was not the expected outcome prior to the user's trial as it was thought that these would be more prevalent after capture when the user was searching for the direction to the new scarecrow. However, this tallied with our direct observations of the users which revealed that on some occasions when the users came in close proximity scarecrows the scarecrow would suddenly disappear from the field of view (FOV) shown on the phone screen and the users would turn quickly in order to find the scarecrow once again, sometimes going through multiples of 360 degrees. Upon reflection of this effect it was considered to be a result of the interface design that currently does not adjust the represented FOV on the phone screen as the user gets closer to a particular scarecrow.

However, this was not the only reason users rapidly changed direction as it was also observed to occur when a user holds the phone and does not use the screen for guidance instead relying on guesswork from the distance guide to estimate where the next scarecrow would be. These users often dropped their hand holding the phone to their side and did not concentrate on keeping the closest scarecrow front and centre on the screen. This may have been a result of these user's experience when navigating using traditional paper maps although this could not be verified from the data captured during these trials and would require further studies.

9.4. ScareBot

9.4.1. Development

The digital scarecrow was conceived from the drawings produced by children at the 2012 festival, a number of which featured a robot, which then became the basis of the design for ScareBot.

The ScareBot stands at 2.5 metres tall and is fashioned from red and yellow transparent acrylic. ScareBot incorporates as wide range of technologies including an Android tablet, a Raspberry Pi, an Arduino, and LED lighting. ScareBot can be interacted with in a number of ways: he blows bubbles from his feet when you send him a text message, and will also text you back a thank you which includes the current date time and weather where he is located; he can play a wide range of sounds using NFC tokens; and you can put your own face on the tablet that makes ScareBot face using the webcam on his arm. ScareBot was taken to the festival in 2013 and proved a huge hit with the children[14] and will now take him on tour to tell the tale of the engagement with Wray.

[14] http://imagination.lancs.ac.uk/news/ScareBot_goes_Wray_Scarecrow_Festival

The construction of the ScareBot was made possible through the use of the Laser Cutter in the department, and it was through this project that lessons were learned on how best to use the machine and how useful it is for rapid prototyping. Using the sketches provided to the group by the children of Wray a common theme of blocks for major parts of the body with thinner rods interconnecting them. This design was translated to having box structures for the chest, pelvis, head, hands and feet, with large bore tubes connecting them. The bore of the tubes was an important consideration as it would be necessary to run wires through the body much like a nervous system to connect the disparate parts. Though the design did not specify it, it was decided to place the 'brains' of the ScareBot in its chest this gave the ScareBot an interesting presence as the lights within the chest would glow when an interaction was occurring.

The Arduino software in the ScareBot was used to switch relays that controlled the bubble blowers' states. The Arduino was used over a straight connection to the RaspberryPi which would check a database every 5 seconds to see if there was a new text message to respond to. Later on this was further added to so that the bubble blowers could be manually controlled from a web page. Following the completion of the ScareBot the team learnt how to control the relays directly from the RaspberryPi however as the ScareBot was complete it was felt best not to change it at this time.

One major complication of the project came with the use of the Webcam to project peoples' faces onto the screen of the tablet. An Android Nexus tablet was chosen to be the display for the ScareBot as it could be charged and used simultaneously, it would also be able to send text messages as the response to people messaging it. However, when attempting to connect the tablet to a Webcam a problem emerged that due to a quirk of the system the camera would not always display and a certain start-up procedure had to be followed strictly to get the camera to show on the screen. This more often than not would also fail and so the ScareBot could take a long time to setup and get into a mode where it could be interacted with using all of its functionality. From many hours spent evaluating this, there appeared to be no clear reason as to why the camera would not work but as it could be made to work and was a key feature of the design it was decided it would be left in.

9.4.2. Evaluation

As the ScareBot was primarily built for the Wray Scarecrow Festival this was its first outing. The festival which generates a large income for the village each year, continues to grow and attract new visitors. At its unveiling the ScareBot was adored by the school children who could see their design elements take form, with younger children and animals especially interested in the bubble blowers.

Figure 39: Children interacting with the Scarebot at Wray scarecrow festival

One thing that was not considered prior to the festival was the transportation of the ScareBot to the location where it would be used, in a field. This posed its own issues as the track to the field was particularly uneven and so a lot of care was required while moving to ensure no damage was done to the ScareBot, something that would need to be considered for future displays. Following a successful day at the festival the ScareBot was retrieved in order for it to go on display at other events. It was at the first of these events, the launch of the welsh equivalent to CX, that damage was dealt to the ScareBot which caused its head to become detached from its body. The design had a flaw that caused stress on the neck joint and the Perspex tube was unable to take the strain. A quick fix was made in the field using solid rodding before the event began. The fix that was made held the head in place for the day but it was clear that this was not a permanent or in fitting fix, plans were then drawn up to fix the problem based upon the quick fix. By cutting plastic disks and placing them around the cracked area the head was mostly stable, but using just this would only cause another crack to occur further up. Not wanting to encase the entire neck in disks, three rods were glued into position in a triangular formation to support the head and reduce its rotational potential. Since this fix has been put in place the ScareBot has been on several outings for display purposes without incident.

Figure 40: Scarebot blowing bubbles at an open day

9.5. Discussion

Arguably, many current AR applications utilise AR as an interesting novelty presented alongside existing functionality and failing to address the challenge of designing new affordances that AR only operation requires. The project has considered the challenge of designing for AR only navigation through the creation of a playful mobile AR POI application created for a local village scarecrow festival. The current design has been evaluated using a combination of space-time paths and direct observation and reveal that the design approaches for providing distance perspective allows users to successfully navigate s given space without too much difficulty. This has clear implications for designers of such interfaces particularly in relation to the how the FOV is represented on the screen in relation to the users' distance from a particular point. Currently, the application does not address the challenge of encouraging or enabling long-term use, as its function is primarily one of raising awareness of the scarecrow festival rather than community building around the activity. If this was to become the focus then additional features such as: users being able to add their own scarecrows, tasks around specific groups i.e. all scarecrows from a particular place or year, likes, comments, etc. could be used, but this would reduce the prominence of Wray.

Building a 7ft tall robot is an interesting task for anyone to take on, but in this case it has been a real success for the project. The individual parts and the prototyping all came together to create a design piece that is enjoyed by all who have seen it. While there have been issues with its resilience to damage, these points have only brought to the forefront the need for iterative design and ensuring that the products are fit for purpose. It's not possible to foresee every eventuality however this project has helped to understand certain aspects of physical design and how best to approach creating a rigid structure.

9.6. Conclusion

Overall, AR is a useful approach for enabling users to interact within a mixed reality space and it is important for designers to consider carefully how it can be used as the primary mode of interaction rather than as a novelty as highlighted through the design of the scARecrow Time Machine application presented in this chapter. Whilst AR has most recently come to the forefront again thanks to PokémonGo the AR is limited to catching the Pokémon and is a feature that is turned off by many players due to the drain on the battery. Other recent attempts such as Microsoft's HoloLens have yet to materialise outside of the U.S.A but does have potential for having found the right interaction method, but only with user uptake can this be determined.

The ScareBot came out of a codesign group and has been successful in garnering interest and being a mascot for the project. Its design often attracts people to enquire and investigate further, one of the key points of the project. From a design point of view, this project was the beginning of the physical rapid prototyping featured throughout this thesis and much was learned through this project to take forward into the rest of the research.

Overall there are several ideas to be taken from this project to the manifesto, from the use of novel interaction concepts such as AR and the care and attention that must be paid in order to create an experience that is advantageous to the overall design, to the use of materials in the physical design and how best to create structures that are capable of taking the strain of their interactions.

10. Digital representing Physical

10.1. Introduction

The Cold Sun project came about through the Making the Digital Physical CX workshop run by Prof. Paul Coulton. The initial idea came from Matt Watkins the Creative Director of Mudlark a game design company based in Sheffield responsible for several innovative games and designs. The project itself is rooted in making climate change more transparent to the everyday person, with the initial thinking that it would be a game that used the real-time weather in the real world along with climate models to accurately recreate a future world with the corresponding weather.

The CX process moved forward by way of bringing in a lead academic; again Prof. Paul Coulton and a further academic Dr. Rob Toulson from Anglia Ruskin University. Following the Kick-Off Meeting held in Sheffield several thoughts and ideas were floated, finalising the starting point that all partners could agree on. This meant that the Project would be divided into three distinct phases; 1. Background Research and a Study into peoples' perception of weather on a daily basis along with a rough game design, 2. Narrative and Game design based upon the research from the prior stage, 3. Development of the game and player testing, these phases held for the duration of the project except that the latter two phases became more of a cyclic design where the development of the game inspired the story and the story changes then led to new developments. These phases will be discussed in further detail below.

For tracking the project and its progress Basecamp[15] was used for its ability to contain numerous different conversations and documents that people could comment on. This was used to great effect throughout the project; keeping people informed on meetings and discussions that were happening when others couldn't be

[15] www.basecamp.com

present. Their checklists were invaluable during the testing phase of the project as they allowed the internal testers to create an item for each bug to track the progress of development. It also allowed the development team an insight into issues that were arising for the testers or little items that needed changing, speeding up the development time.

Following the initial project completion more funding was awarded to the Cold Sun collaborators to further the game design and make the game a more rewarding experience. This Field Test stage took on a life of its own and rather than building upon the initial code and design base the entire project was reimagined from the ground up to create a more rounded, finalised version ready for mass consumption.

Across the scientific community, the media, the political domain and education there is considerable debate about the best way to communicate and engage the public with climate change (Boykoff, 2011). Climate Scientists are increasingly seeking novel forms of engaging the public with scientific climate data, this is because, as Scannell and Gifford suggest, that the global and long-term nature of climate change defies easy or immediate comprehension in our everyday lives (Scannell & Gifford, 2011). Indeed, research shows “one of the reasons what people may not take action to mitigate climate changes is that they lack first-hand experience of its potential consequences” (A, et al., 2011). The climate scientist Buontempo suggests that in order to communicate the risks and impact of climate science opportunities for analysis and debate need to be created, that engage us both logically and emotionally (Giannachi, 2012). Game worlds are arguably ideally suited to explore a global effect such as climate change as many already present apocalyptic visions of the future in which players having to survive using limited resources. However, the aim of this game is to allow players not simply to personally survive in future world but to explore how they might exist within such a world in a more sustainable manner as recently explored in the game Climate Change by Red Redemption Ltd. One of the aims of this research is to illustrate how scientific data can be embedded within a game design to enhance the rhetoric relating to how behaviour can be changed as a society to address climate change. However, one issue is that the climate change data people are exposed to may be incomprehensible from their point of view as those producing this data are often concerned with providing the most robust assessment of the science and therefore the language used often needs to undergo numerous translation exercises to 'make sense' to different audiences such as publics, NGOs, business etc. Therefore, this work seeks to 'humanize' this data by presenting it as a personal experience, allowing players to rehearse plausible futures based directly and in relation to this real world (weather and climate) data. In the following section the rationale for adopting a rhetorical design approach is presented by considering it within wider research relating to using games in contexts beyond pure entertainment. In many respects the approach presented could be considered as emerging from the so-called Art Games movement, as defined by Jason Roher (Bogost, 2011) and movement to which the sensibilities of the authors most closely align. However, Bogost is correct when he suggests that art games are an insufficient term and "is a stand-in for a yet unnamed set of movements or styles, akin to realism of futurism" (Bogost, 2011).

10.2. Background Research

In a relatively short time video games have become a major feature of our cultural landscape that extends beyond the games themselves such that it is now possible to see their aesthetic, iconography, and even their operation represented in other forms of media such as films, books and television - thus arguably culture is becoming more 'games literate' (Coulton, 2014). This growing cultural understanding has led to a number of approaches that seek to utilise games, and game design, in a wider range of contexts. These approaches are represented primarily through:

- Serious Games – These games are predominantly simulations of real world activities or processes and their primary aim is to train or educate the player;

- Games for Change – Is a community which aims to facilitate the creation and distribution of social impact games designed to serve as critical tools in humanitarian and educational efforts.
- Persuasive Games – This is an approach to games designs which argues that games can act as rhetorical tools through which a designer can make arguments or influence players.
- Gamification – This is largely marketing driven approach that argues that elements of game feedback systems (e.g. point, badges, competition with others, etc.) can be applied to other areas of activity to encourage engagement with a product or service.

Although there is a considerable overlap between the motivations for those utilising these approaches, such as schools, NGO's, social enterprises, businesses, etc., the differing philosophical standpoints of those involved causes a great deal of contention over which games, and game designers, are associated with which of these approaches. One simple way of considering these approaches is whether they are aiming to create complete games or simply using game elements to engage players/users. By placing these four areas along a scale between being a fully-fledged game and simply having game elements, then they would arguably appear as shown in Figure 41. While all these areas are often seeking to change players'/users behaviour in some way they differ significantly as to how this is to be achieved by either:

- seeking to directly encourage or discourage a particular behaviour;
- adopting a more indirect approach that's seeks to create an understanding of consequences of engaging in a particular behaviour.

The more direct techniques generally take their influence from experimental psychology and try and reduce a problem so that it can be addressed through the promotion of minor personal behavioural change for easily understood and uncontroversial goals. This approach is exemplified by the Fogg model (Fogg, 2011) for what he refers to as captology which promotes choosing a `simple behaviour to target' when designing a persuasive technology and then promoted to the user through arguments around self-interest.

Figure 41: Game Design Approach Relative to use of Game Elements

Through this research an alternative approach is considered, one grounded in rhetoric that seeks to reveal to the player the underlying processes or concepts that drive a system or activity through playing the game (Bogost, 2007). Ian Bogost argues that that the basic representational mode of videogames is “procedurality” (Bogost, 2011) enacted through rule-based representations and interactions and when used to reveal processes or concepts of another system present the player with a procedural rhetoric. This concept develops from existing practices within art and design where rhetoric has already been considered beyond simply speech with visual rhetoric being associated with image through to products with Richard Buchanan’s argument that all design can be considered “as rhetoric” (Buchanan, 1985) as shown in Figure 42.

As procedural rhetoric is the practice of using interactive processes persuasively (Bogost, 2011) it could also apply to many interactive computer systems. For both the aforementioned approaches to behaviour change the question arises as to how they can be applied to highly complex societal issues, such as climate change, which designers often refer to as ‘wicked problems’ (Buchanan, 1985). Such problems are not wicked in that they are evil, but rather they are difficult or impossible to solve because of incomplete, contradictory, and changing requirements. For example, climate change is not simply a scientific issue it has huge political and social dimensions that vary enormously from country to country. The problem with applying direct approaches such as captology to wicked problems is that their characteristics discount the possibility of being able to produce rules, simple goals or generalize solutions and thus they cannot target a simple behaviour to change (Knowles, et al., 2014). Furthermore, they cannot be reliant on a hope that if enough individuals choose to change a particular behaviour then a larger problem may ultimately be addressed as exemplified in the case of 'Climate Change Heroes' game produced by Devon Council in the UK which presents players with very simple goals such as walking more. Whilst it could be argued procedural rhetoric may also be problematic if there is no obvious process to represent it could be argued that it is still valid if it is used to engage in a discourse about particular logics that would recommend certain desired actions or beliefs (Bogost, 2007) thus allowing players to address any inconsistencies in their internal rhetoric that may be stopping them from changing behaviours.

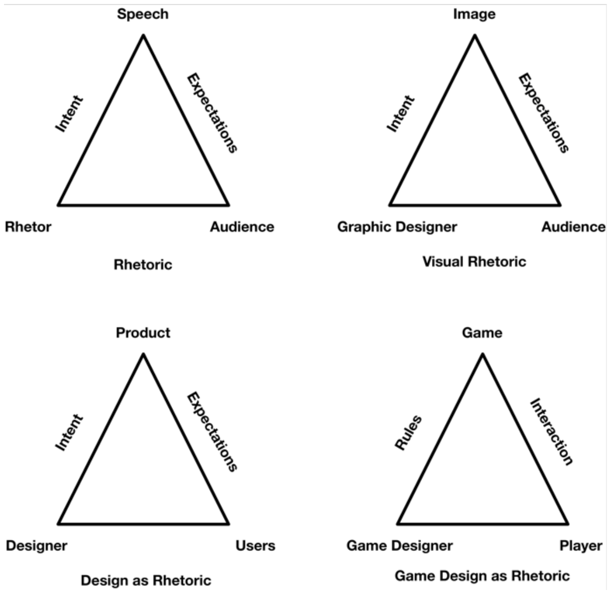

Figure 42: Rhetorical Mediums

In terms of applying rhetoric within a specific design context it can be considered in relation to the three modes of persuasion: Logos, Pathos, and Ethos as identified by Aristotle (Rapp, 2010) and shown in Figure 43. Within these three modes various devices can be used appeal to the player for example:

- Logos might utilise facts, statistics, analogies, and logical reasoning;
- Pathos might appeal to our emotions and drawn upon feelings of fairness, love, pity, or even greed, lust, or revenge;
- Ethos would draw upon credibility, reliability, trustworthiness and fairness.

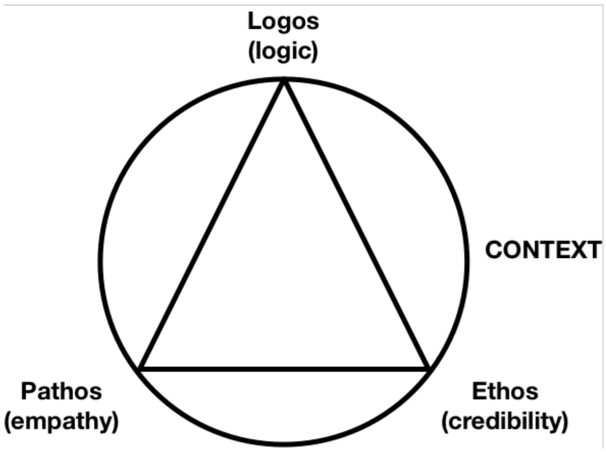

Figure 43: Modes of Rhetoric

Video games are arguably unique in their ability to promote feelings of empathy and whilst many games merely fulfil power fantasies there are a growing number that offer more challenging narratives. For example in Susana Ruiz's game 'Darfur is Dying' the player takes the role of a Darfur child retrieving water from a desert well whilst avoiding the Janjaweed militia (Bogost, 2011)]. The only option available to the player is to hide although lingering too long leads to inevitable capture. Unlike many games it deliberately invokes a feeling of helplessness in the player so that they may better empathize with this terrible real-world situation. When considering logic in games the notion of suspension of disbelief must be addressed. Whilst players will accept abilities and situations within a game that are impossible in the real world they must fit within the overall narrative of the game. When creating games that explore real-world events or situations the narrative of the game should be carefully constructed so that its link to the real world is not broken, otherwise the game world becomes simply to fantastic to be plausible. Credibility and authenticity is arguably the hardest to achieve within a game context although by drawing from verifiable real-world data sources it may be possible as these resources effectively anchor the game to the real world which is known to have a positive effect (Coulton, et al., 2010). Additionally, the narrative used to describe the game before the player has even played, such as the description on the App Store, may be used to emphasize the credibility of the rhetoric contained within. Therefore, the use of rhetoric is very particular to an individual game and therefore in the following section the practical application of rhetoric to issues of climate change is considered - through the creation of the game Cold Sun.

To design a game that relates to weather and climate change the group decided it was necessary to understand the effect weather has on people and their day-to-day lives. The method chosen for proceeding was to research different weather data sources that are available to the public. The result of which being that while there are several different free sources, from Yahoo! to the MET office none of them really provided the data required to run a game that relies on past as well as the present weather. One source did provide the required data however the cost for this was outside the scope of the project. This meant that a weather service had to be created for the project using the available data and recording it in order to have a past record of the weather. The service created uses the MET office data and collects data daily at 8am for the users and their associated locations then records it in a database for future access.

While this was all occurring in Lancaster, the team from Mudlark were working on their Game Design Document (GDD). The GDD was developed concurrently in order to speed up the process of the overall game design. This document included the different states of the game, the overarching story and a rough design that would later inform the final game.

Next in the first phase was to use the newly developed service to gather peoples' input into how they remember the weather. This was performed using a simple website that emailed the users once every week for seven weeks asking them to rate the weather on a scale of twelve different weather types from Clear to Thundery and the temperature from freezing to hot. Both scales included the option for not being able to remember and this was discounted from the data when trying to determine users' views of prior weather. Over the period of the study it was observed that as users respond to the weather further back in time the more optimistic they were whereas the responses closer to the actual date were more pessimistic. The database used for this part of the project was then repurposed for use in the game. This information was then collated and presented to the Cold Sun collaborators at the Game Design Meeting.

10.3. Initial Game Design

With the background research completed a meeting was held in Lancaster to go over the data and come up with an initial idea of how the game could use it to help address the wicked problem that is knowledge of climate change. Mudlark brought the Game Design Document (GDD) they had been working on to the meeting, the presented GDD contained two different modes for the game; one mode would be a narrative based game where users proceed through the story web via different choices they can make to change the outcome of the game. The second mode would be an endless runner style game where the user would have to navigate their way around a myriad of planets each with their own specific climate, dictated by the history of the weather they have built up through the playing of the narrative game. To help facilitate the design of the game and how the whole project should be linked to the weather whiteboards were used to help visualise individuals' ideas. The team was divided into two separate groups whose tasks would be to analyse one of each of the game modes, and to alter them with their own ideas where they felt it necessary.

From the conversations held three distinct objectives were identified as key points that the game must have for the project to be considered a success.

1. Building a compelling narrative around a futuristic world impacted by climate change and controlled by extreme weather events.
2. Engaging players with casual game play that connects to temporal and situated experiences of climate and weather.
3. Encouraging players to make connections between the real world weather and a fictional game.

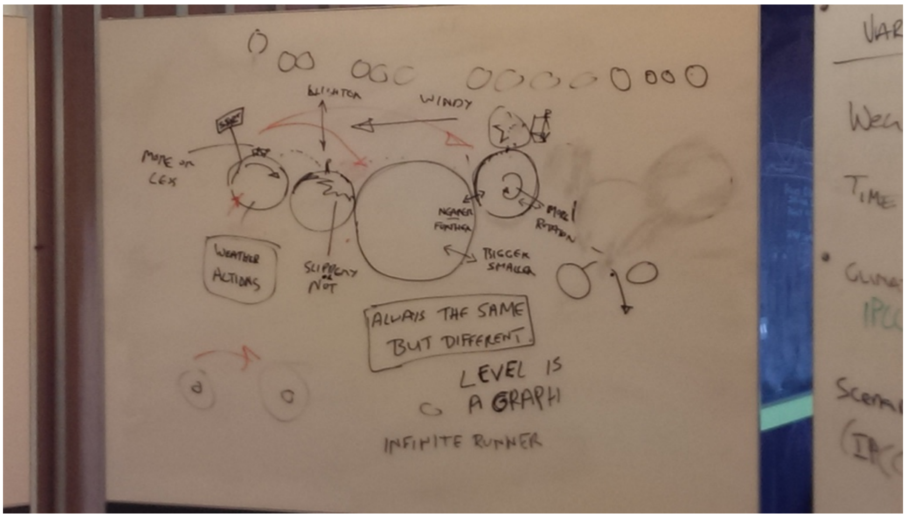

Figure 44: Whiteboard showing final design of Dream Mode

After a time working through the ideas and designs of the respective modes, the groups came together and gave a short presentation followed by a discussion on how each would work and what design elements were important to the overall project. Following this the teams switched over to clarify and refine the points made. The resulting white boards were photographed and used by the team from Mudlark to create a second GDD, which in turn was critiqued by all members to finalise what was to be in the final version of the game.

The white board shown in Figure 44. shows how the infinite runner mode was visualised by the participants while not all of the comments shown on the board made it into the final version of the game the general theme held true through the development process.

Some of the proposals for the infinite runner part of the game were, while each of the planets would be different depending upon the weather so that as the player moves further to the right of the screen the further back in time weather wise the player is moving. Other points that were brought up included having different sized planets with the potential for enemies or for different movement speeds while on the planets. The reward for successfully completing the section would be some kind of helpful object or piece of information to help the player in the next stage of the story mode.

The narrative mode received the same treatment and was considered and refined by the two groups. After deciding on a branching storyline, it was felt that there needed to be other things for the player to do while in the game. Using elements from the casual game genre tasks were created that had to run for a specific time but this time was also influenced by the weather. For example, planting seeds or catching water to drink. Each of these requires a different set of environmental factors for them to complete, the seeds need little rain and plenty of sun whereas for collecting rain water you obviously needed a heavy rain day. The idea was that players who recognised the connection between the weather and the game would be able to plan their activities to coincide with the most advantageous weather conditions. Other activities or story elements included interfaces that required quick reflexes, a good memory or just to wait a specific amount of time. These activities all fed into the gameplay section of the GDD helping to extend the gameplay from a quick 20-minute turnaround to approximately an hour's worth of content. The concept of the "Dream World" was first conceptualised here as a method of transporting between the two game modes. The thought being that it would create a seamless transition and give reason behind the change in interaction modes.

This is also where the draft for the narrative mode was created ready for the implementation in the next stage; Mudlark once again took the lead on this with input from the rest of the team and a fellow CX PhD student. The narrative mode of the game as originally envisaged in the GDD a first-person 3D adventure but due to the time restraints built into the project this was changed in favour of a text based adventure game with a branching narrative that advances the story.

The adapted GDD produced a game called Cold Sun, described as a hybrid dual-mode adventure game where players must survive over a set period of time in a strange future landscape, affected by real-time weather, in order to traverse the extreme climates of a dream world by night. The two game modes – Existence Mode and Dream Mode - respond to real world weather data in different ways:

- The Existence Mode represents a first person fictionalised reality of a character, found in a specific location that is controlled by real world weather during the daytime.
- Dream Mode, takes place at night and involves an abstracted world of 'planetary' like spheres, where the connection between the weather data and the actions within the game are much more complex and less visible.

These different modes are part of the rhetoric and serve to illustrate that weather and climate exist on two completely different scale with the former being a personal view and the latter a world view. The game uses the player's current location through GPS (or Network Estimation) to obtain the corresponding real weather forecast for the players' current location which is then used to trigger extreme weather events in the game world. The game also uses this data to fix the games diurnal cycle (day and night) with that of the real world giving the game a distinct temporal structure. By using the weather and time this way it allows the player to develop a 'logic' that connects real weather events with their own actions and the resulting impacts of these actions within the fictional game world.

The Existence Mode of the game is revealed as a diegetic first person adventure and while the current prototype works as a text adventure. It is intended that this mode will eventually be rendered as a 3D first person environment in the expectation that it may the players' ability of developing empathy for the game character and the situation they find themselves. This mode is experienced as a set of tasks that combine to become levels. The player must carry out these tasks and puzzles in order to make decisions and develop skills that are bound to the real weather data through a complex system of cause and effect. An example of a task in Level 1 of the Existence Mode involves the player finding out what happens if the character moves their arm, does this use too much resources (e.g. energy), do they need to eat something after the effort? Examples of a task in Level 2 begin to engage with the environment, i.e. what happens if I eat this or try and grow this plant? The levels of the Existence Mode evolve towards a narrative finale focused on finding another human being, discovering who you are and where you are, and the reason for this new world that the player finds themselves in. The character has a certain amount of life force represented by their mortal coil, shown in, and is required to play each level they must preserve this mortal coil to survive and move on to the next level. If a player's mortal coil reduces to zero, they will die. In the event of death, the game is reset to the last transition from dream to existence. Therefore, the player is encouraged to learn the logic of cause and effect within the game and how to navigate this as they play, highlighting the connections between the weather and the choices they make for survival this fictional post-climate change world thus providing a rhetoric of how are actions are ultimately linked to climate change. The game world weather is an amplified version of the real world weather - where a rain shower becomes acid rain, a strong wind becomes a hurricane, a grey day becomes a blanket of cloud blocking the sun rays and killing crops. The weather can change the character and their environment for both good and bad. This was developed in response to advice from climate scientists who collaborated with the designers, to show how changes in climate are affecting our experiences of real weather and are impacting on a range of environmental, agricultural, human and animal factors.

When day turns to night in the game the player enters the Dream Mode, which is a 2D platform game, an abstracted world where the character is a small and distant person that must navigate spherical and curved planet like objects to emphasise the shift in scale required between climate and weather. The player must navigate this strange abstract world to find clues to the next level in the Existence World. Within this mode there are also different types of enemies. In the Dream Mode the game is simple, you can win or lose which creates several outcomes (a.) reawaken in the Existence Mode (b.) start again from the beginning of the dream mode (c.) reaching a staging point in the game that releases a visual clue to enable you to return to the Existence Mode and move up a level. Figure 6. Dream Mode Game Screen

10.4. Initial Game Development

With a draft of the second GDD now ready work began on the programming of the game with both modes being developed concurrently. The designs for the game came from the GDD but were interpreted by the developers so that the interface worked within the development environment.

After some deliberation, the game engine was chosen to be Unity due to its free to use nature and its ability to cross compile for the major mobile operating systems giving the final game much more market penetration potential. Also considered were native development for multiple platforms, this was discounted due to the long development time required to code multiple times. HTML5 was discussed but ultimately dismissed for the execution and lag that can be experienced when running on mobile devices.

The game was written in C# and was predominantly built by code and limited use of the Unity GUI. The reason for this being that the game was a text based adventure which does not require the 3D elements Unity typically employs and so creating the interface was much simpler through the coding environment and also allowed for the game to be played on different resolution of device by rescaling the game at runtime for the device.

The story of the game was presented to the development team as a Twine story, with its different branches and options. In order to use this in the game it had to be converted from that format into one that could be easily navigable by some form of id for each element. By dissecting the story into its disparate parts, it was possible to create a database schema that could contain the story and its associated options and follow where those options linked to next in the story. This was important and had to be correct as if it weren't the story could get confused and run in an incorrect order spoiling the players experience. This database was then converted into a mobile readable SQLite format so that the game could be updated periodically by creating a new version on the game server. This allowed for faster iterations and testing while the game was being developed as anything pertaining to the game text or options/actions could be altered and then the game would download the update automatically on its next run without having to rebuild and send out a new game client to all the testers.

Faster iterations were essential to the progress in the development of the game and helped greatly in refining and in some cases radically changing from one style to another. This ability allowed the different versions of the game to be compared and contrasted to find the best parts of the various versions created to build the finest version of the game possible. This process was also praised by our project partners as they could see multiple updates and versions being created daily giving them the chance to have feedback and more than anything see that work was actually proceeding. While basecamp is useful for communicating the update is available the initial decision to make the game updateable remotely often rendered the need to message people through Basecamp redundant.

At each stage of the development the disparate team was kept in the loop by sending test builds out for comment, any comments were then added to a bugs/to do list. This allowed for a quick flowing work method and ensured that everyone was happy with the direction the game was proceeding towards.

While the database for the game was still being developed, and due to the constrained nature of CX projects it was necessary to work on multiple fronts, the game was already designed in the GDD to be split into two modes so it was decided to work on both concurrently and then to reconcile them at a later time.

10.4.1. Dream Mode Development

The design of the dream mode of the game took on the view of a traditional side-scrolling platform game, where players would jump their character from planet to planet while attempting to avoid enemies and other obstacles. These planets would be procedurally created based on the number of times that the player had reached the dream mode and then each planets attributes would be based upon the past weather the player has experienced in the real world. In this way the game would differ for each player, with planets changing in friction or the amount of water on their surface. The aim of the level is to traverse the entire range of planets that have been generated, by collecting objects on the way they are able to gain hint points that can be redeemed in the exploration mode when a player is stuck at a point in the game. However, it wouldn't be a game without the possibility of failure, and this occurs when a players' character has been off the screen for a period of 5 seconds. Upon success or failure, the player would be returned to the existence mode to adventure once again but would only keep their hint points if they succeed.

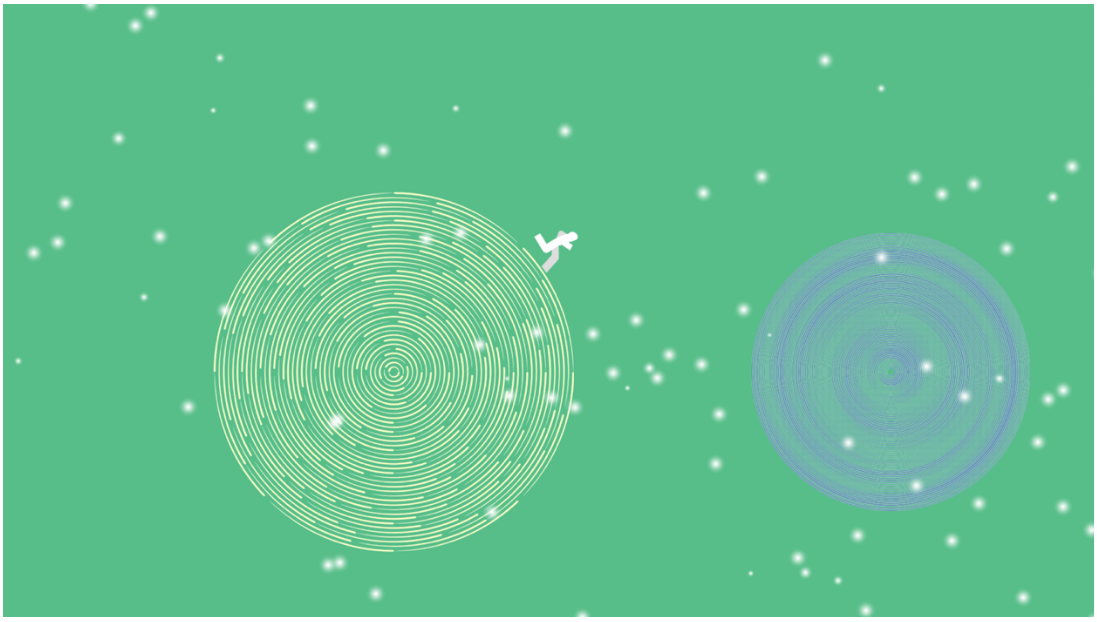

Figure 45: Screenshot of Dream Mode

Planets were originally created by extracting assets that the Mudlark team had created and using the outline of the shape to create a mesh object that the player character could then move across. The character itself was controlled by simple tap commands that caused the player to jump tangentially away from the planet they were on, requiring precise timing for the player to successfully jump from planet to planet. This jumping mechanic was created by building an in game gravity system, fed by each of the planets that were generated at the start of each level but as the planets were fixed in place and the player the only movable object, when the player jumped away from the planet it was immediately caught in the gravity of the planetary system such that they could when timed correctly perform jumps that would slingshot them around planets. This did however have its downsides as it could be very unpredictable without a steady, practiced hand.

10.4.2. Existence Mode Development

The existence mode development was headed by Adrian Gradinar, and primarily due to time constraints was developed as a text adventure. Text adventures came to the front as some of the first computer games, as they required limited graphics and limited processing power. The text adventure took the SQLite database that was created from the conversion of the twine storyline and used the data that could be extracted from there to layout the GUI with the required options as shown in Figure 46.

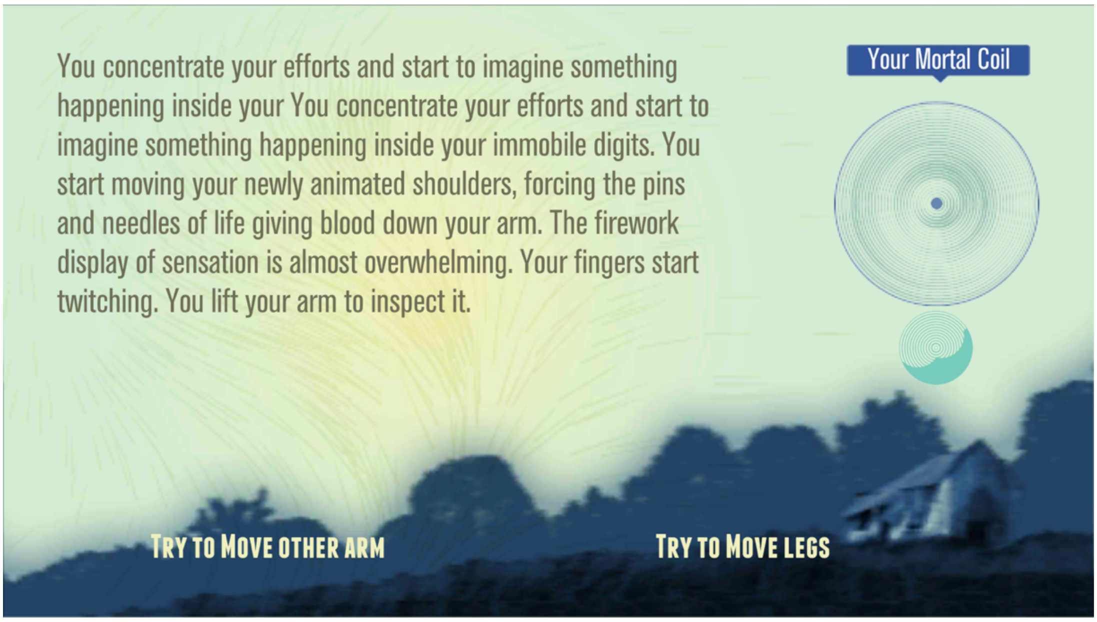

Figure 46: Screenshot of Existence Mode

The primary elements of the GUI as seen in are:

- Story text
- Control Buttons
- Health display
- Current Weather display
- Dynamic Background

These elements are all created at runtime and are determined by both the current weather and the position in the story that the player is up to. The key challenge to this was ensuring that each button connected correctly to the next part of the story and that the weather was taken into account at each stage. By positioning placeholders into the story text using "[wt]" the code was able to then extract the appropriate weather statement and insert it into the text. This method allowed for the text to change with ease when the weather changed. The health display was created using transparent graphics overlaid with one another and then resized based upon the current state of the players' health, which was based as a percentage of 100%. The weather display and the dynamic background were both linked to the current weather information that was gained via the service previously created and gave hints to the player as to what was going on around them both in game and in the real world.

10.5. Prototype Evaluation Meeting

After numerous revisions and bug fixing sessions, the team were happy with the state of the game and it was decided to come together to have a final run through of the project to conclude the development of the game.

A slight change to the team make up occurred with this meeting as Mudlark brought along their lead game designer in a critical capacity to judge what had been created and where necessary to offer constructive criticism for how to move on with the project. The meeting began by restating what the overall reason for the creation of the game was and the steps and decisions that had led to this point.

Each of the team was provided with the latest version of the game and were then asked to play through and discuss how they felt that this version played and how well the experience worked for them.

The comments while mostly positive did have points that were quite critical over the game, that it was not interactive enough, that it was boring or that there wasn’t much to do and that the dream mode specifically wasn’t explained well enough.

Through discussing the comments, it became clear that while the game worked from a technological standpoint it was not ready to be released as a game in and of itself. But with the project window drawing to a close, all were aware that without further funding it would not be possible to create the groups vision of the game as they wanted it. To that end, it was decided that it would be best to conclude development of the game at this stage and to use the game as an example to the CX board that the game had purpose and could be used to help players understand the risks and challenges that climate change will bring.

The team therefore collectively decided that the meeting should also act as the end of the project with all future effort being aimed at securing more funding to create a better version of the game.

Looking at the project as a finished state it was clear that the time period was far too short for the creation of the game, the learning of a new technology and the implementation of all of the different ideas that had been brought about. With this experience however it was feasible that the game could be created within a similar timeframe without the requisite learning of the technology.

The team also had to combat the other issues of the game, and the group from Mudlark went away to work on this led by Matt.

10.6. Field Trial Funding Development

10.6.1. Analysis of current development state

With the original project over and further funding acquired from the CX board, a list of changes was drawn up via basecamp that would need to be made for the game to be in a viable state for it to be released. These changes were:

- Quick Time Events – Reflex games that required users to press buttons within a certain time.
- Puzzle Events – Screens where the users would have to solve some form of a puzzle to proceed.
- Delayed Events – Events that took real time to complete, with the duration of the events linked to the real world weather.
- In game Inventory – A place where collected items could be stored for later use
- More interesting Planet Designs – The designs were all similar and the planets all had the same flat layout, this would be changed so that they had more undulating surfaces.
- Weather History Book – This would be a place where the user could view the past weather that they had experienced when they had been playing the game.
- Tutorials – A tutorial for the dream mode so players could understand what to do.

In order to create these additional features, the team evaluated the state of the current game and if it could be adapted so that these ideas would fit within the current framework. While the existence mode would not be changing a great deal on the face of things, behind the scenes in order to allow these new features and puzzles to be included the entire section would need to be recoded, likewise with the dream world the overall system of jumping from planet to planet wouldn't change but the creation of the planets and therefore most of the mechanics would also need to be rewritten. This led to the decision that while it will be possible to repurpose some of the code it will be better for the project to start again, using all the knowledge gained from the previous iteration to inform the project in the next development stage.

10.6.2. Existence Mode Redevelopment

Following the analysis of the current state of the game and the decision to start again from the beginning it was important to decide on the best practice for redeveloping the project

Figure 47: Screenshot of Reflex Event

Using the requirements for the game was the key to correctly achieving this, the ability to add in different interaction methods and styles would be crucial to the speedy development of the game. To this end a modular approach was proposed that would enclose the game screen and divide it into areas that could be individually changed and edited, rather than having to recreate the entire screen each time. Therefore, several different modules would have to be created, common components across all screens such as the background or the buttons to access the inventory/weather history would be created as individual classes then combined into one major navigation component which would ease the screen creation.

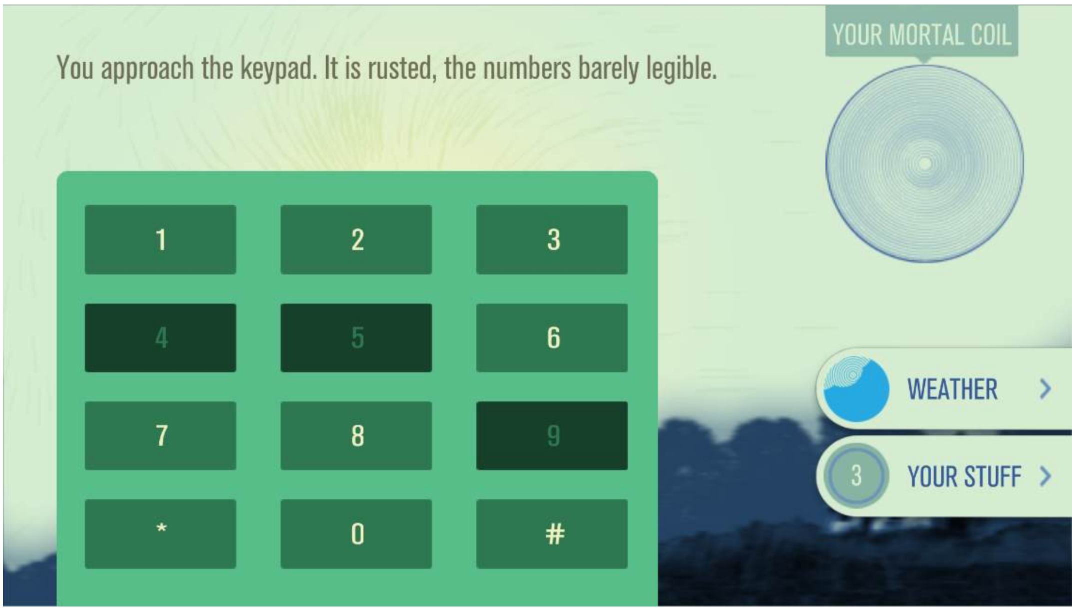

Figure 48: Screenshot of Puzzle Mode

The story text would still be displayed in the same place however the buttons that normally accompany it would be changed so that they could be replaced with the Reflex Event as seen in Figure 47 or Puzzle controls as seen in Figure 48.

By creating these components separately, it allowed the team to work individually upon them, then only bring them back together when they were needed for the next stage of development. The story progress system written by Adrian for the original game version was reused as it performed its job well and could be altered such that the new components could be placed within its layout. The Inventory and weather history screens were created as overlay screens so that they would appear above the rest of the game UI and contain within themselves the elements of the inventory and the previous weather types that have been encountered respectively. Finally, with new skills that had been developed from the creation of the Quick Time Events, the health indicator was redeveloped so that it could be controlled more finely and had better fidelity than just resizing the underlying graphics.

10.6.3. Dream Mode Redevelopment

The changes proposed for the dream mode were not as drastic as they were for the existence mode however, the current state would not allow for the changes in the planetscape that the project team had requested and so the codebase was archived and work began anew on creating the mode. The Mudlark team produced a schematic of the planet generation to help with the new development as shown in Figure 49.

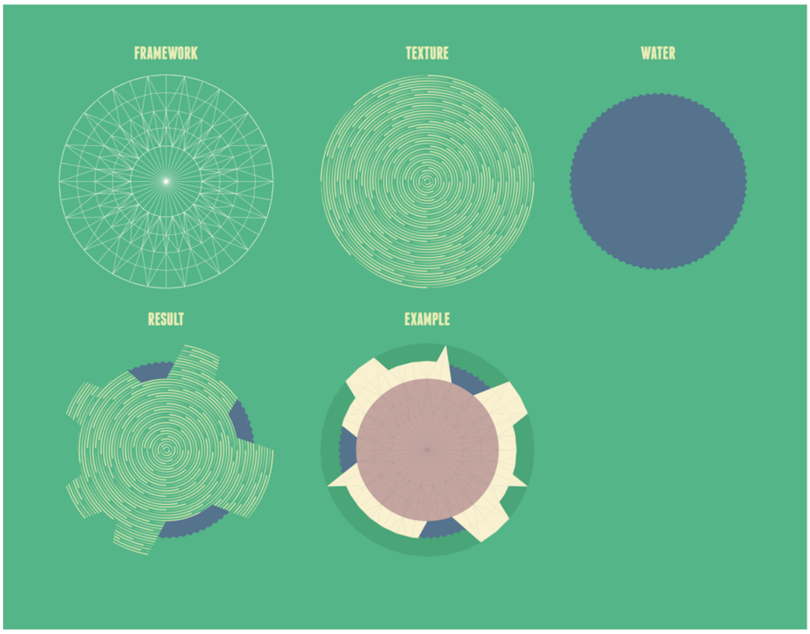

Figure 49: Schematic of Planet Design

From this schematic an algorithm was written that would produce a planet given specific values for how undulating the surface should be and the size of the planet. The planets much like in the previous version would be programmatically created at run time and their properties would vary based on the weather once again, examples of these planets can be seen in Figure 50.

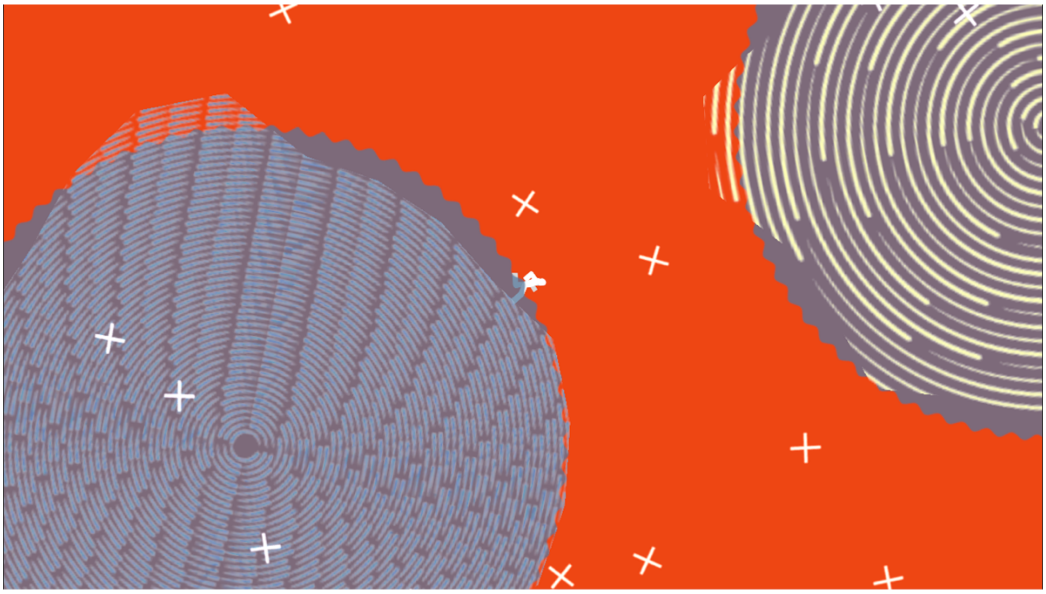

Figure 50: Screenshot of Planet Generation

These planets added much needed variation to the dream mode game and add the challenge of using the terrain of a planet to the advantage of a player so that when they are on higher ground it is easier to traverse to the adjacent planet. Using the new algorithm, a demo level was created where players could be taken through the game in a step by step process to help them understand the aim of the dream level. To aid in this a collection of tutorial overlays were created to give the players further information than could be gleamed from the information on the game screen itself. These overlays would appear at specific timings throughout the first attempt at a dream mode level.

The rest of the mechanics remained unchanged, with the same system of gravity working across the planets, however a double jump mechanism was introduced to help direct planet traversal.

Figure 51: Screenshots of Tutorial Screens

10.7. Field Trial – Team Evaluation

Following the completion of the redevelopment, the team took the opportunity to play the game for a week and then come back with final comments on what the next steps should be.

The team was much more enthusiastic about the game in its current iteration though felt that while it was much more complete than the previous version it was not quite ready to be released into the wild. This was due to the short length of the game and that an interested player would likely speed through the available story in a short period. While the game does have a certain level of replay ability it was thought unlikely that many players would do this.

What was agreed upon was that the game was at such a stage and of high level of production that Mudlark would use it to present to other funding bodies to try and garner interest and to then take the project forward in this manner.

10.8. Discussion

While a study has not yet been completed to ascertain the long term effectiveness of Cold Sun it is believed that the design incorporating both user centred and participatory design approaches described in this chapter, draws upon existing practices within design for addressing wicked problems in that it does not try to break down climate change into simple personal goals expressed through arguments of self-interest, but rather seeks to reveal its complexity. By using real weather data and scenarios derived from climate change data as a way to control events in the game world, it is argued that it is possible to create plausible connections between real weather data and a fictional narrative affected by the real weather data. This approach provides an example of how rhetorical design can support playful engagement with the wicked problems of climate change.

The designers utilized the modes of rhetoric of empathy, logic, and credibility alongside the design strategies of sensory engagement, temporality and multiple interpretations. Through the first person narrative within the Existence Mode the player navigates an environment, reliant on sensory responses to the impact of weather in the fictional game world, in order to experience an embodied connection between weather, the impacts of climate change on weather and the actions and experience of the character within the fictional narrative of the game. Players are encouraged to understand weather and climate in terms of temporality - time, place and space through the diurnal cycle, a localized fictional world and more global abstracted world by tracking the weather throughout the duration of the game, using live real weather data to affect elements of the Existence Mode and using the weather to change the speed, scale and proximity of the objects in the Dream Mode to represent a more abstracted representation of climate data.

The dual mode game play enables the players to experience connections between the real weather, climate and game play through multiple interpretations, in a more complex fashion than if they were just to experience the fictional narrative of the Existence Mode. With the addition of the Dream Mode players are offered a more abstracted relationship between weather, climate and their actions, that the designers have developed to reflect the global, slow and distant nature of climate change and the complexity of the 'wicked' problems involved in defining cause and effect around issues of climate change. These strategies also support the view of Jacobs et al. (Jacobs, et al., 2013) that suggests that while provoking emotional engagement with scientific data is not a simple matter, by employing design strategies that involve emotional and personal engagement, in this case through rhetorical game design, an emotional, human-scale engagement with such 'wicked' design problems such as how to encourage engagement and response to climate change challenges that will affect our futures can be created.

10.9. Conclusion

As this project was entirely interacted with via a touch interface it stands apart from other projects previously discussed in this thesis. While the project does have a physical aspect to it, this aspect unlike in Chapter **6** there have not been any additional affordances created for the gameplay and interaction is purely through the phones' touchscreen. The real world weather also plays a large role within the game but this is more of a context driven relationship rather than a direct interaction.

From the development of the game, the interactions that were chosen were selected not to be radical or to introduce new paradigms but to work on a level that people already understood. Simple tap to jump mechanics are similar to other platform games on touch screen systems and the buttons on the screen are presented in such a way that they are able to be interacted with. This was not the case in the original version and in some cases people attempted to interact with on screen graphics that had no direct interaction built in. This was rectified in the second version by making the buttons more obvious and by changing the design of the other on screen objects.

The key point to this chapter for the manifesto is that the design of purely digital interactions should be clear in their intent, and that while providing large numbers of graphical items on screen is an attractive prospect, it is key to understand how users will see those items and so interactive elements should be made to be more obvious and different to non-interactive elements.

11. Digital representing Physical: physical and social context

11.1. Introduction

The focus of this chapter will revolve around the CX Project that was 'Perceptive Media' the driving force behind this project was a previous project run by the Research and Development department of the BBC. Their 'Perceptive Radio' used a myriad of different sensors to determine the context of the room and any changes to it. The sensors were able to monitor the number of people within the room, take note of how many different Bluetooth antennas were active, monitor the sound levels and much more. This was all housed within a box designed to appear like a typical DAB radio, all the while actually running on a small form factor PC with Arduino like prototyping platforms plugged into it to expose the sensors.

Traditional storytelling methods, rely in part on the storyteller personalising the experience by welcoming the listeners, commenting on the surroundings or even using local colloquialisms, it is through these methods that the storyteller can engage their audience. Storytelling has been a major part of culture for many thousands of years, and was at one time before reading and writing became a common trait, the major way for news to be spread (Zipes, 2012). More recent storytelling methods such as film media or radio are typically more static than their origins, while there have been exceptions, shows that allow for an audience to send Short-Messaging-Service messages to influence the outcome of branching points in the storyline these are far from the norm. Video games have in many ways embraced the more traditional style, as players have the option of choosing the flow of the story a story that can be personalised to their play style. Pioneers in this style such as the games from BioWare[16] or more recently TellTale[17] games series that have a number of choices within the games that will influence the outcome to many different endings. While the idea behind the Perceptive Radio does not have the

[16] http://www.bioware.com/en/

[17] https://telltale.com/

same interactive narrative elements as Video Games, it does have a lot in common with the branching storylines that control the flow of the story.

This project, the final in this thesis is intended to look at the design and implementation of devices that don't require human interaction to perform their intended function. While interaction is not required it is not correct to say that the device would perform the same if a person were not around, the philosophical thought experiment that is "If a tree falls in the forest and no one is around to hear it, does it make a sound?" is quite poignant here, as the presence of the person can impact the device without their knowledge, but likewise if they were not there the device could be doing something entirely different and they would not know it.

The BBC came to CX with the idea of recreating this project but with improvements in mind after the previous success that was the 'Physical Playlist' project collaboration. Their original 'Perceptive Radio' while performing its job adequately was very difficult to create stories for and required quite a lot of background in programming to create an effective story along with a lengthy setup process anytime the radio was to be demoed. The idea behind this new collaboration was to create a platform where scripts and stories could be produced within the space of a couple of days, using very simple JavaScript code, that could then be easily deployed on the device to give an audience the experience intended. Another improvement requested of the system was an easy to use administrative interface, one that could alter the settings on the device to change the context that the radio perceives. This would not be used in production, but would be a helpful tool when showing the system to prospective story tellers/technologists within and outside of the BBC ecosystem to build up interest in developing stories for the platform.

11.2. Initial meeting

Along with the BBC another of the previous projects partners, in this case 'Cold Sun' and Mudlark, were involved with the project and brought with them the same enthusiasm for adaptive and branching story lines that worked well within the

Cold Sun game. The first meeting of the entire group via Skype brought forth a range of ideas for the project, while many of these were centred around the sensors that could be included within the device there was also discussion of the ways in which story designers could use these elements and how to effectively change 'station' by which that is to say change the story that is playing on the device.

This meeting went forward in such a way that any and all ideas were written down and discussed for their feasibility and how well they fit into the overall vision for the project. A myriad of contextual circumstances were considered, along with potential sensor ideas, from counting the number of people in a room to discovering the amount of ambient noise in the room. At this stage these discussions were only held in the abstract with the actual specifics of how to measure these contexts left for further research.

Once the discussion of the sensors was over, the conversation turned to the creation of stories for the purpose of demoing the project to the casual outside observer. This had three key objectives; the story must encompass as great a number of the sensors as possible, the story must be under 5 minutes long, the story must repeat certain elements to show it can be changed dynamically. Mudlark chose to take the lead on this, and showed a prototype story they had been working on.

The created story was based upon one of Aesop's fables and revolved around a traveller asking about the people of a nearby city. This obviously gives the option of location to be included along with the weather at that location. The ambience of the story was being told around a space such as a campfire, this allowed the narrator to interject at times to comment on the story using cues from the sensors in one case if a person were to enter the room, the narrator would respond with one of several canned options asking the person to sit down and join in. This story gave the team a good jumping off point for the creation of the system as it would allow easy testing and demonstrations to be possible within a short period of time.

It was at this stage that the future design of the device was discussed, with most agreeing that some interpretation of an old style radio would be a good choice. With analogue controls and interactions to change the story being played. Options to be included within the final design were elements such as tilting the radio to turn it on or off, or waving a hand over it to achieve the same outcome. While some of these options do not specifically fit in with the aim of a perceptive media player, some method of controlling it would still be required. These were thought to be natural user interactions that people would understand.

The team discussed the best method of keeping the disparate members in the loop about project developments. Where Cold Sun had been developed with Mudlark to great success using the Basecamp platform, Physical Playlist had greater success with Trello. This was suggested as the platform of choice and was accepted by the team, due to its easier accessibility than Basecamp.

11.3. In-depth sensor research

After the initial meeting, ideas were suggested on the trello system about what specific sensors would be required and what the limitations would be on those sensors. In this section, each sensor will be briefly discussed and then in the next sections each option will be evaluated to gauge their feasibility.

The first sensor that was suggested was a camera, as this could be a main part of the radio that could be used for many different purposes, from counting the number of people within the space to determining their distance from the radio. However, people were quick to point out the limitations of these kinds of cameras, such as low light would affect its ability to pick out people and their distances.

Microphones in the current device played an important part within the radio and was felt to be essential to the project if it were to tell engaging stories. The microphone could allow the player to detect the sound levels within the space immediately around it, however there was discussion that the microphone may have feedback issues, where the levels could be contaminated by the player itself as it tells the story.

A more contextual sensor for the location of the player was felt would be of use, to locate stories in a local setting or to give the narrator a particular accent depending upon the region. Perhaps this could be done using GPS, this would be an important part to investigate.

Bluetooth was also brought up as a topic of discussion with the BBC mentioning that they had used it in the previous iteration of the player to some success in determining the number of people within a space.

Finally, on the sensor front an option for getting a range on how far away people are was floated. This was touted by the team to be a good idea as it was non-invasive and could be a novel feature atop the 'radio' to make it stand out from the norm.

11.3.1. Web Camera / Face Tracking

As one of the primary sensors and potentially the most influential the Camera was the first to be researched, with several options taken into account. These were

1. Traditional Camera
2. Infra-Red Camera and Traditional Camera
3. Traditional Camera with Infra-Red filter removed
4. Traditional Camera with Infra-Red filter removed and Infra-Red LED backlighting
5. Intel RealSense Camera with depth and Infra-Red options

These options were first graded against what would be possible for each to determine across the requirements of day/night/low light visibility, resolution great enough to resolve facial details and their ability to gain a sense of depth from the image/sensor, finally the usage of the CPU was checked for feasibility of running it in collaboration with other sensors.

Camera Type	*Visibility (day)*	*Visibility (Night/Low Light)*	*Resolution*	*Depth*	*Processor Usage*
Traditional Webcam	Excellent	Poor	720p	No	100%
Infra-Red Camera & Traditional Camera	Excellent	Excellent	720p	No	200%
Traditional Camera w/o Infrared Filter	Excellent	Poor	720p	No	100%
Traditional Camera w/o Infrared Filter with LED backlighting	Excellent	Good	720p	No	100%
Intel RealSense Camera	Excellent	Excellent	1080p	Yes/No	100%

Table 3: Evaluating Camera Options

These tests were performed in an office space, with camera placement the same for each test. The visibility was determined by the software's ability to resolve a face in the different conditions. From these results and from a restricted space requirement the Intel RealSense Camera can be seen as the best option, however this only became possible approximately 6 months into the project as the product was not available to the project until then. Up to that point the Traditional webcam alone was used as while without the filter and with backlighting the camera is usable it does not provide a wide enough view angle to be usable in the required environments.

Due to the project being run on a Linux operating system the support for the RealSense camera was limited and this is the reason for the yes/no rating for the depth sensor. While it worked well and could be used to get a sense of distance from the images extracted, the implementation of the software for the camera caused frames to be dropped and corrupted images sent in their place. These corrupted frames meant that the measurements calculated from the images would vary wildly from frame to frame. Obviously this could throw off the perceived stability of the 'Radio' and so it was decided that until such a time where it proved stable that feature would be disabled.

11.3.2. Microphone / Sound Level Checking

As the sound level of an audience can give important feedback to the storyteller in a traditional environment a thorough analysis of the possible options is necessary. Several options are possible for the implementation of this sensor, such as

1. Single Microphone
2. Dual Directional Microphones
3. Webcam Microphone
4. Single Microphone passed through a noise filter
5. Dual Directional Microphones passed through a noise filter

As the cost of purchasing the microphones was outside the scope of the projects budget, a single microphone was used but the directional microphones could not be sourced. So these options were not tested. Additionally, while every attempt was made to purchase the noise filters, they were not received and so could not be tested.

The noise filter would take in both the input from the microphone and the output of the 'radio' soundcard. This would then be processed on the filter to remove the output of the soundcard from the input of the microphone to leave a clean level that would represent the background noise level of the room. This could then be used to create a Fast Fourier Transform (FFT) that could be used by the story creator to change items within the story. Due to circumstances outside of the projects control these filters were not made available but should they become available they may prove a useful component for future versions of the 'radio'.

The two options tested for the project were, the single microphone and the microphone input from the web camera. It was noted that the single microphone picked up more of the output from the soundcard than the web camera did. It is thought that this is due to the nature of typical web camera operations that require for teleconferencing the sound from the speakers be removed from the sound input of the microphone. So with this data it was decided that the best option would be to use the web camera microphone until such a time where the audio filters are available to test and implement.

11.3.3. Bluetooth / People – Distance Sensing

The purpose of these sensors was to detect the distance of people from the 'radio' and if possible detect the number of people around the radio as well. While some of these requirements have already been met by other sensors the research was being carried out in parallel and so it was not immediately apparent as to which was the most appropriate answer.

These Beacons work as active emitters of Bluetooth data, as a phone comes into range of a beacon the phone receives a UUID that the phone can then use to determine which device it is talking to. If the application on the phone knows where that beacon is located it can determine its distance from it within a certain order of magnitude relative to its distance from the beacon, i.e. the further away the greater the uncertainty. If there are three or more active beacons within range of the phone, then triangulation of the phones current position is possible however when combined with the uncertainty in the measurement this can be off by quite some distance.

When testing these beacons in a lab environment it was possible to get a range from the phone to the beacon within a range of accuracy approximately +-2.0m with the phone in a range of 2 meters. Once this same experiment was performed in a working environment with people and objects in the line of sight between the beacon and the phone the accuracy dropped off further and in some cases fell to zero if the beacon was entirely obscured by a person or object. In the scenario where it would be used in a production environment losing the person altogether or having wild fluctuations in the measurements when people had not moved could cause a break in immersion of the story.

The lack of reliability in the distances combined with the lack of consistency in the tracking of the beacons meant that these iBeacons were not a viable option for the tracking of people within the space. Another reason for them not being the chosen option, is that requiring a user to connect a Bluetooth app or to carry an object to track them could be a barrier to adoption/interest in the final project.

11.3.4. GPS / Location Data

Making the 'radio' context aware was a very important part of the project and giving it access to the current location data would provide the writers the possibility to regionalise the stories. Several possibilities were mentioned during the initial meeting that warranted further investigation. These options were

1. GPS receiver plugged directly into the computer
2. Mobile phone with GPS/Wi-Fi/Mobile Network location
3. External IP address of the player
4. GPS receiver connected to an Arduino style prototyping board

Each of these options were investigated to find the most appropriate solution, based upon their cost, reliability and accuracy.

The first and fourth options both faced the same limitation when it came to reliability as both struggled to gain a location when the GPS sensor was inside, but could obtain a location if the sensor was placed outside through a window. This would not be ideal in a production or even a presentational device and so these options were removed as possibilities.

The third option reliably provided a location and was free making it an ideal candidate, however as the final location of the 'radio' is unknown and may change on a daily basis, several different networks were tested. The tested networks were, a VPN into a different network from the office, a mobile hotspot, a University provided Wi-Fi access point and a University LAN connection. The VPN as expected provided the location of the home server for the VPN, however this test was important as when logging in to a network away from an ISP such as Lancaster University, the IP address that is allocated have may not be locatable to within such a specific region. The mobile hotspot provided the correct country but again gave the location as the mobile network endpoint which was some several hundred miles from the actual location. The final two options of both the wired and wireless networks at the university located the 'radio' to within a 1-mile radius of the actual location. So while both of these options were very accurate, without knowing the location ahead of time there was no way of gauging the veracity of the accuracy of the location.

The second option was the most expensive requiring a £200 android mobile phone, however it also afforded both the most accurate and most reliable location data. Utilising the GPS within the phone in combination with the Wi-Fi location data held by Google, a location fix within a few meters is possible, and due to the Wi-Fi location being indoors bears the 'radio' no hindrance. The added advantage of having a phone connected to the 'radio' is that it allows the option of using the phone as a remote control for the 'radio' making the system much easier to demonstrate.

11.3.5. Distance Sensing

The ultrasonic distance sensor was built onto a platform that could measure distances when communicating with an Arduino, this data could then be passed by Serial to the 'Radio'. When testing this system and creating a virtual map of the area, limitations were immediately apparent. The sensor as it is a dumb sensor can only detect the distance to an object and not what that object is. So in order to get a true sense of the room it would need to be calibrated before it was usable and this calibration would require that the area being scanned was not going to change afterwards. This in a demonstration environment might be possible, however if the 'Radio' were to be deployed there could be difficulty in sensing the distances correctly. So while the proposed sensor holds a lot of promise, the ability to use it in this context would be limited. The answer to this was to use the depth sensing camera from the Intel RealSense webcam to locate the face in the normal webcam then find those pixels in the depth camera and use that data to get the correct distance.

11.4. Potential Server Platforms

The requirements for the 'radio' platform were such that the only one was to create stories all that would be needed is limited JavaScript knowledge. Using this as the basis of the search for possibilities, several options jumped out these were; NodeJS, an Apache PHP Server, Python or some custom server system that would provide JavaScript interfaces to the native hardware.

Each of the aforementioned technologies has their limitations but also have advantages, therefore picking the most appropriate one is not as simple as identifying which one is the most wide ranging in terms of features, but is actually which one provides the best and most stable platform for the project to be built upon. This will be discussed over the next few pages, with a final discussion on the merits of each at the end.

11.4.1. NodeJS

This is a server side architecture that has a multitude of packages that can extend its capabilities outside of serving dynamic web pages. These packages are created by a community and can be created by anyone that can follow the coding structure and API. Helpful packages exist that would allow a lot of the processing intensive work to be done in lower level languages such as C and Python and as this is going to be deployed on a Linux machine this is by far one of the most extensible server side architectures on the list.

One of the most used NodeJS libraries, Socket.IO is used to send data back and forth across multiple clients, this messaging model would allow for remote admin interfaces to be built that could control the 'radio' making a demonstration much simpler by dynamically changing the available data on the server. While Socket.IO is available for other server side languages, the fact that NodeJS is built upon a JavaScript interface means that when the project goes open source the barriers to coding for it or modifying the server side would be negligible compared to other languages.

11.4.2. PHP

PHP: Hypertext Pre-processor (PHP) is one of the most developed server side languages and is more than capable of creating the kind of dynamic data that will be required to get the 'radio' working with a collection of different sensors, however connecting those sensors through to PHP may be an issue. However, while PHP offers great speeds, it does not typically run with a constantly open connection and so does not allow speedy data transfer between clients which will be needed when running the 'radio'.

11.4.3. Python

Python much like NodeJS has a multitude of different plugins and runs at a low level on the computer where it has access to a great deal of the systems architecture such as USB peripherals and has some of the best mathematical systems available (NumPy) which would allow for fast computation for many aspects of the 'radio's abilities. Python as a web server runs continuously and would allow much of the same data transmission as NodeJS.

11.4.4. Final Platform Discussion

The three platforms discussed above are by no means an exhaustive list of all server platforms they do represent the most appropriate options for this use case. Python from the offset seems like the best platform as it has the widest range of access to the underlying architecture of the system. NodeJS also allows this but does so through a layer of bindings to another language, so has a slightly higher processing overhead when running with multiple packages enabled. PHP by comparison does not allow access to the underlying architecture and so would need other technologies running alongside it to provide these options pushing it outside the scope of this project.

The next consideration is that this system be easily expandable through as little programming background as possible, having discounted PHP the remaining two languages are both scripting style languages and are relatively easy to use. However, the sheer abundance of web developers and the lower complexity of JavaScript would offer an easier learning curve to a story writer.

11.5. Designing the first Prototype

11.5.1. Building an Application Program Interface (API)

The main purpose of this project was to build and design a platform that others could then use to write and design perceptive stories. To this end and to enable people to do this in the easiest way possible an API was written that would give story creators access to the data from the sensors in a simple to consume manner.

From the outset the working team decided that the API needed a strict naming convention to maintain an obvious structure to the code that would allow new programmers to understand what to expect when a certain method was used. For example, methods used to request data are of the structure:

get 'SensorType' 'SensorFunction'

as an example, 'getCameraPeopleCount'. This would return the latest count that the camera has for the number of people in the scene.

Of course building an API is but the first step, testing the API and using it to create a story is the next stage of the process. The API and the associated functions built into it, allowed the team to recreate Mudlark's Aesop Fable story on the 'radio'. It was through this process that several new functions were added into the API, as it was only once the team had begun building a story that it could be seen where the limits of the API began to show themselves.

One of the cases where a change was required was during the initialisation of the API, in the first version the, a story creator simply called 'beginAPI()' and this would start all of the sensors on the NodeJS server. However, this did not allow for customisation where a creator could state what type of data they would need from the server, and so a new structure was created allowing the creators to tell the server the types of sensor that were to be a part of the story and what type of analysis if any they wanted to have applied to the data.

The API was a substantial move forward from the BBC's first iteration of the project where each story had to be crafted anew and while code could be copied across from one story to another it would then have to be implemented in a new way and if anything needed to be changed you had to be able to understand the entire code base. This is where the API gave the creators a much simpler and faster creation mechanism the API where one line commands that returned as much data as was required for a certain function that could be used as is without any further computation required.

11.5.2. Initial Stage Completion Meeting

With the API written and the demo story running on the 'radio' a meeting was held with the BBC and Mudlark to demonstrate the progress that had been made. From the outset the group was very happy with the rate of progress, especially the extent of the API and its associated documentation. Although having learned from previous projects that making the software start up automatically allows for a smoother workflow, in this case there was an inconsistency with the compatibility of the USB ports of the computer that stopped the demo from working in the correct way. This was eventually resolved however it proved the point that the project had to be deployable without worry of misconfiguration.

Another point was raised by Ian from the BBC that the original radio always had to have a keyboard, mouse and screen in order to connect it to whatever network was available in the space and that this was often a hindrance to the setup and presentation of the radio. Deciding this was worth looking into a point was made to ensure that networks could be joined without the requirement of a screen to sign in to them.

Ian expanded on his previous point, explaining that when demoing a "perceptive radio" it was very difficult to explain to passers-by what's happening as because the story changes to suit the audience without them knowing, they quite simply understand that, that is the entire story, not knowing that it changes according to the environment. Previously this has been countered by having people listen to the story twice but on the second run through the parameters were changed manually simulating a new story environment. As the previous requirement would already call for some form of administration interface an extension to this was suggested to allow any of the variables called for in the story to be changeable at any time. While this would not play a part in stories as a final product, it would help to explain the platform to potential backers and to storytellers who are unsure of the projects potential.

The final point of the meeting was that while the case for the machine was functional it didn't evoke the same sense of nostalgia as did the old radio, and that perhaps a fascia or a new encasement would help with its presentation.

The key outcomes of the meeting were that the project was moving in the correct direction, but was running into similar issues that had plagued the original version. Therefore, the team sought a closer relationship with Ian of the BBC as he had most experience of demoing the original radio. This relationship took the form of more frequent Skype and email conversations explaining the current progress of the team on the proposed changes. This change to the current working style would help as the project moved forwards as it allowed the knowledge that Ian possessed of the first radio to be exchanged with the Lancaster team as work progressed.

11.6. Second Prototype

11.6.1. Required Changes

The changes as suggested in the meeting were to enable control of the radio from a remote interface via the API, to allow the connection of the radio to a Wi-Fi network without a keyboard/mouse/screen, to create an admin interface that would be simple to control and use by a demonstrator and finally to change the case for a more aesthetically/in-fitting design akin to the original version.

11.6.2. API redesign

Following the first stage meeting a list of changes to the API was drawn up. As much of the API was already written and the process for passing information to and from the backend of the radio to the frontend already existed, it was decided that expanding upon this to introduce a third endpoint, the admin interface. For the admin interface the existing API methods would not be enough as they existed primarily as 'get' methods meaning you can retrieve data but not set the data remotely. Therefore, a new set of methods would be created, where every get method was mirrored with a 'set' method. The API would also require new methods for searching, selecting and connecting to Wi-Fi networks along with a way of resetting the entire radio back to its initial state. These methods would all be created within NodeJS as before, but for the Wi-Fi network connection a separate program would be required that would be called from the NodeJS to the underlying operating system.

11.6.3. Admin Interface

It was decided at this stage that an Admin Interface would be created for mobile devices so that they could display the appropriate commands on a web page allowing the demonstrator to simply connect to the radio and control it remotely. Through discussions between the Lancaster team a workflow was created for how the start-up and setup of the radio would occur and it is listed below in order.

1. Connect all peripherals to the radio
2. Plug in and start the radio
3. Connect the control phone to the radio
4. Load the admin webpage on the control phone
5. Select and connect to the appropriate Wi-Fi network
6. Select the story to play
7. Control the playback and variables of the story from the phone

To provide this form of interface there were two methods available, a webpage or a dedicated application. While both have advantages the final decision was to use a webpage as it would work across platforms and devices where as a dedicated application would require a new build for each platform/device so the webpage has speed of development on its side.

To enable these changes to be possible, a new network card was required to be set up on the radio, this network would be an Ad-hoc network, such that the radio would broadcast a network that the admin phone could then connect to. From here the phone would be able to setup a connection to another wireless network via the other network adapter by selecting the correct SSID and supplying the password.

The interface was initially developed as a plain web html form that allowed for quick testing and development, however the group felt that as it is unknown who might be the demonstrator of the radio it was important that it was as user friendly as possible. As such Adrian began the design of the web application so that it was compliant with current HTML5 web application and design standards.

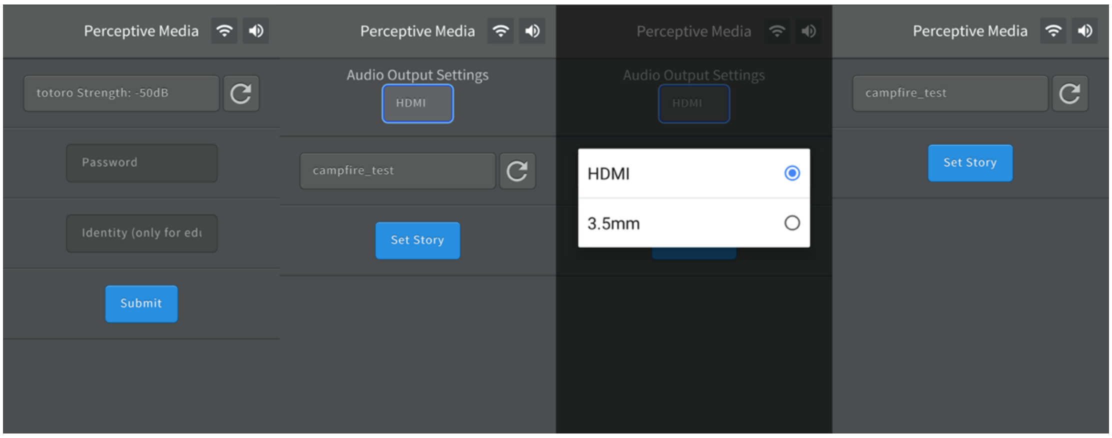

Figure 52: Admin Interface Setup Screens

The resulting interface was not only simpler to use but also enabled greater control over the myriad of sensors from a single mobile screen. The interface as shown in Figure 52 enables the demonstrator to connect to whichever Wi-Fi network they require as well as being able to change the audio output whenever they deem necessary. This is something that became evident after demoing the prototype in different spaces where speakers were not always associated with the HDMI output. Once they've setup the environment a story selection screen is shown, allowing them to select from the list of stories available to them.

The controls as shown in Figure 53 allow the demonstrator to either take control of the story or to leave it to use the sensors values. At any point they are able to take control by ticking the override box, this is helpful as it can allow for the dynamic story to be heard by an audience that otherwise would be static.

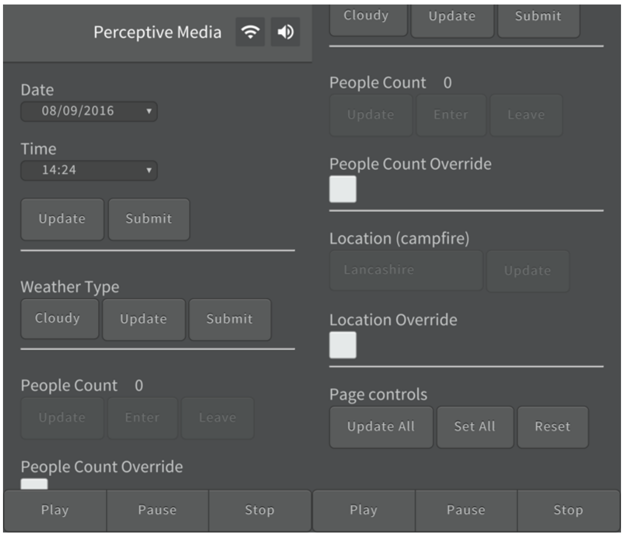

Figure 53: Admin Interface Controls

11.6.4. Case Redesign

With limited time on the projects it was often difficult to prioritise certain aspects of the project and in this case it was decided that finalising the software and control interface was more important. Not to say the design of the shell isn't important but it was felt that for the current prototype where the case is incidental and shouldn't be the focus of people's attention, that simply removing the radio from view during demos would be the simplest solution.

Figure 54: Perceptive Media v2 in Orange with the Original Radio Behind

11.7. Final Project Evaluation Meeting

Following the finalisation of the changes requested in the previous meeting, the project was now reaching its end point. According to the CX project structure this required a full team meeting to evaluate the project and the process that has allowed the project to proceed to this stage.

The meeting began with a run through of the project with explanations given about the changes that were made, the most appreciated change was the demonstrator remote control as it radically simplified the setup that was required for the original radio. However, comments soon moved to the fact that the outer shell of the radio had not changed, and that while they were happy with the function the form was not up to the standard they were expecting. Discussions moved towards bringing in the same designer that had previously worked on the outer housing of the Physical Playlist project to create a new case for the radio. An application for further funding was sought and the potential for external bids was felt the correct move for this project. The entire team felt that the project had achieved the goal of producing a workable platform for the development of branching audio narratives, that could be written with instruction from an experienced programmer, quickly and with ease by content writers. Carrying on from this point was the idea to educate the content creators on how you could use the different sensors to create these branching narratives and Ian from the BBC suggested a workshop at Mozfest 2015. Having previously attended with Physical Playlist, the group believed that the atmosphere at the festival would be the correct place to try out this form of content creation. While the further funding to extend the project was being sought the design of the workshop was paramount to the bid process and would be used to show the potential of the technology.

11.8. Discussion

On the whole the project from a CX perspective allowed knowledge to be exchanged at a theoretical and a practical level between all three parties, Lancaster University, BBC and Mudlark. That along with the feedback received from the two companies show that this method of bringing creative companies together with academics has a lot of potential for future growth for both sides.

From the point of view of this thesis there are many things that can be extracted from the project to inform the design manifesto, chief amongst these are the principles for designing the API for ease of use of future designers/programmers and how digital and physical elements are supported for future development and maintainability. This is an important consideration that can be overlooked, but just the act of creating a phygital object than spans both physical and digital space does nothing, it also has to be usable from both vectors. Therefore, when looking at this project, and being able to ignore for the most part the physical side has allowed more time and freedom to create a layer of interactivity and control that will go on to inform phygital design choices in the future.

11.9. Conclusion

While this project concentrated on the lack of interaction and in fact actually relied upon people being unaware that the radio was forming a narrative based on their actions and of those around them, it too has an important position with respect to this thesis. Knowing what needs interaction and what doesn't is an important distinction, one that is becoming all the more prevalent as the world moves towards the third decade of the 21st Century, a decade that is sure to be the decade of the Internet of Things. Only now in the latter half of this decade are IoT devices becoming mature enough that people are regularly interacting with them on a day to day basis, what was previously a niche product is rapidly sweeping North America in the form of the Amazon Echo a device that sits in a corner and can control your home through voice commands. It is widely accepted that as these devices become smaller and less obtrusive they will also be multiplying to a stage where their numbers will be so great that the information they'll be able to garner from simple sensors such as distance sensing, sound levels and face recognition will change the way lives are lived across the world.

What is to be taken from this chapter towards the manifesto is that the design of these objects that humans will be surrounded by but not necessarily interact with will be important to their perception by the public. The simple shapes and lack of visible buttons lead people to a point where they believe that they have no control over what occurs within the box, when in fact it is what is all around the box that is controlling it creating the illusion that the story is in fact a static flow.

12. Summary

Throughout my tenure as a PhD Candidate there have been several different projects that have coalesced into the body of this thesis. From the outset of the CX project it was made clear that the projects that came as a part of the CX would not necessarily fit with the overall thesis question. In many respects while the variation in the projects does not lend itself to confirming one individual overall point to the research it does allow for a creation of a best practice manifesto. The manifesto presented in Chapter 13 will extract the salient details from each individual project and then combine them into an answer to the research question of *"Designing Physical and Digital Interactions for the Digital Public Space"*.

The first project in this thesis came before the creation of The Creative Exchange, and dealt with methods of adapting how users interact with touchscreen devices. This project kicked off in many ways the first steps into the research for this thesis and made key points about how different interactions across different digital and physical technologies can be augmented with additional physical objects. These objects from the research conducted showed a greater interest in the game and more physical investment from the players when it came to using the physical objects over the typical interaction of just using their fingers. This seemed to be due to the way that the physical object mimicked the traditional role of the air hockey mallet and how people use it. Furthering the idea that for these phygital devices ensuring the matching of affordances was critical to the design.

Following on from the previous project was CheckinDJ a project which strove to disrupt the way in which public spaces are used by the public. By democratising the music in a venue a new social space could be born every day with users constantly reinventing it. As previously mentioned the potential of this project to change spaces is currently limited to music however with the plethora of new technologies in the realm of IoT being released each year these options will be able to expand until all aspects of a space could be digitally customisable by the people residing there. Again this project came before The Creative Exchange, but also had in it an important technology for later usage, namely NFC which would be used in both the ScareBot and the Physical Playlist projects.

First of the CX projects, the Physical Playlist was the first to involve collaboration on with an independent creative company, in this case the BBC. The project was all about recreating a curation aspect to online music playlists and adding a physical aspect to them. The process of creating the project and testing it with many different groups of people revealed that the curation side of the project was something that everyone was interested in. While older users disliked some of the design choices such as the inability to skip tracks the younger generations seemed to really enjoy the slow technology aspect of it all. The project as a whole brought forward that the creation and curation of the mixtape was a lost art form and that the customisation of the digital artefacts gave rise to a great deal of interest from all age ranges.

Continuing the physical prototyping the Wray Scarecrow project produced two outputs that have fed into this thesis; one, the ScARecrow mobile application and two, The ScareBot itself. Both had impact on the overall Wray project, though the ScareBot has since made even more of an impact after the project. The mobile app sought to test the methods that go together with designing and building an AR only application, the techniques used helped to develop ideas for how best to create these types of applications in the future. The ScareBot has had many adoring fans, and gave understanding to rapid prototyping methods that went on to ease the production of The Physical Playlist. Both parts of the project gave rise to novel interactions and observations of how people interact with them.

Moving towards the more digital side of the thesis, Cold Sun took on climate change and tried to address this wicked problem by the creation of a game that had elements that changed based on the real-world weather while the player was interacting with the game. The game was backed by data provided by a previous study into the perception of weather, this gave insight required to influence the story in appropriate ways. The project again brought together creative companies and academics, which enabled the group to have further connections to climate change scientists and data to try to ensure the accuracy of the predicted future world. The project helped to ratify how best to approach the design of interactive elements and the affordances of working on mobile devices.

Finally, completely extracting interaction from the basis of a project came Perceptive Media. This project was perfectly placed to decide how interaction-less devices for future IoT devices should work. In all the project looked at how to create branching narratives that took cues from the context of the space in which it inhabits. Workshops and exhibitions of the project have shown that there is considerable interest in the new medium created by the first Perceptive Radio that inspired this project. The API designed for the project is vital to its future uptake and use, something that all IoT device designers need to be keenly aware of. Their design is non-trivial especially when designing for content creators and not designers.

13. Conclusion & Manifesto

The design of digital and physical objects has never been more important and it is for this reason that this thesis has made a point of extracting the important design considerations from each of its constituent parts in order to produce a design manifesto.

The outcomes from the projects, have collectively made the arguments that there is no one way of creating a Phygital interactions and that the lines between the physical and digital are constantly shifting. These blurred regions are inherently difficult to design for. Through each chapter of this thesis and so each project has attempted to design a Phygital device, spanning from the more physical such as the Scarebot in Chapter 9 to the more digital systems such as the Perceptive Radio in Chapter 11. These devices encompass very different interactions, but both rely on the physical aspects of the world around them and the digital workings within them to produce unique experiences. What has been found through these projects is that the publics interaction and perception of these objects varies wildly. The methodology as used in this thesis with the quick cycles of prototyping and constant feedback from different groups enables rapid changes to be made in order to create the best possible output.

The Creative Exchange Doctoral program was integral to many of the projects previously described within, but more than that, as a new type of PhD it brought together people from many different disciplines and gave them a space where they could design and innovate collaboratively with SMEs. This process was not seamless due to a steep learning curve as the PhD programme began with little time to acclimate before starting projects. In the future if this form of PhD became the norm, there are several places where improvements could be made. Firstly, instead of starting projects as soon as the PhD began, it would be better to spend six months at the beginning where the students could be involved in the project proposal stage and the design of workshops that would lead to said projects. Secondly, limiting projects to run from after the initial six-month period to two years, leaving the student with the final six months to collect their ideas and begin the writing up of their thesis. Finally, giving the student their final project to be designed by them and then left to them to find the SME to work in partnership with would build on the project management and design skills they have learnt up to that point. As a pilot project CX was incredibly successful and if some of these points were addressed it could be the new method of PhD in the field of Design.

Each individual project has brought forth its own conclusions, each of these are integral to the final manifesto as each project has contributed in their own rights. The first project described in the thesis in Chapter 7 identified key points of design that users look for when interacting with digital devices it also brought forward the insight of the users' involvement greatly enhancing over the traditional touch screen inputs.

Chapter 8 looked more at the customisation of the space around the user but did so in a way that involved users physically accessing a system through an NFC card. This aspect of personalisation took on a grander scale than it did in Chapter 9 though both show how passionate people can become when given this ability and so can drive further interactions.

Changing tact and looking more at the bridge between the Physical and Digital from contrasting standpoints Chapter 10, found that codesign with younger people can bring about truly imaginative creations and that allowing a multitude of different interactions allows users to feel more in control of the system. Whereas the Augmented Reality application identified key aspects that can either help or hinder the use of this technology for navigational purposes.

Continuing the theme of digital interaction Chapter 11 and the Cold Sun game that was created to attempt to help players understand the possible future effects of climate change, while the interaction methods that came from this are on the purely digital side, it does lend itself to showing how these digital interactions should work and the right and wrong ways to provide appropriate affordances.

Finally, removing the interaction entirely from the project in Chapter 12 described how interaction-less devices could work in the Internet of Things world, where interaction may not be the final input but actually is used to understand the world around it and provide feedback based on what their sensors deduce. Creating the software was the final output of the project and highlighted the fact that any software produced for IoT devices needs to be maintained else it falls into disuse and then forgotten about/is broken.

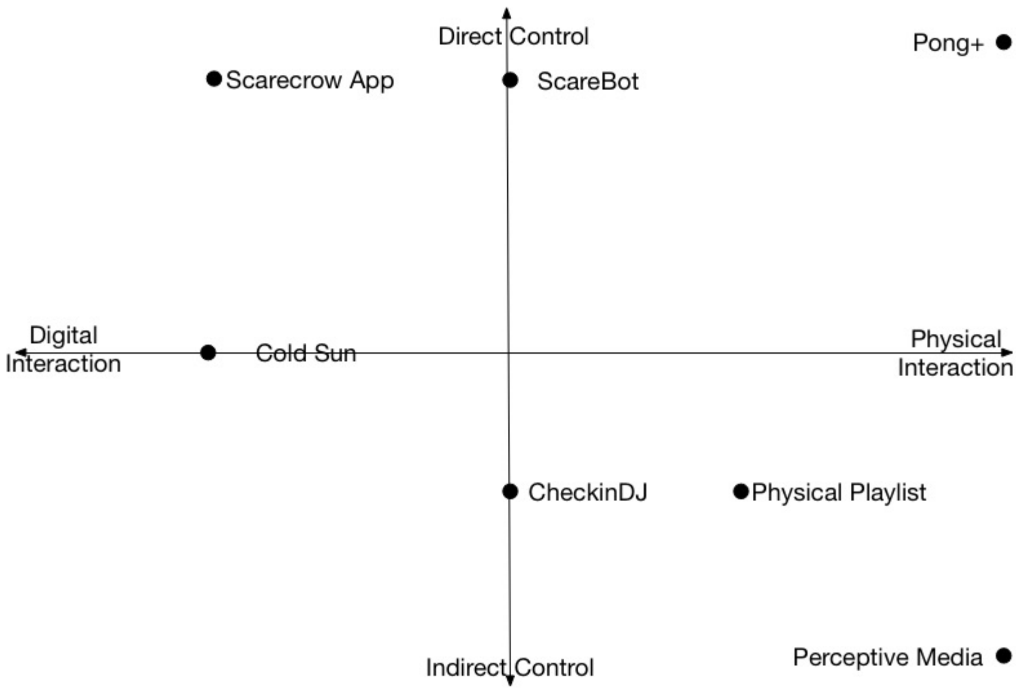

Figure 55: Phygital Spectrum of Phygital Interactions in Thesis Projects

Above Figure 55 shows where the projects lie on a map of physical interaction to digital interaction and direct control to indirect control. This map reveals the spaces that this thesis has covered and shows at least one space that is still to be explored with respect to Phygital Interactions, a space of indirect control with digital interaction, this topic would likely be best confronted via analysis of peoples' online interactions via websites or apps and then changing their environment according to their behaviours. This is actually the way online advertisers, social platforms or search engines tailor their information to individual users without them having direct control over the outcome. Designers could expand this into the physical world by changing environments based on users' online profiles. The Scarecrow Project has two positions on the map, as it had both the physical ScareBot and the ScARecrow time machine application. The two are therefore positioned differently due to their different interaction methods. The App is positioned deep within Direct Control and Digital Interaction territory as it relies on the users' interactions in the digital realm to collect the scarecrows but is towards the centre of the region due to the applications reliance on the users' GPS location to find the scarecrows to begin with. The Scarebot had several interactions that were possible, sounds were played as a result of the physical interaction of placing the disk on its reader arm, faces were presented on the screen based on the view of the camera and finally bubbles were blown as a reaction to a digital interaction by way of SMS message from the user. From here the movement to Pong+ and the Space Invaders game where the physical interaction of moving a game piece was augmented with a physical game piece to give the users' a stronger sense of control over the game. Cold Sun again sits well towards digital interaction due to its reliance on users' interacting with the screen of the device however it also requires the GPS data to customise the game experience using real world weather data pushing it towards the centre once more. CheckinDJ is an interesting case as while the user has direct interaction in a physical sense when they use their NFC card to 'checkin' there's a balance with their profile creation and connection that needs to occur when registering and the processing of their data to change the overall music preferences. While they do interact with the device directly the results of their interaction are actually on the indirect side of the scale as they don't directly choose the genre of music, just swing the preference more to their tastes. The Physical playlist project again features the physical interaction where the user both physically and digitally curates their bracelets though when it comes to the actual usage of the device there is only indirect control as the user has to allow the player to play through the tracks in the order they were placed in the bracelet to begin with. Finally, with Perceptive Media the interaction was completely removed from the users control and had no digital interaction from the users whatsoever. The object purely looks at its surroundings and uses that data to play a story, while that may change if a user enters the area where it is playing, they cannot otherwise influence the device other than by their presence. If a perceptive radio is in a forest and no-one is around, does it still tell a story?

The map as a descriptive medium is effective in showing the range of outputs that have fed this thesis and while there are areas of the map left to explore, a fair amount of ground has already been covered by the projects.

The purpose of this thesis has been to create a manifesto to guide towards supporting interactions during the creation of these Phygital devices for the DPS. As it is an evolving field this is by no means an exhaustive list but having worked to identify the important details of each of the projects these are the rarefied ideas that have been found.

13.1. Manifesto

The manifesto, in no particular order:

- Consider carefully when designing a phygital replacement for an object, what affordances to include and what to exclude. Especially if the form is the same, as users will expect affordances to match.
- Giving Physicality to a digital system gives users a sense of greater involvement in the digital world. Though not all things should or need to be digitized and good designers should also know when design is not the solution.
- Personalisation of objects is often now seen as key requirement and this presents considerable challenges for objects that are both physical and digital.
- Support and maintaining phygital objects is a challenge as while software improvements can be downloaded, physical improvements to an existing object are not normally practical. Therefore, careful consideration to this is required from designers if they are not to produce phygital devices that are quickly obsolete.
- During development, fast iterations enhance the design and allow quicker innovation and reactions to new developments. Whilst Agile practices are growing in software development new practices will need to be adopted for physical development.

- Even when interactions aren't integral to the design of the object, ethical considerations must be taken for how information that is gathered by the object is then used.
- When providing information to the user it is important that making things simple does not turn into making things opaque of a device is connected to the internet.
- Work with as diverse a group as possible to create amazing new designs.
- Always work as a group to decide how the project should move forward, ensuring to listen to every member.
- Try as many productivity tools as possible to find what works best for the whole group.
- When in a managing role, ensure that you delegate whenever possible and encourage your team members to achieve their full potential.
- Work with new people, take on new ideas, build robots!

While the points in the manifesto are important, they are not strict rules to follow, but more accurately could be referred to as provocations for those developing new products in this area. It is also important to note that these points were not arrived at arbitrarily, they came as an output of both The Creative Exchange Projects and from the projects that came before CX. The design processes that also led to these ideas should not be discounted as they have a significant part to play in the way in which Phygital objects are created in the future.

13.2. Personal Reflections

Overall these projects have transformed the way I believe Design Research should be performed. However, it was at times difficult to identify where my research question fit with the overarching projects and indeed the CX Project. It wasn't until the second year where things began to fall into place for me and the design methodology began to realise itself. The work presented in this thesis came about as part of a collaborative process, a process that I have now come to see as essential to my research agenda. Working with these other people over the course of the projects opened up so many opportunities to learn new skills and exchange ideas, that simply would not have occurred in a typical PhD format. From being the project lead on Cold Sun, I saw from the outset the difficulties that can be found when trying to bring people and their ideas together. However, through the design of the workshop that enabled people to discuss their ideas and then expand upon them with the help of others really brought the team together in a way that previously seemed impossible.

Whereas in the Perceptive Media project when my colleague was the Project Lead, I enjoyed the opportunity to problem solve and write the code that eventually led to the Perceptive Media API being a viable system.

In the Physical Playlist project, I was instead working in an engineering and programming role and had to determine the best way of producing the system that the group had collectively decided upon. Using skills that had previously come about as part of the ScareBot project I was able to design and build a prototype that with only minimal changes went on to be the main mechanism and software control system for the final product.

The Wray Scarecrow festival was my first introduction to collaborative design practice, when first looking at the drawings that the school children came up with it seemed that the entire project would be incredibly difficult to realise. Though through discussions with my supervisor it became clear that by experimenting with each part until we successfully completed them that step by step the project would be completed. It was this constant reflection on the build process that is central to the entire methodology that this thesis now represents.

Overall the PhD process, not just the projects have informed the way I will be approaching research in the future, from the methodology that came about from the process of the projects, through to the points in the manifesto these will be the tenets for my research in the coming years.

14. Further Work

Throughout this body of work, there has always come a point where it was no longer possible to continue the research into those specific areas primarily due to the start of the next project not because these projects are fully explored with respect to all research avenues.

Starting with physical game pieces, at the end of that project a new method of classifying objects that are placed onto touchscreens was proposed, while there has been some further research in this area it is by no means exhaustive (Santos, et al., n.d.). The opportunity to develop an object recognition system for touchscreen devices would have great potential for research as it could enable further interactions with everyday objects allowing for several users to carry their own game pieces with them to play in stories on a tablet with friends as just one example. This could suggest research into whether the value of digital assets is enhanced when it obtains physical form?

With CheckinDJ the ability to customise spaces and venues has great potential to be expanded upon, with the possibility of not only changing the space's sounds but also its lighting conditions, even aspects such as what channel a TV is tuned to or whether curtains/blinds are open or shut. The crowd-curating system has an interesting place for research into the democratisation of spaces. In order to do this the recommendation would be to build a space from the ground up with all potential aspects controllable, it would be interesting to push the limits and see just how much customisation people would want over a space and the difficulties of architects and interior designers to deal with these morphing spaces.

Research into the ability to curate playlists in physical forms has only just been touched upon in that chapter, and while the reader itself is likely to never be mass produced, with the prevalence of NFC within the majority of Android phones and hopefully Apple iPhones will be accessible to the developer community soon, there will be the option to create playlists that people read with their phones with some other media or apps linked in as well. There would be significant challenges to overcome with this process however due to the educating of people in how to use these objects and the need to program them before use.

Cold Sun barely touched upon the enormous possibilities of using real world events within a branching narrative gaming system, there are so many other data sets that could be interacted with at an abstract level within a game environment. Using global stock market data to influence the abilities of characters within a game, or limiting the story options until the stock price rises above a certain level or increases by a set percentage and timing this with the release of new in-game items. Addressing wicked problems through the genre of mobile games also has some interesting possibilities, providing either liminal or subliminal messages to the user and seeing if their actions in the real world are influenced, this would require a longitudinal study to trace the effects of playing such a game, though it could lead to new avenues for educating people about complex issues such as climate change.

Finally, we come to Perceptive Media, the idea of removing all direct interaction with a device meant to be telling stories that change based on the actions and events occurring around it. The BBC partners with this project have already started research into a visual version of the system, which has very interesting possibilities if it combines the same area sensing capabilities with social media access to further tailor the stories to the individuals watching it, potentially without their knowledge that it's happening. This area thus requires significant amounts of research addressing questions such as how do producers develop the content for all the possibilities that can occur, or how do audiences react when discussing a programme they might have seen with someone who may have experienced something different?

With any of these projects moving forwards the recommendation would always be to work in a team with varying skillsets to eliminate the possibility of one researcher moving it purely in one direction as there are a myriad of different routes the research could take.

15. References

Ageh, T., 2010. *Tony Ageh on the BBC Archive and how to remake the internet.* [Online]
Available at: https://www.theguardian.com/media/2010/nov/01/tony-ageh-interview-bbc-archive
[Accessed 20 September 2016].

Anon., n.d. *RFID Music Table Created Using Arduino, iPod And RFID Tags.* [Online]
Available at: http://www.geeky-gadgets.com/rfid-music-table- created-using-arduino-ipod-and-rfid-tags-video-06-10- 2011/
[Accessed 30 May 2012].

Apple, n.d. *Apple, Event Handling Guide for iOS.* [Online]
Available at: http://developer.apple.com/library/ios/documentation
[Accessed 3 10 2011].

Arnstein, S. R., 1969. A Ladder of Citizen Participation. *Journal of the American Institute of Planners,* 35(4), pp. 216-224.

A, S., W, P., C, B. & N, F. P., 2011. 'Perceptions of climate change and willingness to save energy related to flood experience'. *Nature Climate Change,* Volume 1, pp. 46-49.

Avison, D., Lau, F., Myers, M. & Nielsen, P. A., 1999. Action Research. *Communications Of The ACM*, January, 42(1), pp. 94-97.

Azuma, R., 1997. A Survey of Augmented Reality. *Presence: Tele-operators and Virtual Environments,* 6(4), pp. 355-385.

Ballagas, R. et al., 2007. REXplorer: a mobile, pervasive spell-casting game for tourists. *CHI '07 Extended Abstracts on Human Factors in Computing Systems (CHI EA '07).*

Bamford, W. et al., 2008. *Using mobile phones to reveal the complexities of the school journey.* New York, ACM.

Bernades Jr, J. L. et al., 2008. Augmented Reality Games. In: *Extending Experiences: Structure, analysis and design of computer game player experience..* Lapland: University Press.

Birks, M. & Mills, J., 2011. *Grounded Theory: A Practical Guide.* London: SAGE Publications.

Bogost, I., 2007. *Persuasive games: The expressive power of videogames.* s.l.:MIT Press.

Bogost, I., 2011. *How to do things for videogames.* s.l.:University of Minnesota Press.

Boykoff, M. T., 2011. *Who speaks for the climate?: Making sense of media reporting on climate change.* Cambridge: Cambridge University Press.

Buchanan, R., 1985. Declaration by design: Rhetoric, argument, and demonstration in design practice. *Design Issues,* pp. 4-22.

Burnett, D., Coulton, P. & Lewis, A., 2012. *Providing both Physical and Perceived Affordances using Physical Games Pieces on Touch based Tablets.* New York, ACM Press.

Burnett, D. & Lochrie, M., 2012. *CheckinDJ.com.* [Online]
Available at: http://www.checkindj.com

Buxton, W., Hill, R. & Rowley, P., 1985. *Issues and Techniques in Touch-Sensitive Tablet Input.* New York, ACM Press, pp. 215-224.

Chen, Z., Yavuz, E. A. & Gunnar, K., n.d. *Demo of a collaborative music sharing system.* New York, ACM, pp. 77-78.

Cohen, L. & Manion, L., 1994. *Research Methods in Education.* 4th Edition ed. London: Routledge.

Copic Pucihar, K. & Coulton, P., 2013. Exploring the Evolution of Mobile Augmented Reality for Future Entertainment Systems. *Computers in Entertainment (CIE) - Theoretical and Practical Computer Applications in Entertainment,* 11(2).

Coulton, P., 2014. Mobilizing Gamification. In: *The Gameful World: Approaches, Issues, Applications.* Cambridge: MIT Press.

Coulton, P., Bamford, W., Cheverst, K. & Rashid, O., 2008. 3D Space-time visualization of player behaviour in pervasive location-based games. *Int. J. Comput. Games Technol.*

Coulton, P. et al., 2014. Game Design in an Internet of Things. *Transactions of the Digital Games Research Association.*

Coulton, P., Lund, K. & Wilson, A., 2010. *Harnessing Player Creativity to Broaden the Appeal of Location Based Games.* s.l., s.n.

Coulton, P., Rashid, O. & Bamford, W., 2006. *Experiencing 'touch' in mobile mixed reality games.* Liverpool, Liverpool John Moores University, pp. 68-75.

Council, N. I., 2008. *Disruptive Civil Technologies.* [Online]
Available at: https://fas.org/irp/nic/disruptive.pdf
[Accessed 20 September 2016].

Csikszentmihalyi, M. & Halton, E., 1981. *The Meaning of Things Domestic Symbols and the Self.* Cambridge: Cambridge University Press.

Davison, A. R., Moulton, I. & Stasse, O., 2007. MonoSLAM: Real-Time Single Camera SLAM. *IEEE Transactions on Patterns Analysis and Machine Intelligence,* 29(6), pp. 1052-1067.

Dos Santos, A., Strada, F., Martina, A. & Bottino, A., n.d. *Designing collaborative games for children education on sustainable development.* Utrecht, s.n.

Drascic, D. & Milgram, P., 1996. Perceptual Issues in Augmented Reality. In: *Stereoscopic Displays and Virtual Reality Systems III.* s.l.:SPIE Press, pp. 123-134.

Edwards, J., 2014. *The iPhone 6 Had Better Be Amazing And Cheap, Because Apple Is Losing The War To Android.* [Online]
Available at: http://www.businessinsider.com/iphone-v-android-market-share-2014-5?IR=T
[Accessed 20 September 2016].

Fallman, D., 2007. Why Research-Oriented Design Isn't Design-Oriented Research: On the Tensions Between Design and Research in an Implicit Design Discipline. *Knowledge, Technology & Policy,* 20(3), pp. 193-200.

Findeli, A., 1999. Introduction. *Design Issues,* 15(2), pp. 1-3.

Fogg, B., 2011. *Persuasive Technology: Using Computers to Change What We Think and Do.* San Francisco: Morgan Kauffman.

Frayling, C., 1993. Research in Art and Design. *Royal College of Art Research Papers,* 1(1), pp. 1-9.

Frohlich, D. & Murphy, R., 2000. The Memory Box. *Personal and Ubiquitous Computing,* August, 4(4), pp. 238-240.

Gasson, S., 2003. Rigor In Grounded Theory Research: An Interpretive Perspective on Generating Theory From Qualitative Field Studies. In: M. Whitman & A. Woszczynski, eds. *Handbook for Information Systems Research.* Hershey: Idea Group Publishing.

Gaver, W., 2012. *What should we expect from research through design?.* s.l., ACM, pp. 937-946.

Gaver, W., n.d. *What should we expect from research through design.* s.l., s.n.

Giannachi, G., 2012. Representing, Performing and Mitigating Climate Change in Contemporary Art Practice. *Leonardo,* Volume 45, pp. 124-131.

Gibson, J. J., 1977. *The theory of affordances.* Hilldale: s.n.

Glaser, B. & Strauss, A., 1967. *The Discovery of Grounded Theory.* Chicago: Aldane.

Häkkilä , J. & Chatfield, C., 2006. *Personal customisation of mobile phones: a case study.* New York, ACM.

Hallnas, L. et al., n.d. *Expressions: Towards a Design Practice of Slow Technology.* Tokyo, s.n., pp. 447-454.

Hallnas, L. & Redstrom, J., 2001. Slow Technology – Designing for Reflection. *Personal and Ubiquitous Computing,* 5(3), pp. 201-212.

Heath, H. & Cowley, S., 2004. Developing a grounded theoryapproach: a comparison of Glaser and Strauss. *International Journal of Nursing Studies,* Volume 41, pp. 141-150.

Hemment, D., Thompson, B., de Vicente, J. L. & Cooper, R. eds., 2013. *Digital public spaces.* s.l.:FutureEverything.

Herbst, I., Braun, A., McCall, R. & and Broll, W., 2008. *TimeWarp: interactive time travel with a mobile mixed reality game.* New York, ACM.

Hinske, S. & Langheinrich, M., 2008. RFIDice– Augmenting Tabletop Dice with RFID. *Virtual Reality and Broadcasting,* 5(4).

Hinske, S., Langheinrich, M. & Lampe, M., n.d. *Towards guidelines for designing augmented toy environments..* New York , ACM, pp. 78-87.

Ishii, H., 2008. *Tangible bits: beyond pixels.* New York, s.n.

Jacobs, R. et al., 2013. *A conversation between trees: what data feels like in the forest..* New York, ACM, pp. 129-138.

Juul, J., 2009. A Casual Revolution: Reinventing Video Games and Their Players.

Kähäri, M. & Murphy, D. J., 2006. *MARA – "Sensor Based Augmented Reality System for Mobile Imaging".* Santa Barbara, s.n.

Kato, H. et al., 2000. *Virtual object manipulation on a table-top ar environment..* s.l., s.n.

Klein, G. & Murray, D., 2007. *Parallel Tracking and Mapping for Small AR Workspaces.* Washington, IEEE Computer Society.

Klein, G. & Murray, D., 2009. *Parallel Tracking and Mapping on a camera phone.* Washington, IEEE Computer Society.

Knowles, B., Coulton, P., Lochrie, M. & Whittle, J., 2014. Wicked persuasion: a designerly approach. *Lecture Notes in Computer Science,* Volume 8462, pp. 137-142.

Koskela, T., Julkunen, J., Kassinen, O. & Ylianttila, M., 2010. User Evaluation of a Community-centric Music Voting Service Journal of Digital Content Technology and its Application. *INTERNATIONAL JOURNAL OF DIGITAL CONTENT TECHNOLOGY AND ITS APPLICATIONS,* 4(1), pp. 69-78.

Koskela, T. et al., 2009. *User Experiences on a Community- Based Music Voting Service.* Washington, IEEE Computer Society, pp. 747-753.

Lam, B. et al., 2011. *Voice Your View: An Inclusive Approach to Civic Engagement.* s.l., s.n.

Lenhart, A., Purcell, K., Smith, A. & Zickuhr, K., 2010. *Social Media & Mobile Internet Use among Teens and Young Adults. Millennials,* s.l.: Pew internet & American life project.

Lyons, K., Gandy, M. & T. Starner, T., 2000. *Guided by Voices: An Audio Augmented Reality System.* s.l., International Community for Auditory Display.

Magerkurth, C., Memisoglu, M., Engelke, T. & Streitz, N., 2004. *Towards the next generation of tabletop gaming experiences..* Waterloo, Canadian Human-Computer Communications Society, pp. 73-80.

Mandryk, R. & and Maranan, D., 2002. *False prophets: exploring hybrid board/video games.* New York, ACM.

Marco, J. et al., n.d. *Bringing tabletop technologies to kindergarten children.* Swindon, British Computer Society, pp. 103-111.

McLuhan, M., Fiore, Q. & Agel, J., 1967. *The medium is the massage.* New York: Bantam Books.

McLuhan, M., McLuhan, E. & Zingrone, F., 1996. *Essential McLuhan.* s.l.:Basic Books.

McNiff, J. & Whitehead, J., 2011. *All You Need to Know About Action Research.* London: SAGE Publications.

Milgram, P. & Kishino, F., 1994. Augmented reality: A class of displays on the reality-virtuality continuum. *SPIE,* pp. 282-292.

monobanda, n.d. *monobanda. Do It Yourself DJ!.* [Online]
Available at: http://www.monobanda.nl/?portfolio=do-it-yourself-dj
[Accessed 30 May 2012].

Nandwani, A., Coulton, P. & Edwards, R., 2011. *Using the physicality of NFC to combat grokking of the check-in mechanic.* New York, ACM, pp. 287-290.

Norman, D., 1999. Affordance, conventions and design.. *Interactions 6,* pp. 38-43.

Norman, D., 2002. *The Design of Everyday Things..* s.l.:Basic Books.

Odom, W. et al., n.d. *Slow Technology: Critical Reflection and Future Directions.* New York, ACM, pp. 816-817.

Ohshima, T., Sato, K., Yamamoto, H. & Tamura, H., 1998. *AR2Hockey: A case study of collaborative augmented reality.* Los Alamitos, IEEE Press, pp. 268-295.

Paek, T. et al., 2004. *Toward universal mobile interaction for shared displays..* New York, ACM, pp. 266-269.

Petrelli, D. & Whittaker, S., 2010. Family memories in the home: contrasting physical and digital mementos. *Personal and Ubiquitous Computing,* 14(2), pp. 153-169.

Plaisant, C., 2004. *The Challenge of Information Visualization Evaluation.* New York, ACM.

Rapp, C., 2010. *Aristotle's Rhetoric, The Stanford Encyclopedia of Philosophy.* [Online] Available at: http://plato.stanford.edu/archives/spr2010/entries/aristotle-rhetoric/ [Accessed 17 May 2014].

Saffer, D., 2008. *Designing Gestural Interfaces: Touchscreens and Interactive Device.* s.l., O'Reilly Media.

Santos, A. D. D., Strada, F., Martina, A. & Bottino, A., n.d. *Designing Collaborative Games for Children Education on Sustainable Development.* s.l., Springer.

Scannell, L. & Gifford, R., 2011. 'Personally Relevant Climate Change: The Role of Place Attachment and Local Versu s Global Message Framing in Engagement',. *Environment and Behavior,* 20 October.

Scheible, J. & Ojala, T., 2005. *MobiLenin combining a multi-track music video, personal mobile phones and a public display into multi-user interactive entertainment..* New York, ACM, pp. 199-208.

Schnädelbach, H. et al., 2002. *The augurscope: a mixed reality interface for outdoors..* New York, ACM.

Stevens, M. M., Abowd, G. D., Truong, K. N. & Vollmer, F., 2003. Getting into the Living Memory Box: Family archives & holistic design. *Personal and Ubiquitous Computing,* pp. 210-126.

Strauss, A. & Corbin, J., 1990. *Basics of Qualitative Research: Grounded Theory Procedure and Techniques.* London: SAGE.

Tuikka, T., n.d. *'PhonePhone' – NFC Phone as a Musical Instrument, CHI EA '09.* s.l., s.n., pp. 2627-2630.

Ullmer, B. & Ishii, H., 2000. Emerging frameworks for tangible user interfaces. *IBM Systems Journal,* Volume 39, pp. 915-931.

Verplank, W., 2009. *Interaction Design Sketchbook by Frameworks for designing interactive products and systems.* [Online]
Available at: https://hci.rwth-aachen.de/tiki-

download_wiki_attachment.php?attId=797
[Accessed 27 September 2016].

Wagner, D. et al., 2008. *Pose tracking from natural features on mobile phones.* Washington, IEEE Computer Society.

Wagner, D. & Schmalstieg, D., 2006. *Handheld Augmented Reality Displays.* s.l., IEEE.

Wagner, D. & Schmalstieg, D., 2007. *ARToolKitPlus for Pose Tracking on Mobile Devices.* s.l., s.n., pp. 139-146.

Wagner, D. & Schmalstieg, D., 2009. *History and Future of Tracking for Mobile Phone Augmented Reality.* Guangju, s.n.

Weiser, M., 1993. Some Computer Science Issues in Ubiquitous Computing. *CACM,* July.

Wigdor, D. & Wixon, D., 2011. *Brave NUI World : Designing Natural User Interfaces for Touch and Gesture.* s.l.:Morgan Kaufmann.

Wisneski, C. A., 1999. *The Design of Personal Ambient Displays. Master's Thesis.* s.l.:Massachusetts Institute of Technology.

Yu, N. et al., 2011. *TUIC: enabling tangible interaction on capacitive multi-touch displays..* New York , ACM, pp. 2995-3004.

Zimmerman, J., Forlizzi, J. & Evenson, S., 2007. *Research through design as a method for interaction design research in HCI.* s.l., ACM, pp. 493-502.

Zipes, J., 2012. *The Irresistible Fairy Tale: The Cultural and Social History of a Genre.* s.l.:Princeton University Press.

16. Appendix

16.1. Physical Playlist

The code for Physical Playlist RaspberryPi software can be found here:

http://cxprojects.lancs.ac.uk:8585/redspike/physical-playlist

16.2. Perceptive Media

The code for The Perceptive Media NodeJS software can be found here:

http://cxprojects.lancs.ac.uk:8585/redspike/perceptive-media-bbc