CRAFTING WITH TECHNOLOGY: AN EXPLORATION INTO LOW-TECH SOLUTIONS FOR HIGH-TECH ISSUES

SHANE CUNNINGHAM

16094794

Master of Science in Interactive Media

University of Limerick

Supervisor: Dr Mikael Fernstrom

Submitted to the University of Limerick

August 2017

DECLARATION

CRAFTING WITH TECHNOLOGY: AN EXPLORATION INTO LOW-TECH SOLUTIONS FOR HIGH-TECH ISSUES

Supervisor: Dr Mikael Fernstrom

This Thesis is presented in partial fulfilment of the requirements for the degree of Master of Science in Interactive Media. It is entirely my own work and has not been submitted to any other university or higher education institution, or for any other academic award in this university. Where use has been made of the work of other people it has been fully acknowledged and fully referenced.

Signature:

Shane Cunningham

14, August 2017

Acknowledgements

I would like to express my gratitude to the IDC and the various people for their contribution to this project, my project supervisor Dr Mikael Fernstrom for his enthusiastic encouragement, his technical guidance, and for his advice and assistance in keeping my progress on schedule. I would like to thank the course coordinator, Dr Cristiano Storni for his useful critique and guidance throughout the year. I would also like to thank Colm McGettrick for his technical assistance. Finally, I wish to thank my parents for their support and encouragement throughout my study.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1: Introduction

Within the last two decades, there has been an influx of interactive technology that has become more ubiquitous than ever before. Today user interaction is moving away from the conventional tools and is becoming much more omnipresent, physical, and tangible. This thesis explores emerging interactive technologies that allow for the experimentation and the development of new interaction methods that augment the experience of human computer interaction. Fischer (2010a) highlights that the emergence of Web 2.0 brought about a fundamental cultural shift from a consumerist culture to a culture of sharing and participation with the arrival of collaborative design environments, social media, and social networks. This relatively new ideology has caused a paradigm shift in regard to design practices and is altering perceptions about the consumerist relationship to technology. This is discussed in more detail in Chapter two, where the conceptual and contextual framework for this thesis is analysed through the design concepts and methodologies that have informed my practice. The second section of Chapter two is concerned with related projects and inspirational material that have had an influence regarding the conceptual framework for this thesis. Chapter three outlines the design process involved in the project which entails the methodological approach, prototyping tests and the technical aspects of the project. The context of this project was further demonstrated in the DAWN exhibition by creating an interactive tabletop based interface that utilised capacitive sensing technology to convey to the user the concept of using any non-conductive surface as a touch and gesture-based interface. My preference for working with off-the-shelf components stems from the methodology of a maker as I am interested in unpacking what Pinch and Bijker (1984) refer to as the black box of technology.

Chapter 2: Background

2.0 Introduction

This chapter introduces the conceptual and contextual framework for this thesis by first analysing the different design concepts and methodologies that have informed my practice. The second section of this chapter is concerned with related projects and inspirational material that have had an influence in laying out the conceptual framework for this thesis.

2.1 Literature Review

2.1.1 Introduction

This section of the paper focuses on the conceptual framework of the thesis and how it has informed the overall process. This section begins by analysing the topic of end user development and how it has been considered a liberating force that has democratized the way humans interact with computational technology, while also emphasising the downfalls of end user development and how improvements have been explored through the findings of Sanders and Stappers, Fischer, Ishii (2002a, 2010b) who explore the solution in the form of meta-design. This section concludes with an exploration into how the ideology and values of meta-design have been incorporated into current practices. This section examines through findings of Fischer, Löwgren, Schön, Silver, (2002a; 2016; 1983; 2009; 2009) how similar methodologies could be explored to inform the design process.

2.1.2 End User Development and Meta-Design

Joerg Beringer states in his article *Reducing Expertice Tension* that End User Development (EUD) is the design issue that permits experts of their own areas to personalise software components for their own specific field of expertise. Beringer (2004) emphasises that this design issue is not only a problem for the experts who the software is designed for, meaning the expert of their field, the Web Designer and so forth, who are trained to use the specific software and tools that were built for their particular field, the domain experts. These domain experts lack the true understanding of how these easy-to-use development applications actually work. The underlying technology of these applications is also constrained due to the optimization of the product to enhance the usability. Therefore, the end user developers are not technically adept at utilising the development tools that are made for them, by which they are relegated from being true experts. A primary example of this would be the comparison between programmes such as Google SketchUp and OpenSCAD, with the former focusing on creating a user-friendly interface for composing graphical representations of 3D models while the latter uses a programming IDE (Integrated development environment) that teaches the user how to programme in C# language and to compose more technically accurate 3d Cad projects. Programmes like OpenSCAD help bridge the gap between the end user and the IT professional. In Sanders and Stappers (2008a) paper entitled *Co-creation and the new landscapes of design*, the focus is towards how the user-centred method in reference to co-designing is transforming the landscape in regards to the roles of designers, researchers and users. The work of Sanders and

Stappers (2008a) emphasises that the practice of design is evolving from a user-centred approach to more of a co-designing approach that focuses on embracing the user's creativity. The manufacturer's focus has generally been towards design methods that generate products initially based on a deterministic idea of what people need. The work of Sanders and Stappers (2008a) states that the first advances in user- centred approach originated from industrial practices from which it was used from the expert's viewpoint where researchers would be appointed to interview the users, who were mainly passive in the process. This was the American approach whereas the Northern European approach was exploring a more participatory method whereby the user's role was more of a partner in the design process. Sanders and Stappers (2008a) believe that by conjoining these two methods, the concept of co-creation/co-design has emerged within the field of participatory design. Although, when the user has been promoted to co-designer, the authorship remains with the designer, as it is the designer's role to create the scenario for the user. The roots of co-design are very much steeped in business and marketing practices and are somewhat lacking in a truly creative ethos. Fischer's paper entitled *Beyond 'Couch Potatoes': From Consumers to Designers and Active Contributors,* examines the issue by declaring that a culture is defined by their media and their tools in order for them to think, work, learn and collaborate. Fischer believes that through the arrival of new media artefacts, that the culture has shifted to one where the artefacts are designed from the viewpoint that the human is the consumer (Fischer, 2002a). To counteract this issue Fischer (2002a) explores the concept of the designer as

" a person who wants to act as an active participant and contributor in personally meaningful activities " (Fischer, 2002, p. 2), from which he believes that anyone should take on the role of designers should they desire to do so. Sanders and Stappers (2008a) Highlight what they believe to be the reasons why the principles and practices of co-design have had so many setbacks, they begin with the point that co-creativity involves the belief that everyone has creativity, which would not be a generally accepted viewpoint, particularly from those involved in the world of business. For Sanders and Stappers (2008b) co-designing in business terms can be seen as a threat to the existing hegemonic structures of companies who they believe prefer to adopt the model that the leading people, the so-called experts are the only ones capable of taking on the role of the co-designer. Fischer (2002b) calls for a paradigm shift in regard to the production of next generation of technological artefacts believing that knowledge must not be restricted to those who he labels as 'high-tech scribes', those whose roles are distinguished by the division of the computing world from the greater population who are marginalized by their lack of knowledge into the role of the consumer, further emphasising the need for social discussions and a more collaborative approach to design practices. Fischer (2010b) explores reflective practice involved in the *Envisionment and Discovery Collaboratory* (EDC), a research platform that brings participants of various backgrounds to collaborate to resolve complex urban planning issues. The EDC incorporates the use of HCI technologies such as tabletop computing and integration of tangible computing components. Ishii (2008) emphasises that the use of tangible computing under these circumstances allows the users to take advantage of their dexterity, to get hands-on with physical forms. The purpose of tangible user interfaces in this setting is to make the design process trans-disciplinary, where participants of various backgrounds when brought together, can inform one another and reflect through the collusion of ideas without requiring a great deal of skill to perform the tasks. Fischer (2010a) advocates that the Web 1.0 model primarily supported web page publishing and e-commerce but with the emergence of Web 2.0 there was a fundamental cultural shift from a consumerist culture to a culture of sharing and participation with collaborative design environments, social media and social networks. Sanders and Stappers (2008a) agree with this point of view stating that the internet has given a voice to those who were previously disenfranchised, they believe that the next generation will have more of a choice in regard to the distribution and control of ownership of web content. Sanders and Stappers (2008a) also agree with Fischer (2002b) on his stance that participatory thinking is in opposition to consumerism. Fischer (2002b) maintains that consumerism is associated with the notion of happiness, and that people are slowly seeking the middle ground regarding consumerism, as the option to partake in different creative experiences are emerging, but Fischer and Sanders, Stappers (2002b, 2008a) believe that it will take some years before consumerist culture moves towards an equilibrium with creative practices.

2.1.3 Reflective Practice in Design

Participatory design has been viewed by the competitive marketplace as nothing more than academic endeavour, but in recent years perceptions have changed as product development has become predominantly more knowledge-based as the focus shifts from just designing products for user's to designing products for the future experiences of people, communities and cultures"(Sanders and Stappers, 2008a, p. 6).

The research of Resnick and Silverman (2005) iterates this methodology where they focus on designing construction kits for kids, to help them become more assured, creative and expressive with new technologies by teaching them programming and introducing them to basic electronic skills. Resnick and Silverman (2005) encourage the children to play around with the materials to explore alternatives from the initial design, to modify and then iterate the process. Löwgren (2016) agrees with this methodology and believes it to be attributed to the rising appreciation for the process of making, as he believes it is an important area in the further studies of interaction design.

Through Löwgren's own design practice, from which he was exploring the idea of combing physical computing with bookbinding to make a book that could count its pages, he highlights an important point. On a project to which he felt was problematic and beginning to become a dead end due to fact that the book was not giving accurate readings, it was through his failure that Löwgren discovered a new design concept of a pressure sensitive book that had the potential of creating new augmented book experience (Löwgren, 2016). Donald A. Schön's paper *The reflective practitioner – how professionals think in action*, Schön (1983) asserts from his findings that the reflective practitioner through trial and error " the situation talks back"(Schön, 1983, p. 3) to the practitioner who then discovers new possibilities and outcomes from the task at hand.

The work of Jay Silver embraces the concepts of the maker methodology and DIY nature to which he refers to as his 'awakening'. Silver (2009) began his journey began with exploring the idea of using a basic 555-timer circuit to make anything from everyday objects to living things into a Theremin style electronic musical instrument. The device worked by making physical contact with anything conductive that in turn created a closed circuit whereby the 555-timer chip began to oscillate the electrical current that outputs through a connected speaker as audio. Silver experimented with different conductive materials and could even use the device to play musical notes on a puddle of water. It was not until Silver discovered that graphite from a pencil could be used as a conductive circuit that the idea of the Drawdio came to fruition. The Drawdio is an electronic musical instrument that allows the user to draw their own circuits to control audio. Silver (2009) insists that the ideation of the device was acquired partly through his own reflective practice and from sharing ideas with other people, many other artists and craftspeople have used this circuit design. The success of the idea is due to the simplicity of the circuit, many from the field of design are of the belief that prototyping with electronics is mainly about experimenting with Arduino and Raspberry Pi microcontrollers, Evans (2012) believes that the arrival of opensource microcontrollers have introduced people to the world of hacking electronics but still considers them to be artefacts that interlinked with consumerist values, Evans (2012) believes that society should promote the re-using and recycling of discarded obsolete technological artefacts and therefore the maker/hacker or potential designer can use the discarded raw material as a source of motivation to re-design and be creative. De Roeck et al. (2014) emphasise that using current interactive prototyping tools (Arduino, Processing, Raspberry Pi) have pitfalls in that they may have too much influence in how an artefact is designed. The writings of De Roeck et al.(2014) are mainly focused on early ideation processes and promote the concept of low-fidelity prototyping while initially stating that there is a need for more explorative digital tools for the ideation process to which tools such as the

Scratch programming environment and MakeyMakey, which are mentioned at the beginning of the paper. Silver (2009) describes the Drawdio as a toolkit that allows users to explore and improvise on a broad spectrum of possible activities through the appropriation of the original design, the Drawdio is also the predecessor to the MakeyMakey. Silver et al.(2012) assert that the Drawdio makes designing interfaces simple for people but they are constrained to generating music, the MakeyMakey enables users to explore tangible interfaces that can be used to control any software on a computer. The MakeyMakey helps experts to ideate and explore the gap in the landscape for tangible user interfaces while also being inclusive to beginners.

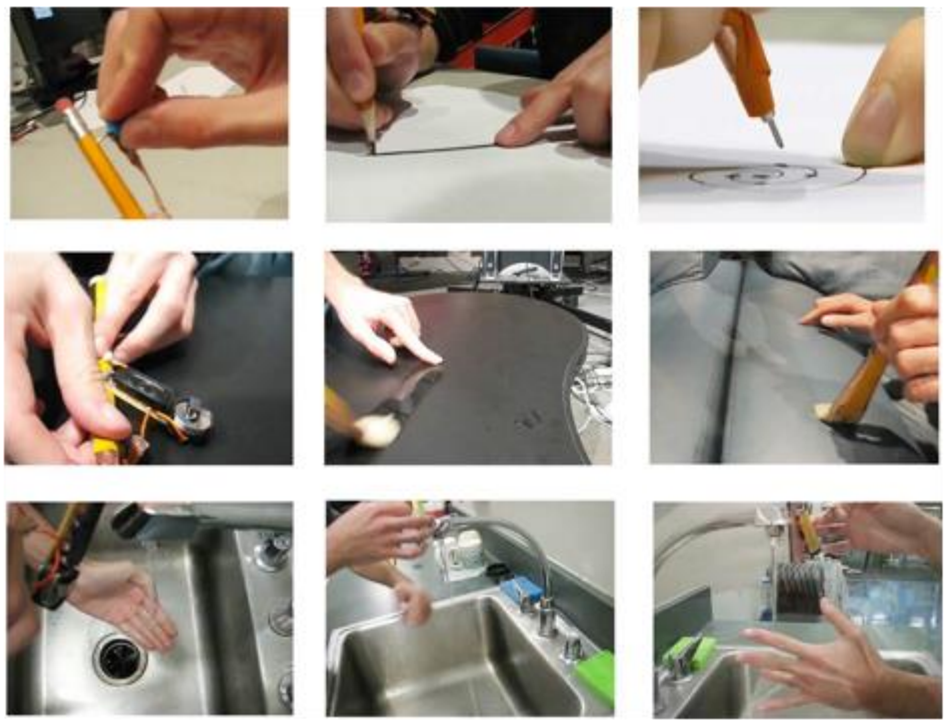

Figure 1: Drawdio, stills from Jay Silvers video

2.1.5 Conclusion

This section of writing begins with an analytical view into the topic of end-user development and how it has been considered a liberating force that has democratized the way humans interact with computational technology, but in many ways it is still lacking as there is still a tendency to dichotomise the different expert user groups into the roles of consumers of technology who are not experts in the tools they use. Sanders and Stappers (2008a) and Fischer(2002a) believe that the practice of design is evolving from the user centred approach where the focus is towards the idea that the designer or developer determines what the potential user needs, to a co-designing methodology that includes the potential user and involves them in the design process. Fischer (2002a) calls for a shift away from the production techniques of the past and to look towards ways of collaborating and sharing knowledge between the IT developers and the greater population, who are marginalised into the role of the consumer. The work of Fischer (2010b) and Ishii (2008) explores collaborative reflection in action by the means of interactive tabletops that includes users of various backgrounds and skill sets. The arrival of web 2.0 has brought about an ethos of participation, sharing knowledge and a rejection of consumerist culture, paving the way for open source software, collaborative design environments and social networks giving a voice back to the previously disenfranchised (Fischer, 2002a; Sanders and Stappers, 2008b).

The second section of the literary review explores how this methodology has been implemented into current practices. Resnick and Silverman (2005) explore the methodology when collaborating with children and believe that it is through expressing their creativity that conversations about the design begin to emerge, to which pertains to Schön’s (1983) methodology of reflection in action, where the situation “talks back” to the practitioner. This rising appreciation for the process of making is an important area for further exploration. This section further analyses the topic through the findings of Löwgren (2016), by where his craft practice improves his initial design concept, and how through various projects by Silver (2009) and the Kindergarten group at MIT generate ideas through tinkering, sharing information and making to create innovative electronic toolkits out of bare minimum resources and how these practices have informed the ideology of meta-design practices.

2.2 Related Projects and Inspirational Material

2.2.1 Introduction

Within the last two decades, there has been an influx of interactive technology that has become more ubiquitous than ever before. Today, user interaction is moving away from the conventional tools and is becoming much more omnipresent, physical, and tangible. This section explores emerging interactive technologies that allow for the experimentation and the development of new interaction methods, to augment the experience of human-computer interaction. It is from this section that the core of the inspiration for this project is explained.

Figure 2: Kinect

2.2.2 Microsoft Kinect

The Microsoft Kinect is a motion sensing device initially designed for Microsoft's gaming platform, the Xbox 360 and was released worldwide in 2010 to appeal to a broader demographic of gamers and compete with the Nintendo Wii. Unlike the Nintendo Wii, which requires a hand-held controller (the Wiimote) to map the user's gestures, the Kinect can be controlled by using a far broader range of natural human gestures that involve waving, clapping, head nodding, or kicking in a spatial area of roughly 6 m2. The Kinect features an RGB camera, depth sensor and a multi-array microphone that enables full body motion capture, facial recognition and voice recognition. the Kinect deciphers a 3D space by projecting infrared light which is then recorded with a monochrome CMOS (complementary metal-oxide semiconductor) image sensor which is converted into video data (Biswas and Basu, 2011). The image is then divided into different colour gradients to create a depth map that differentiates people and objects in the space, this system is known as Light coding. In 2012 Microsoft released Kinect for Windows SDK, an application development tool for creating programs for the Kinect sensor, initially released for Windows 7. Jana (2012) declares that with moderate knowledge of #C programming language, the Kinect SDK can be used to develop applications for healthcare, education, sports analysis security systems and so forth. Throughout their findings, Chen et al.(2015) highlight the discrepancies of the Kinect's depth map, for instance, when an object increases its distance from the Kinect the accuracy of depth measurement decreases. The Kinect processes inaccurate measurements at the outlines of detailed objects but produces stable measurements when recording objects with smoother surfaces. Another downfall of the Kinect is that it is confined to be used indoors as it does not work properly when exposed to natural light.

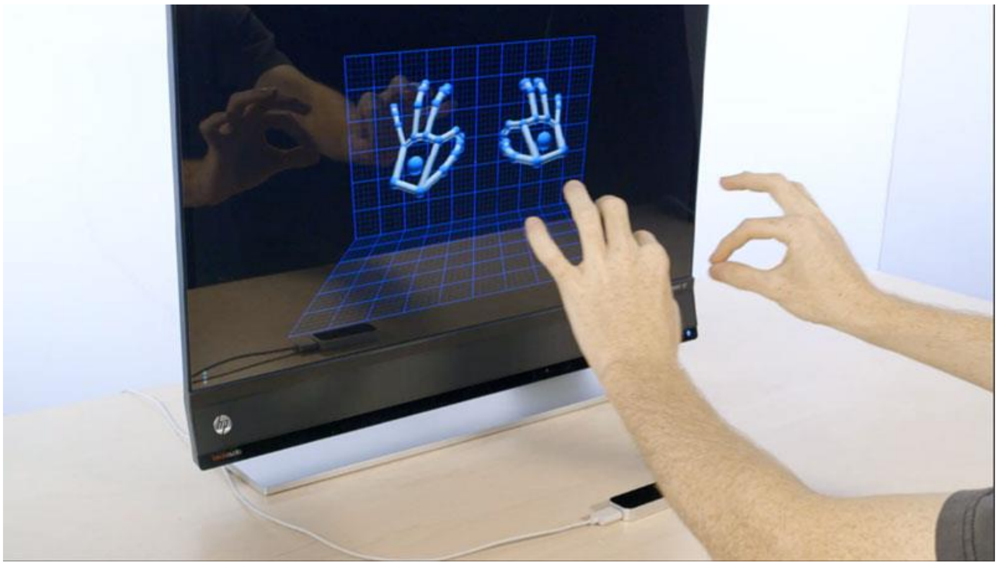

Figure 3: Leap Motion

2.2.3 Leap Motion

The Leap Motion controller is a consumer grade sensor that is primarily designed for gestural based motion and finger position detection for interactive software applications. The device itself is packaged into a compact 79 x 30 x 11mm shell that houses three IR (Infrared) emitters and two IR cameras that plug directly into a computer via the USB port. Unlike Microsoft's Kinect, the Leap motion works by using infrared optics and cameras instead of depth sensors (Gorman, 2013), and is designed to only sense motion at a range of 180 x 180 degree's, tracking motion at an arm’s length. Its motion sensing capabilities operate at an unmatched fidelity as it can track all 10 fingers simultaneously in conjunction with an application programming interface (Weichert et al., 2013). As stated by the manufacturer (leapmotion.com, 2017) the Leap Motion has a finger detection accuracy of approximately 0.01mm averaging 0.07mm when used for gesture control, well beyond the capabilities of the Kinect.

In a review upon its release, the Leap motion was described as more of a novelty device best suited for entertainment purposes rather than being utilised as a productive tool (Gorman, 2013). Although, Weichert et al (2013) disagree and emphasise the further innovative potential of the technology for the development of a diverse range of applications such as 3d modelling tools (3ds Max), interactive navigation tools for medical volume data, and so forth. Cabreira and Hwang (2016) examined the Leap motion through performing user tests to investigate how older adults perceive and perform with mid-air gesture interaction. The tests involved twenty younger and twenty older adults who were asked to perform several computing tasks using five mid-air gestures to learn how each age group would engage with the technology in regard to physical effort, intention of use, the confidence they had in using gesture-based technology and whether the task was perceived as easy or difficult. The results of the user tests proved that the older users were less confident at performing the tasks than their younger counterparts, also the test highlighted major affordance issues as many of the participants complained about an element of fatigue as the system required the user to perform the gestures with their arms in a fixed position to correspond with the graphical representation on the screen. Most users believed the interactive experience could be vastly improved if the same gestural actions could be performed from anywhere within the sensors field of view.

The creators of Leap motion are currently embedding their technology into VR/AR (virtual reality/ augmented reality) headsets in collaboration with major manufactures whereby the Leap motion may track the user's finger positions and represent them as avatars directly in the user's virtual field of view with the potential of performing more practical functionalities than previously mentioned. Like the Microsoft Kinect, the Leap motion has its own application development software but due to the current patent pending, limited information of the Leap Motion's internal framework is available. This does not leave much room for further experimentation of the technology which constrains the device, as only certain types of applications can be developed for it.

2.2.4 Electronic Toolkits

Many efforts at bridging the gap in regard to the education and accessibility of electronic prototyping have taken the form of toolkits. These toolkits are simplified in their design and embedded programming is generally adopted specifically to make them more accessible for novices allowing quick, easy assembly and ideation, although the design may levy numerous limitations and constraints. The Makey Makey toolkit is marketed as "an invention kit for everyone"(makeymakey.com, 2017), and has had some success as a gateway device used to introduce a broader demographic of novice enthusiasts to the world of electronics and human-computer interaction(HCI). Rogers et al (2014) endorse the product where they introduced a group of retirees aged from 60 to 80 years of age to the Makey Makey through a series of workshops with the intention of evoking their creativity, by exploring through play how to use random conductive objects and the human body to interact with technology. The participants would then debate and discuss their own relationship with technology and what they would like to do with the technology, instead of a second party deciding what technology they need. The Makey Makey performed well as an introductory tool but therein lies its limitations. These toolkit modules are generally designed for artistic endeavour and educational use, but they bypass the opportunity to truly engage with the inner workings of the technology. This is the case with the Makey Makey which masquerades as open circuitry but does not allow the user to explore the full potential of capacitive sensing technology. The device only allows the user to experiment with a limited number of touch sensors and the majority of its software is embedded, it can, however, be programmed from the Arduino IDE but the same purpose and more can be explored by using an Arduino prototyping board and off the shelf electronic components for a fraction of the cost. The same argument can be made for open source hardware, Evans (2012) states that open source hardware such as Arduino are useful introductory tools for the world hacking and electronics but believes there is more to be learned from the salvaging of scrap electronics which are already in abundance, Evans(2012) also points out that using microcontrollers as a raw material can prove to be costly. Evans (2012) highlights that many devices are built to be un-hackable when referring to the production of electronic artefacts in general. Mellis et al.(2013) highlight that the electronic components of these toolkits are often built into sealed units that do not afford the ability to interface with foreign components obscuring what they sought to make user-friendly. Evans (2012) endorses the re-purposing of everyday devices by giving examples of how discarded electronic devices such as modems, mobile phones, digital picture frames, coffee machines…. etc. and how the embedded programming can be appropriated via the serial bus protocol using debugging software such as IDA pro and Hex-Reys.

Mellis et al. (2013) emphasise the major differences between how to craft and how electronic artefacts are produced. Further, they explore the subject of the microcontroller as a toolkit by hosting a series of workshops, introducing the participants involved to experiment with electronics through the process of crafting with paper. These workshops introduced participants to electronics by painting circuitry onto paper with conductive ink and allowed them to explore how to integrate and iterate their designs while also learning to operate microcontrollers. The participants felt that the integration of a craft into technology introduced them to new skills, goals, and outcomes as they had to balance creativity with technical skills to maintain the functionality of the circuit design or by constructing structural objects. From the findings of the research, they discovered that the participants found using off-the-shelf materials like paper and conductive ink a very accessible and appealing approach to constructing electronic prototypes and far less daunting than working with the standard breadboard and jumper wire approach. Learning to produce electronic artefacts through the process of craft differs from the standard modes of operation in that it engages the individual to become more immersed with the raw materials at hand, exploring an infinite number of variations with an emphasis on diverse creative expression and employing the manual skillset of the individual, allowing people of different skill levels to engage (Mellis et al., 2013).

Figure 4: Scratch Input

2.2.5 Scratch Input

Harrison and Hudson (2008) explore the potential of transforming everyday objects (tables, dry-walls, furniture, clothing) into touch-based interactive interfaces through the Scratch Input device. The Scratch Input device is based on acoustic sensing technology, whereby a modified stethoscope is connected to a microphone, that it is then attached to a flat surface. The device operates by specifically listening for the sound of a fingernail scratching on a potential textured surface. The scratching sound made by the user is then recorded, and can potentially be used in a computer application as a control mechanism. The Scratch Input differentiates between gestural actions performed by the user, allowing for variation and the possible personalisation when controlling applications. Another interesting concept that the Scratch Input explores is gestural control without the need of a graphical interface or spatial mapping, a gestural action may be performed anywhere on an object, the device could prove to be a useful tool for people with disabilities.

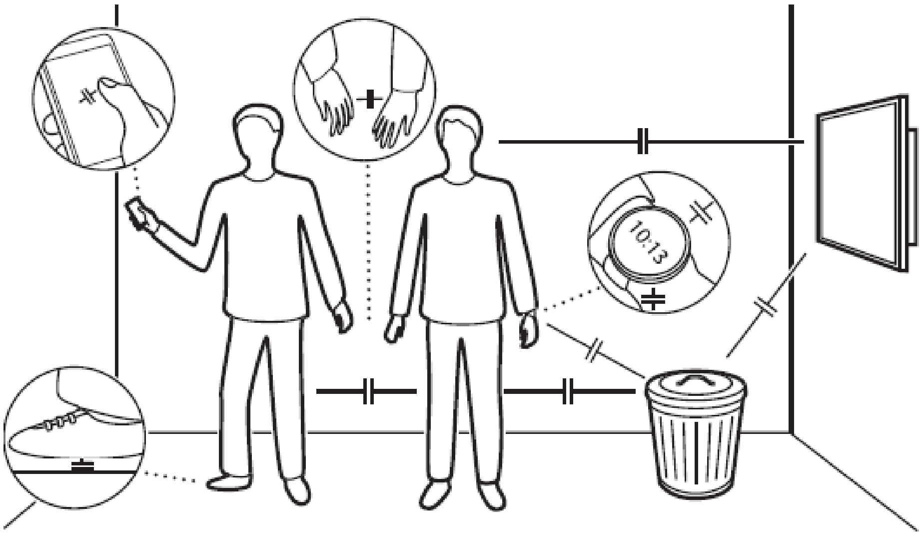

Figure 5: Cap Sensing

2.2.6 Capacitive Sensing Technology

Over the last few years, capacitive sensing has become one of the most ubiquitous technologies in the field of human-computer interaction and has included a whole new demographic of users to computational devices. The technology has become so deeply entwined into everyday life that it has become difficult to envision life without it, capacitive sensing literally connects people to the world through their finger-tips. Capacitive sensing technology is generally used to estimate physical values such as sensing touch, proximity or sensing environmental changes (eg. liquid levels in vats) by measuring changes in the electric field between two or more electrodes, electrodes are generally made from metal but any conductive material can potentially be used as an electrode including the human body (Grosse-Puppendahl et al., 2017). The reason capacitive sensing is so successful is because of the technology's versatility, it has been integrated into touchscreens on smart phones, tablets also touchpads for laptops, many household appliances and commercial electronic product now opt for capacitive sensing buttons over the traditional modular buttons. The compact size, low power consumption and low cost make the technology appealing for production and for prototyping. The electrodes can be placed in non-dielectric, non-conductive objects such as furniture, clothing or other materials that do not disrupt the electric fields (Smith et al., 1998). An electrode could also be made from conductive paint which could potentially turn any surface or object into a capacitive sensor. In the project entitled Platypus, Grosse-Puppendahl et al (2016) explore the potential of using capacitive sensing technology to create a tag-free system for localizing and identifying individual people in indoor spaces. This is achieved by detecting changes in the individuals' electric potential that are created by the human body which occur when walking. This system estimates the individuals' data at an accuracy rate of 94% and could be potentially used in smart homes and security systems. Unlike other motion detection technology such as passive infrared sensors, the Platypus system does not just detect if someone is in room, it can detect their identity without the need for any other hardware (electronic chips, tags, mobile devices etc.). The discovery of capacitive sensing technology is not as recent as many people would believe, in fact, an early example of the technology is the Theremin electronic musical instrument. Paradiso and Gershenfeld (1997) highlight the history of musical instruments and compare them to electronic musical instruments, in which the latter lacks the same essence of expressiveness. Smith et al. (1998) believe that the Theremin is a good example of how an electronic instrument can be utilised for expressive gestural control even if the Theremin is a very old idea, there is still much to learn from its physics and mathematics.

2.2.7 Conclusion

This section of writing highlighted the related projects and current interactive technologies that formed the main source of inspiration for this project. Rather than analysing a series of interactive installations or artworks, the focal point of the inspiration for this project is more concerned with interactive artefacts and the technologies involved to which coincided with topics raised in the previous section and with the concluding chapters of this paper. This section explores emerging interactive technologies that allow for the experimentation and the development of new interaction methods that augment the experience of human-computer interaction. By exploring embedded artefacts such as Microsoft's Kinect, the Leap motion, Makey Makey and the concept of the electronic toolkit, many of the advantages and disadvantages were investigated. Although they are all technically innovative products, they are generally designed for limited purposes and do not truly explore the creative potential of the technologies involved (Evans, 2012; Mellis et al., 2013). The work of Grosse-Puppendahl (2015) highlights the versatility of capacitive sensing technology as it can potentially be integrated into any non-conductive object, and due to its low power consumption, its low cost, along with the technologies touch sensing and proximity sensing capabilities makes it very applicable for interactive prototyping. Also, due to the technologies simple integration into potentially any object, surface or clothing, and its environmental adaptability make it a very interesting interactive technology for exploring creativity,

"With such materials, interface design becomes "arts and crafts," since one can quickly cut the materials to try a variety of geometries." (Smith et al., 1998, p. 6). This element of crafting with technology is explored by Mellis et al (2013).

by highlighting how the process is inclusive to beginners, Mellis et al (2013) believe it may also enhance the process for meta-design practices in the context of interaction design, that the techniques explored enhance the overall creative process when prototyping. Paradiso, Gershenfeld(1997) and Smith et al (1998) highlight how electrical field sensing by means of capacitive technology should be explored to enhance the user experience for creating gestural controlled graphical interfaces, and they believe that the answer for exploring natural gestural expression can be found in musical performance.

Chapter 3: Design Process

3.1 Methodology

For my methodological approach, I have adopted Schön's theory of reflective practice as the basis of my theoretical framework. Through my research, I have explored the concept of meta-design and what I have found particularly interesting was the user centred methods involving the users as designers and the call for a cultural shift towards how we collaborate and co-design, in an effort to liberate the marginalised, those who were relegated to positions that deemed them unfit to the expert mindset. The general theme that emerged from my findings was the idea of creating new design tools that can transcend various disciplines and skillsets involving a broader range of people in the creative process (Beringer, 2004; Fischer, 2010a, 2002a; Sanders and Stappers, 2008b). Fischer(2010b) and Ishii(2008) emphasise the importance of transdisciplinary collaboration through their research on desktop-based tangible user interfaces and how through collaborative means and reflective practice, the users/ designers can reflect and inform each other of different possibilities and potential outcomes, all the users have equal roles in the creative process. This collaborative element is explored in the low-fidelity user testing section, where participants of various backgrounds could help to inform the design process. This was explored by presenting problems in the design that was previously unforeseen in the initial iteration. In order to explore the interactive potential of embedding capacitive sensing technology into everyday objects, certain scenarios were presented, scenarios to explore the user's relationship with the technology and to allow greater insight in how to enhance the experience. Paradiso and Gershenfeld, Schön, Smith et al. (1997; 1983; 1998) Believe that the answers are found in the format of creative expression. Discovering through my own reflective practice by experimenting with materials is also important to me and as Schön's theory upholds it is important in a creative process that the material communicates or 'talks back' to the practitioner, in turn, the practitioner discovers previously unseen outcomes and creates new possibilities (Schön, 1983).

3.2 Concept Development

The early stages of the concept development for this project were an investigation into the more generalised issues surrounding human-computer interaction (HCI) in relation to emerging ubiquitous technologies, the technical, social, and economic importance of how these technologies are being utilised to potentially impact the way we live. Through the culmination of the previously discussed research on end-user development, reflective practice in design and the practicalities and implications of using electronic toolkits and past projects (fig 6), a general theme was beginning to develop.

A previous project that I worked on involved creating through the appropriation of unused electronic artefacts, and how to incorporate elements of interactive functionality for artistic endeavour, to produce an installation for the Plinth2 exhibition in Limerick city. The installation consisted of a laser tripwire activated, interactive acoustic instrument, where the public could use the plinth to interact with motors connected to drums and guitar strings, allowing the public to interact with the instruments in a different way. (fig 6).

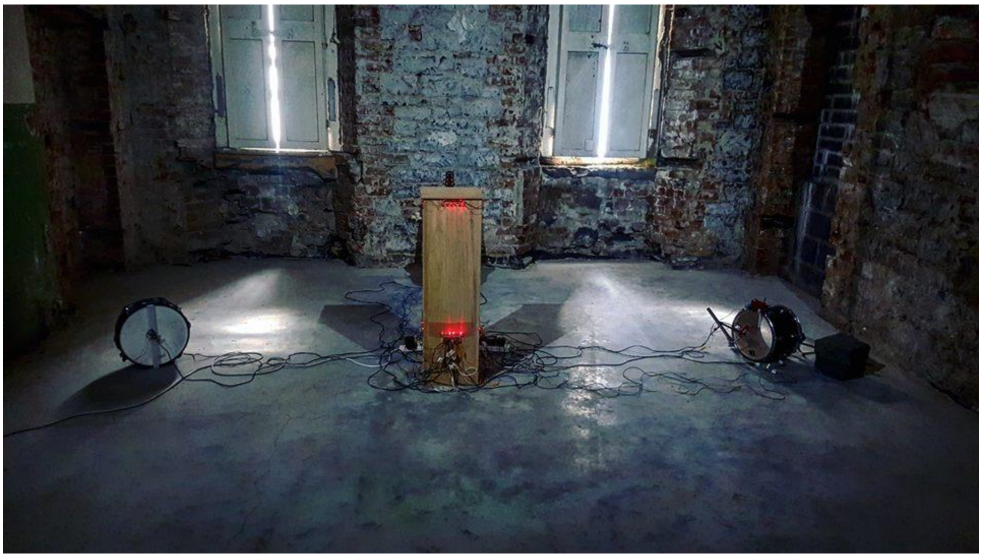

Figure 6: Shane Cunningham, PLINTH2

Other projects and experiments involved physical computing with the Arduino and using Processing for motion detection. In these experiments, I was exploring various modes of operation from motion and touch-based to modular control primarily using off-the-shelf materials and found objects. My preference for working with off-the-shelf components stems from the methodology of a maker, I am interested in unpacking what Pinch and Bijker (1984) refer to as the black box of technology. Freed and Wessel (2015) emphasise that the production techniques used in touch-screen technology are restrictive towards exploring the true interactive potential. Weiser (2002) proclaims that the most profound technologies are those that entwine themselves into everyday life until they become indistinguishable and part of common activities, In comparison to early silicon-based information technology to which confined the user to a desk, accessing information through a monitor based modular interface although the arrival of capacitive touch-based ubiquitous computing technologies have introduced a far broader demographic to computational devices. Grosse-Puppendahl et al.(2014) agree that recent advances in interaction technology have shifted from traditional methods like Graphical user interfaces to ubiquitous interaction methods, the communication between objects and external computing infrastructures. This thesis explores interactive potential of electrical field sensing by the means of Capacitive technology. It is because of the technologies low-cost and versatility that it is relatively easy to apply the technology to everyday objects, an area that can be explored by using off-the-shelf materials that are generally associated with practices involving arts and crafts. It is the simplification of the technology that makes it inclusive to all and paves the way for exploring easy to apply prototyping tools, in the context of interaction design.

Figure 7: Shane Cunningham – Low-Fi Test

3.3 Low-Fidelity Prototyping

To explore how the layout and the overall user experience of the proposed installation would come to fruition, low-fidelity prototyping techniques were adopted. These prototyping techniques were crucial in defining how potential users could possibly interact with the technology while also conveying to them the potential of transforming any non-conductive surface into a touch and gestural interface. A workshop was organised where participants performed a series of tasks using a low-fidelity prototype.

The objectives of the workshop were to:

- Observe how the participants interact with the interface
- document any difficulties the participants had in performing a task
- document any unforeseen outcomes during the user-test
- identify potential improvements

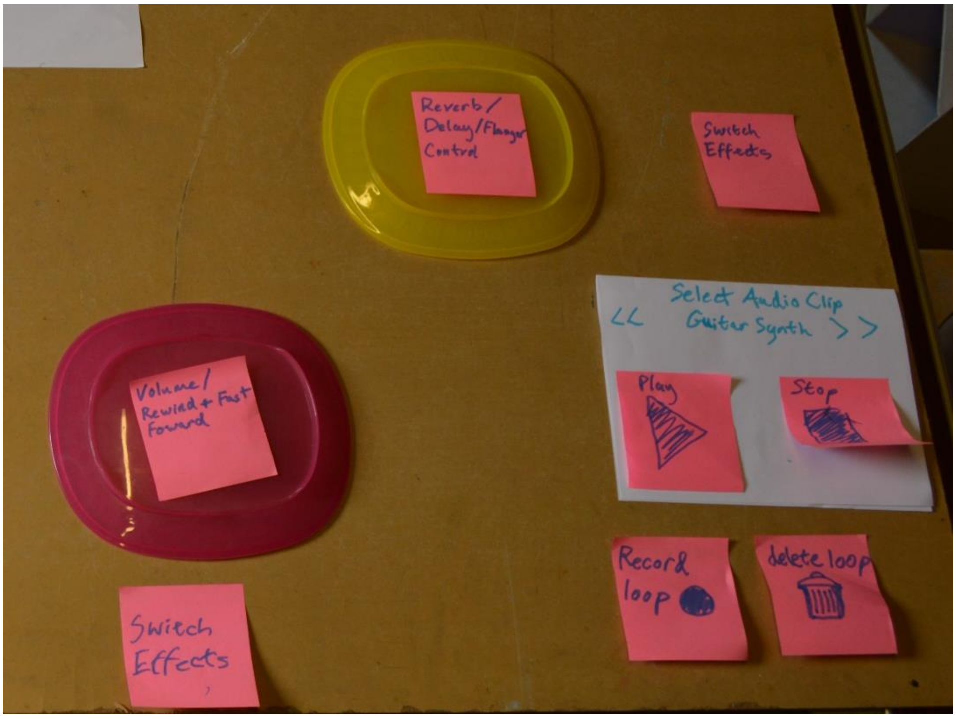

Figure 8: Shane Cunningham – Low-Fi test

The low-fi prototype was simply constructed on a tabletop using post-it notes to represent the touch controls and four coloured plastic plates to represent the projected gestural controls of the graphical user interface (GUI). The interface was designed to be used for one person and represents a virtual dual channel audio mixer similar to a set of turntables. The prototype would allow the user to simulate the real functions such as selecting audio from the library, adding effects and the ability to create loops of the selected tracks. The user would use the gestural controllers to increase or decrease the volume range, control the effects switching from reverb/delay/flanger, and fast forward/ rewind control of the playing audio file. The layout of the GUI was designed for the simultaneous use of both hands, as there is symmetry in the left and right sides. At the beginning of the session, the concept of the project was described to the participants and it was explained to them that they would be partaking in a user-testing session involving low-fidelity prototyping techniques to simulate a gestural and touch-based interface and how potential users would interact with the design. The process of reflective practice allows the user to explore new outcomes and possibilities overlooked in the initial design. Throughout the process of the low fidelity prototyping tests, problems were presented to the potential users and it is the format of creative expression that the true potential of exploring how everyday objects may be used as a gestural interface (Paradiso and Gershenfeld, 1997; Schön, 1983; Smith et al., 1998). The participants aged between the of 18 – 65 were then asked to read through and then sign the Declaration of Consent form (see Appendix B). During the workshop, the participants were encouraged to make changes to the design of the interface if they saw fit.

User Task List

1. Select track on the left, then the right channel.
2. Turn volume up on the left, then the right channel.
3. Turn volume down on the left, then the right channel.
4. Select effects and control effects on the left, then the right channel.
5. Switch from volume control to rewind/ Fast-forward control.
6. Create a loop of selected audio track.
7. Dump loop on the left or right channel.
8. Attempt to use all controls with both hands simultaneously.

3.3.1 Observations and Outcomes of Low-Fidelity Tests

The Low-Fidelity tests provided a more in-depth insight into how potential users would interact with the design. In conclusion of the user test, each participant was asked a series of questions (see Appendix B). The table below is a summary of how the participants responded to the questions.

Table 1: Low Fidelity Prototype tests

Participants	**Initial Responses**	**Overall Feedback**	**Comments/ Suggestions**
Female, 41	Positive – The user found the layout of the interface straightforward and completed most of the tasks	Positive – The user liked the overall concept and found the gestural aspect expressive	Coming from a musical background the user felt that the gestural element enhanced the interactive experience
Male, 29	Neutral – The user felt that the interface could have been more simplified	Positive – The user liked the idea of turning everyday objects into smart interfaces	The user was a little confused with the layout but could see the practicality of using the technology for different scenarios
Male, 43	Positive - The user found the interface easy to navigate and could create a positive interactive experience	Positive – The user liked the range of tools and effects featured in the touch display and believed that they could enrich the interactive experience	
Female, 27	Positive -	Positive-	The user liked that gestural controllers were operated by sensing the hand's distance from the surface of the table

The participants selected for the low-fidelity testing ranged from the age groups of the mid to late twenties, to participants in their early forties. The group of participants that were chosen would have a consumer's relationship with technology and would not have been familiar with the concept of open source systems. The majority of the participants found that the prototype gave an insightful introduction to meta-design and by getting involved in the design process they questioned their own relationship with technology by exploring how an everyday object like a table could be used as an interactive interface by relatively low-tech means. The participants felt that the overall user experience was good, but some of the participants suggested that the interface could be somewhat more simplified by perhaps opting for just two gestural controls instead of four, while others seemed to like having extra controls as they felt it would allow them to be more creative and expressive. One of the users selected for the test had an adept knowledge of various musical instruments, and found that using a performative audio based application was an interesting and immersive way of exploring gestural control as it would provide more of a challenge for the user, it could be something that the user could develop new skills and techniques with. When using the gestural sensors, one of the participants highlighted that the aesthetics of the project would be vastly improved if the intensity level of the volume and effects would raise as the user's hand would come closer in proximity to the sensor, in an almost downward pushing motion.

Figure 9: user test

Figure 10: user test

3.4 Second Prototype, Testing and Evaluation

3.4.1 Initial Design and Development

The initial ideation for this thesis project explored the area of interactive design tools and by the means of creating an interactive tabletop interface and explore how it could augment the overall user experience. The idea for this project came from a project that I discovered online which involved a cardboard box with the inside lined with tinfoil, the foil would then be wired to an Arduino from which it could detect movement from anyone who placed their hand near the foil. The Arduino then transfers the readings into a Processing sketch to control graphics or sound. To further iterate on this idea, smaller foil panels were attached to the underside of a table in order to make an interactive surface that could be used as a computer interface for games, design applications or music applications.

3.4.2 Capacitive Sensing tests and Arduino Library

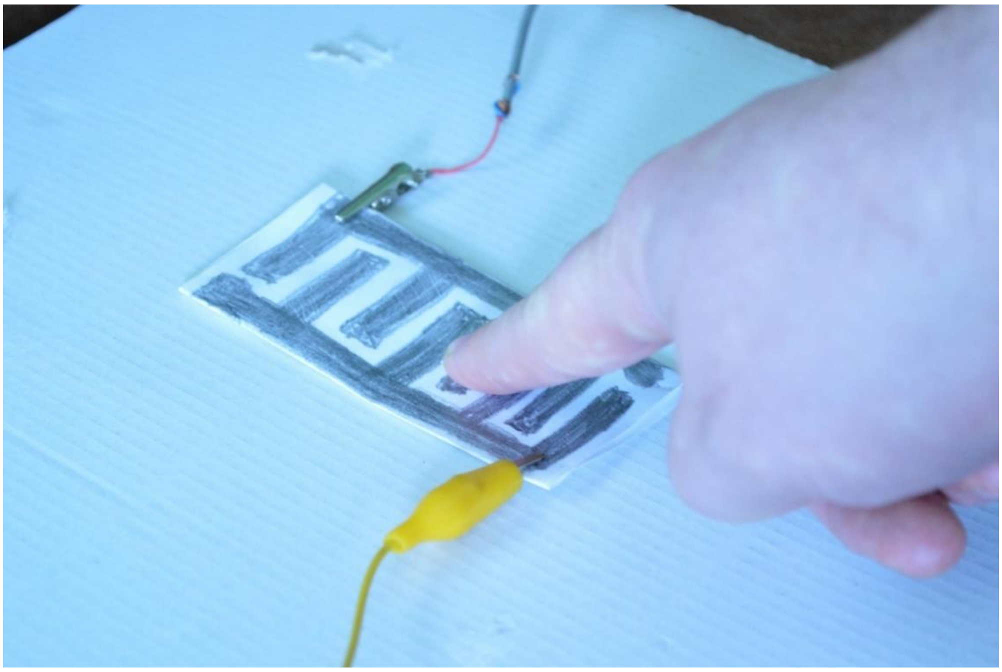

Figure 1: Graphite base capacitive sensor

The origins for the initial testing for this prototype began with exploring how different conductive materials could be used as touch sensors when connected to an Arduino Uno prototyping board. The Arduino sketch that was programmed is a modified version of the CapacitiveSense Library Demo Sketch by Paul Badger which works much like the Analog Read Serial example on the Arduino IDE, whereby analog resistors are used to measure physical information from varying resistance of the flowing voltage, then the physical information is passed to the Arduino software running on a computer, where the results can be altered and used to control autonomous and interactive applications and everyday artefacts. Instead of using variable resistors, light dependent resistors or heat sensors to create data for manipulation, the CapacitiveSense demo sketch is concerned with exploring the potential of electric field sensing by the means of capacitive technology. The circuit schematics for the Arduino sketch use one digital pin on the board as the send pin, this pin outputs an electrical signal from the board, that flows through a resistor and carries on to an electrode (conductive material such as copper or tin foil), then a second connection is made from the electrode to an assigned pin on the Arduino board completing the circuit. This Arduino sketch was initially designed for mainly touch sensing and the majority of projects and examples online have used the sketch for that very purpose. My intentions for using this sketch was to explore the proximity sensing capabilities as I had attempted to do before with a similar project involving a motion sensing cube constructed from off-the-shelf materials that could detect the position of one's hand. When initially testing the CapacitiveSense demo sketch in the early stages of the project, different types and sizes of materials were explored to be used as potential electrodes. Preferably I chose to use what was the most accessible to me, so the decision was to construct the electrodes by glueing 300 x 300 mm sheets of tin foil onto cardboard.

Table 2 : Modified CapSense Arduino Sketch

```
#include <CapacitiveSensor.h>
/*
 * CapitiveSense and Serial Call Response
 * Shane Cunningham - May 2017
 * Uses a high value resistor e.g. 1M between send pin and receive pin
 * Resistor effects sensitivity, experiment with values, 50K - 50M. Larger resistor values yield larger sensor values.
 * Receive pin is the sensor pin - try different amounts of foil/metal on this pin
 */
int val1 = 0;
int val2 = 0;
int val3 = 0;
int inByte = 0;
CapacitiveSensor   cs_4_2 = CapacitiveSensor(4,2);        // 1M resistor between pins 4 & 2, pin 2 is sensor pin, add a wire and or foil if desired
CapacitiveSensor   cs_4_6 = CapacitiveSensor(4,6);        // 1M resistor between pins 4 & 6, pin 6 is sensor pin, add a wire and or foil
//CapacitiveSensor   cs_4_8 = CapacitiveSensor(4,8);        // 1M resistor between pins 4 & 8, pin 8 is sensor pin, add a wire and or foil

void setup()
{
   cs_4_2.set_CS_AutocaL_Millis(0xFFFFFFFF);     // turn off autocalibrate on channel 1 - just as an example
    cs_4_6.set_CS_AutocaL_Millis(0xFFFFFFFF);
   Serial.begin(9600);

   pinMode(2, INPUT);
   pinMode(6, INPUT);
  // pinMode(8, INPUT);
   establishContact();     // send a byte to establish contact until receiver responds
}
```

The

electrode was then connected to the Arduino board using two crocodile clips, with one clip connected to a 10 MegaOhm resistor attached to the send pin, while the other clip was connected to the assigned receive pin. When the electrode came into contact with a human presence, the readings on the Arduino IDE serial monitor would begin to change, but there seemed to be a problem as the messages received seemed to be uploading to the serial monitor at a slower rate than expected, the connection was timing out due to issues caused by the size of the electrode, the resistor being too large and also by not grounding the circuit properly. Bigger electrodes allow for better capacitive coupling as they consume a greater load but they also detect more unwanted noise (Grosse-Puppendahl et al., 2014). In an attempt to improve the proximity sensing range, more 10 MegaOhm resistors were included in the circuit, but doing this made no substantial improvements. By reducing the electrode size to 100 x 100 mm, reducing the resistor from a 10M to a 1M, and by grounding a larger insulated piece of foil and placing

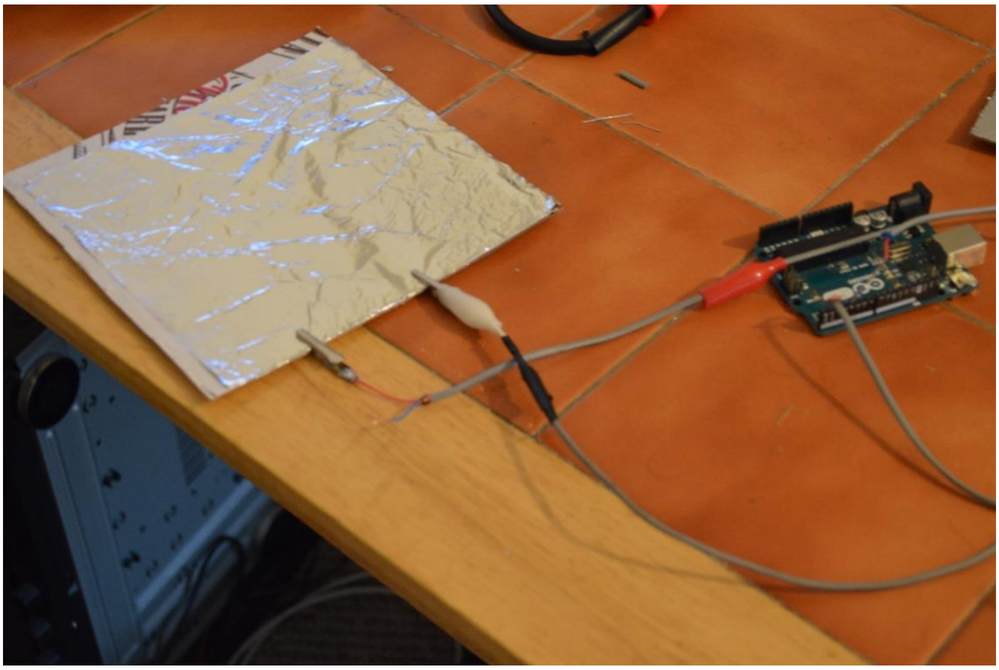

Figure 12: Arduino test

it underneath the electrode reduced unwanted noise and yielded vast improvements for proximity sensing with clear at a range at roughly 50 mm. This distance was doubled by redesigning the electrode, by implementing the stator pattern the sensor capacitance was increased (Baxter, 2000). The next step was to add more capacitive sensors to the Arduino board in order to increase the amount of functionality in the finished project.

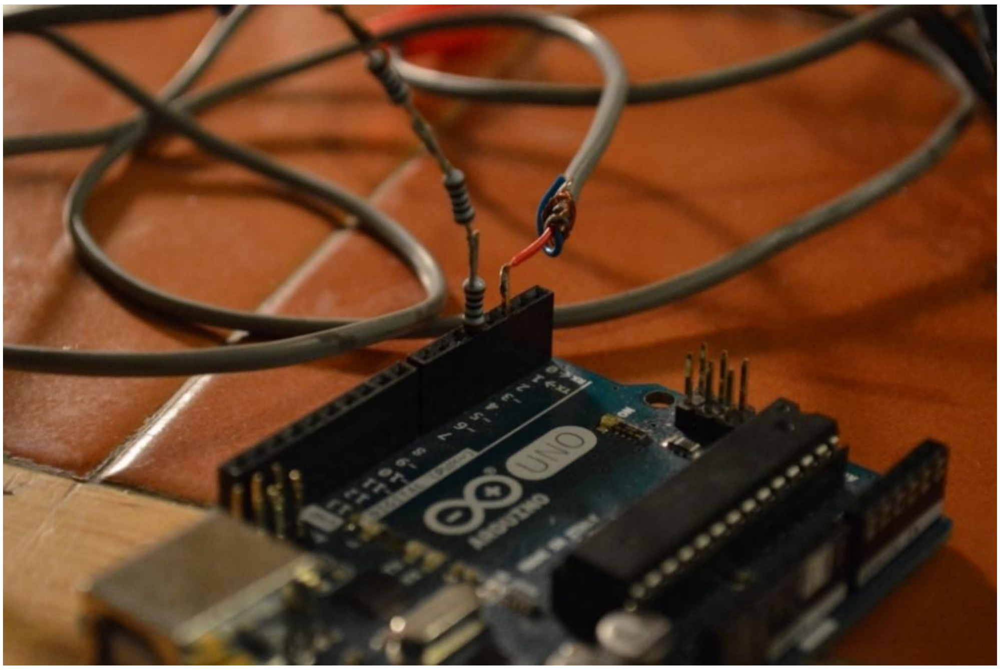

Figure 132: Resistors connected to Arduino

The CapacitiveSense example sketch is programmed to read data from three capacitive sensors made from relatively small strips of conductive tape or foil that enables touch sensing capabilities, but in experiments with the sketch and the larger electrodes (100 x 100mm), the Arduino Uno could read sensor data efficiently from five capacitive sensing electrodes and could potentially read sensor data from ten inputs using only one data out pin. As the current Capacitive sensing library is built only for the Arduino Uno board, to add more inputs for more complex projects, the serial peripheral interface (SPI) serial data protocol could be adopted. The SPI protocol is used to initiate communication between two or more microcontrollers whereby one Arduino is set up as the master and receives data from a 2nd Arduino which is declared the slave. The slave could be used to send the capacitive touch sensor data to the master, and the master sends the accumulated data to the computer software. With the sensors working and the Arduino communicating with the computers serial, the next step involved setting up a communication with Processing to create the graphical user interface for the project.

Figure 14: stator pattern

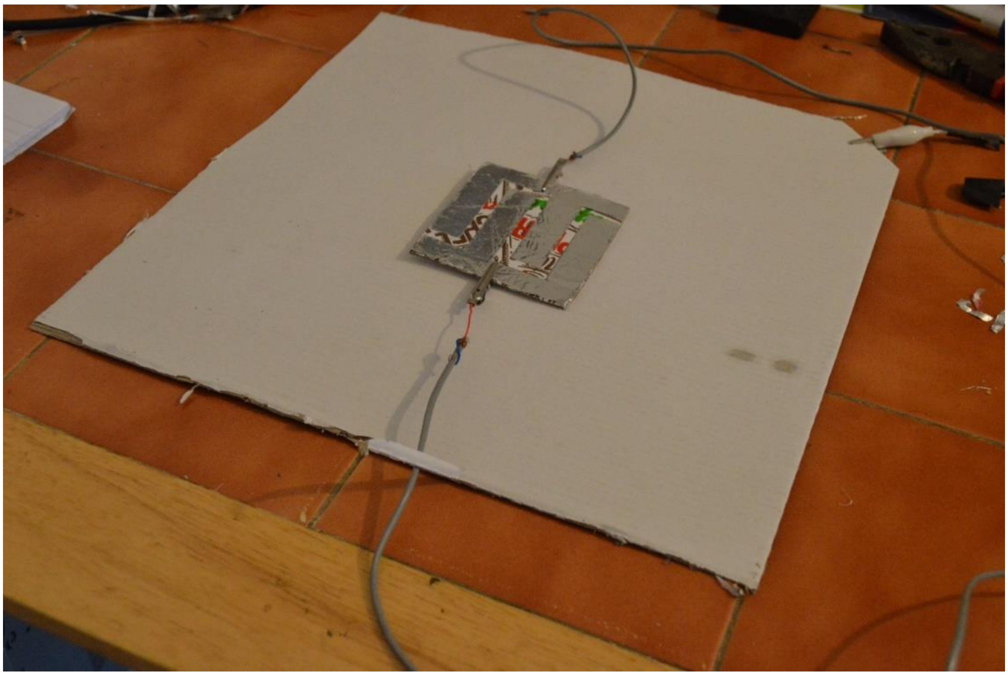

Figure 15: Crocodile Clips connected to electrode and ground plate

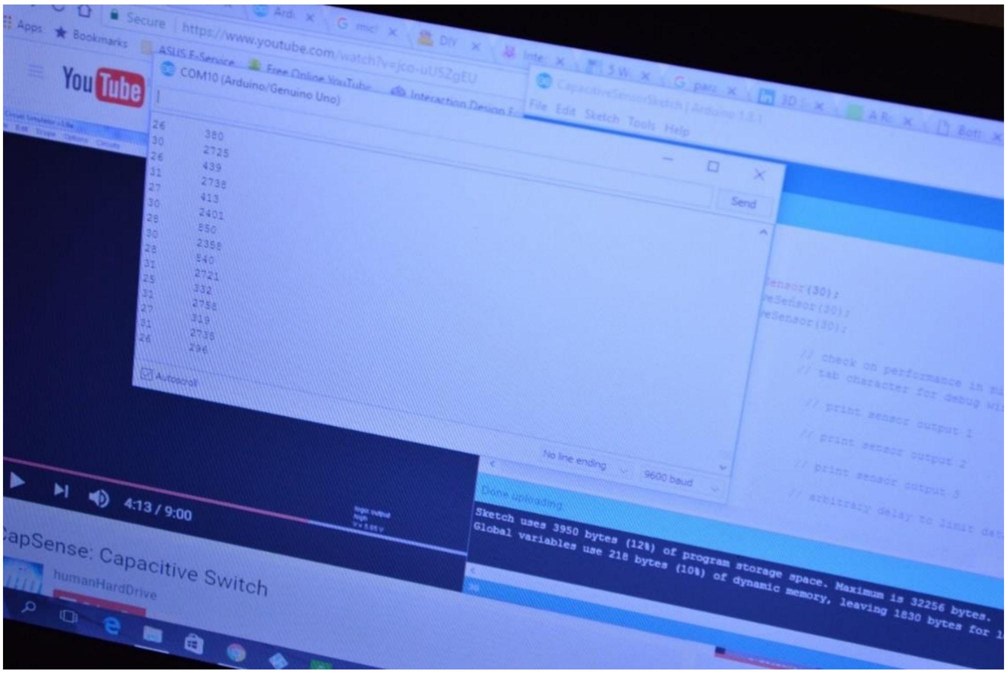

Figure 36: Arduino Serial Monitor, printing data created by the sensors

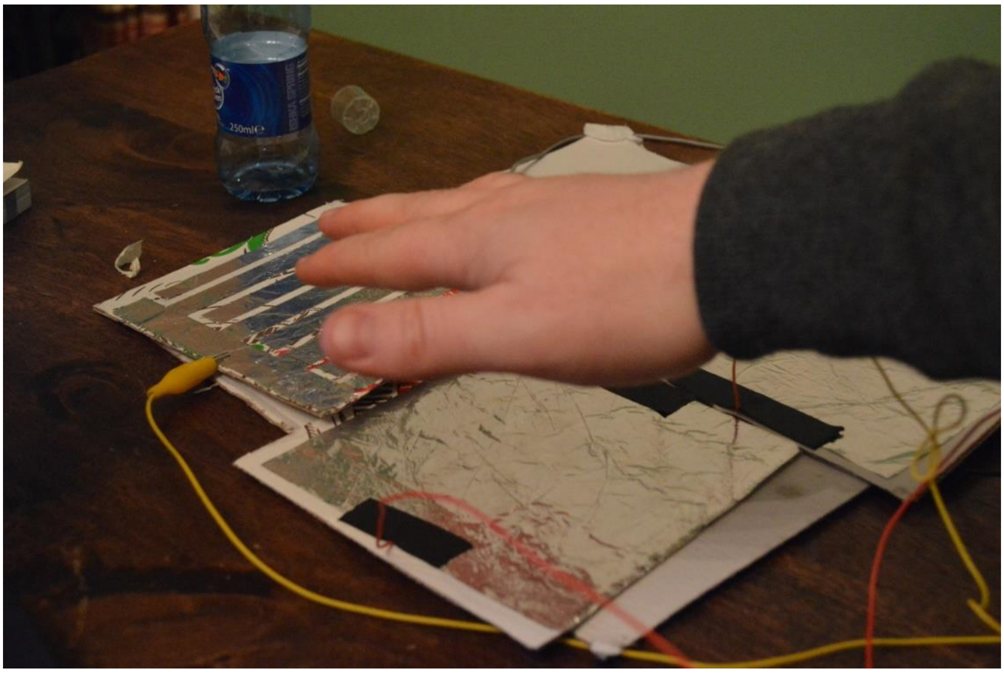

Figure 17: testing with multiple sensors

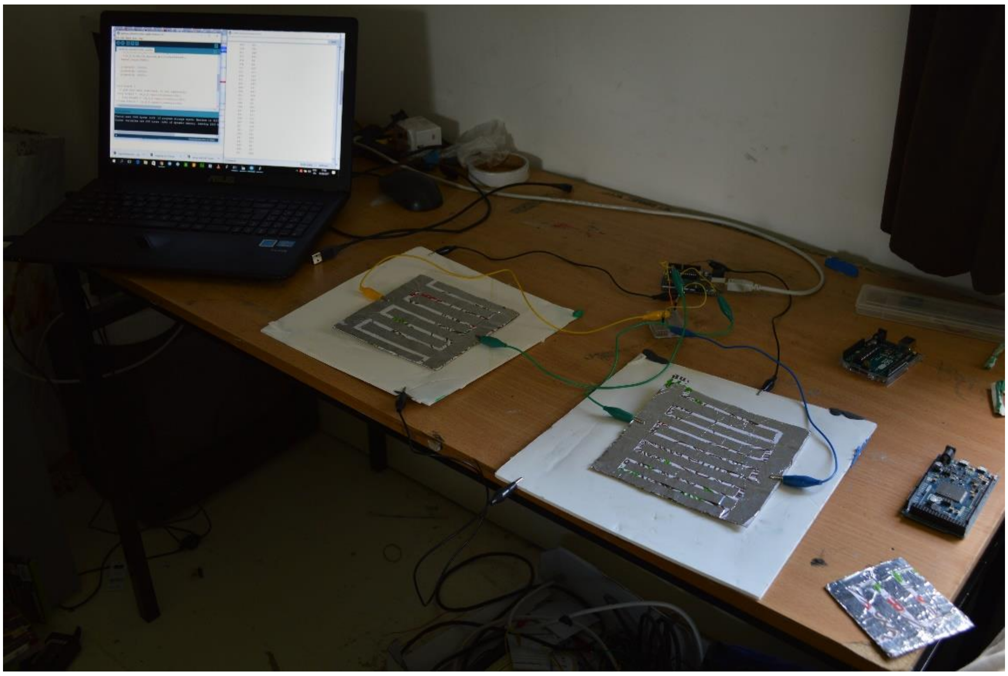

Figure 18: Calibrating sensors

3.4.3 Processing Tests

Processing is an opensource software programming environment that promotes software literacy for those who are not IT specialists and has encouraged many from the fields of visual arts, design and general hobbyists to learn the basics of programming. For this project, Processing was used to create a graphical interface that communicates with both the Arduino board and another programming environment called Pure Data. The first steps involved setting up communication with the Arduino using the SerialCallResponse sketch by Tom Igoe. This sketch is written in two sections for both the Arduino and Processing.

Table 3 : Processing Sketch

```
import processing.serial.*;
import oscP5.*;
import netP5.*;
OscP5 oscP5;
NetAddress puredata;
Serial myPort;       // The serial port
int[] serialInArray = new int[3];    //where we will put what we receive
int serialCount = 0;                 // A count of how many bytes we receive
float Lchange = 0;                   // where the left sensor values are stored
float Rchange = 0;    // where the right sensor values are stored
boolean firstContact = false;    //wehether we've heard from the
microcontroller
```

Upon implementing elements of the SerialCallResponse sketch into the Processing sketch, firstly the Processing serial library had to be imported (table 3), this initiated serial communication between Arduino and Processing. Then a list of variables was declared, *int[] serialInArray = new int[3];* set up a place where the incoming sensor data was received which was then separated into three integers (int – stores a 16bit, or 2-byte value). These three integers were used to manipulate data in the Processing sketch. *int serialCount = 0;* counted how many bytes were to be received from the Arduino, and *boolean firstContact = false;* declared whether any contact was established from the Arduino (table). On the Arduino sketch *int inByte = 0* was declared, this was where the data sent from Processing was stored and initiated communication from. In the Arduino's void setup, *establishContact();* was used to send a byte to Processing to establish contact until receiver responds. In void loop an 'if' statement was declared, *(Serial.available() > 0){ inByte = Serial.read(); },* meaning if a valid byte is received from *Serial.available,* the incoming sensor data is received from *Serial.read* and the sensors input value is stored in *int inByte* (table 4). The sensor values were the collected by Processing by initiating the function *void SerialEvent(Serial myPort).* The communication is put into action, while Processing waits for contact from the Arduino, it was programmed to send a message confirming that it is ready to receive. From *void SerialEvent(Serial myPort)* Processing was programmed to read a byte from the serial port by first declaring that *int inByte = myPort.read();,* to confirm first contact, an *if* statement was employed that cleared the serial buffer and added the incoming data from sensors to the array, when there was no activity from the Arduino, Processing contacted Arduino indicating that it was ready to receive more data (table 4,5). The final step of the process was to gather the sensor values in Processing and pack them in an array. In *void SerialEvent(Serial myPort)* The array of values were then unpacked and were assigned to user-defined variables. These user-defined variables that were initially declared had a value of zero (float Lchange = 0) and this is where the sensor data was stored whenever there was an interaction. Wherever the variable Lchange was implemented in the *void draw* function of the sketch the sensor data was sent there to manipulate the objects created.

Table 4 : Establish contact code on Arduino

```
* CapitiveSense and Serial Call Response
 * Shane Cunningham - May 2017
 * Uses a high value resistor e.g. 1M between send pin and receive pin
 * Resistor effects sensitivity, experiment with values, 50K - 50M. Larger resistor values yield larger sensor values.
 * Receive pin is the sensor pin - try different amounts of foil/metal on this pin
 */
int val1 = 0;
int val2 = 0;
int val3 = 0;
int inByte = 0;
CapacitiveSensor   cs_4_2 = CapacitiveSensor(4,2);        // 1M resistor between pins 4 & 2, pin 2 is sensor pin, add a wire and or foil if desired
CapacitiveSensor   cs_4_6 = CapacitiveSensor(4,6);        // 1M resistor between pins 4 & 6, pin 6 is sensor pin, add a wire and or foil
```

Table 5: Establish contact code on Arduino

```
void setup()                    {
   cs_4_2.set_CS_AutocaL_Millis(0xFFFFFFFF);     // turn off
autocalibrate on channel 1 - just as an example
    cs_4_6.set_CS_AutocaL_Millis(0xFFFFFFFF);
   Serial.begin(9600);
    pinMode(2, INPUT);
   pinMode(6, INPUT);
  // pinMode(8, INPUT);
   establishContact();     // send a byte to establish contact until receiver
responds
void loop()  {
 // if we get a valid byte, read inputs:
  if (Serial.available() > 0){
  // get incoming byte:
     inByte = Serial.read();
    //long start = millis();
    long total1 =  cs_4_2.capacitiveSensor(30);
    long total2 =  cs_4_6.capacitiveSensor(30);
    //long total3 =  cs_4_8.capacitiveSensor(30);
   //delay(10);
                        val1 = map(total1, 700, 2300, 0, 25);
val2 = map(total2, 30, 175, 0, 255);
//val3 = map(total3, 0, 13000, 0, 255);
                        Serial.write(val1);
Serial.write(val2);
//Serial.write(val3);
//Serial.print(val1);
//delay(50);
}
void establishContact() {
  while (Serial.available() <= 0) {
    Serial.print('A');
    delay(300);    }
```

Table 6: Receive Byte on Processing from Arduino

```
void serialEvent(Serial myPort) {
 // read a bytefrom the serial port:
  int inByte = myPort.read();
  // if this is the first byte received, and it's an A,
  //clear the serial buffer and note that you've
  //had first contact from the microcontroller.
  //Otherwise, add the incoming byte to the array:
  if (firstContact == false) {
    if (inByte == 'A') {
      myPort.clear();         // clear the serial port buffer
      firstContact = true;    //you've had first contact from the arduino
      myPort.write('A');      // ask for more
    }   }
  else {
    // Add the latest byte from the serial port to array:
    serialInArray[serialCount] = inByte;
    serialCount++;
    // If we have 3 bytes;
    if (serialCount > 1) {              // must be equal to amount of sensors
      Lchange = serialInArray[0];
      if (serialInArray[0] < 63) {
        Lchange = 0;
      }
      Rchange = serialInArray[1];
       if (serialInArray[1] < 63) {
        Rchange = 0;
      }
      // print the values (for debugging purposes only):
      println(Lchange + "\t" + Rchange);
      OscMessage msg = new OscMessage("/test");
         msg.add(Lchange);
         msg.add(Rchange);
         oscP5.send(msg, puredata);
      // Send a capital A to request new sensor readings:
      myPort.write('A');
      //Reset serialCount:
serialCount = 0;
```

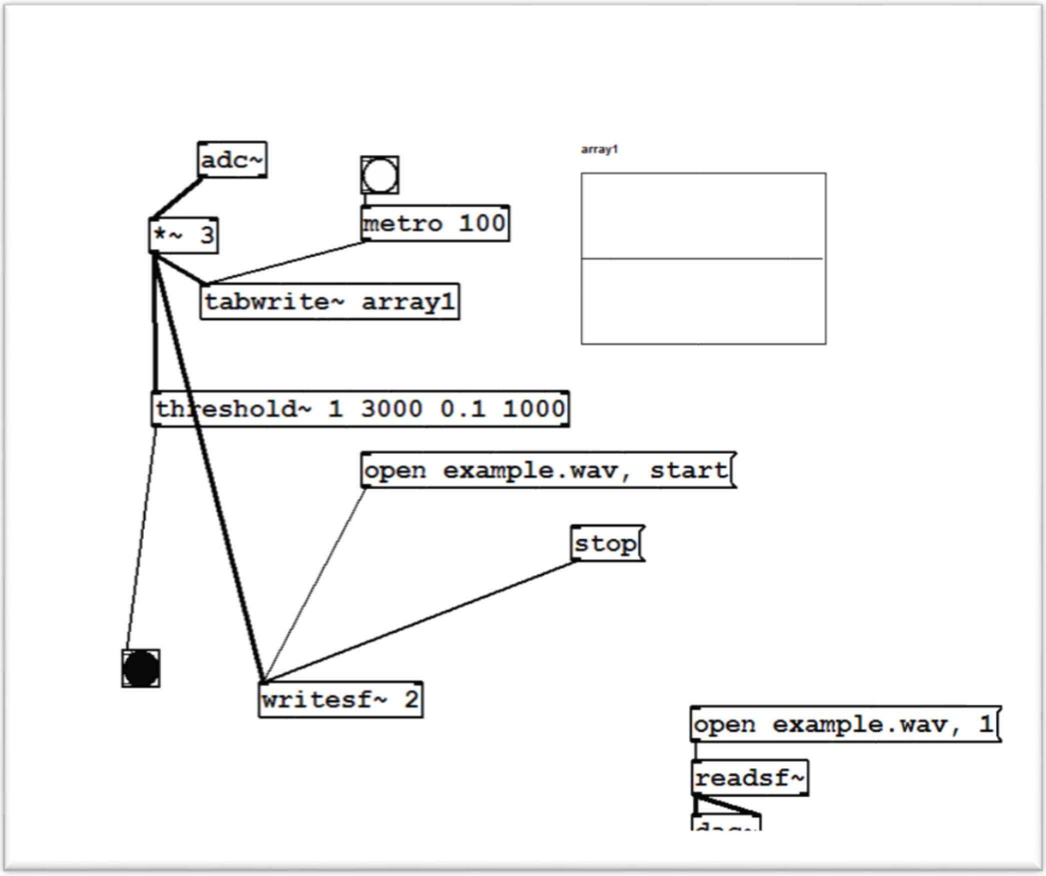

Figure 19: Pure Data, readsf, writesf, records and plays live audio

3.4.4 Pure Data Tests

Pure Data is a visual orientated programming environment made for developing multimedia. Similar to Max/msp, Pure Data enables its users to produce multimedia software by using a graphical interface to create objects that perform functions without using long scripts of code. Pure Data is very useful tool for creating simple audio applications and it can also be used for sending and receiving data between applications. Pure Data has multiple functions and allows for experimentation on a broad scale as it is relatively easy to create sound instruments such as oscillators, sequencers and it is reasonably adaptable when used with external controllers such as the wiimote.

Table 7: Declaring Serial ports and new NetAddress for communication between Processing and Pure Data, 8000 is the port created for Pure Data

```
void setup(){

//fullScreen();

size(400,400);

noStroke();          //no border on the next thing drawn

myPort = new Serial(this, "COM10", 9600);

oscP5 = new OscP5(this,12000);

puredata = new NetAddress("127.0.0.1",8000);
```

For the project, I experimented with the sound filer object, this allowed for the reading and writing of sound files to arrays. I had hoped to develop a virtual dual channel audio mixer, similar to a set of turntables that would allow the user to select audio from the sound filer library, add effects and make loops of the selected tracks, and to also use gestural controllers to increase or decrease the volume range and control the effects. Unfortunately, due to time constraints and technical issues, the design of the project was simplified to using just two proximity sensors, instead the sensors placed under the table controlled phasor~ objects from the pure data library that generated sawtooth audio signals by receiving sensor data sent from Processing through the netreceive object (fig 20). The netreceive – u -b received any udp-binary messages from the port assigned as 8000 (fig 21). In the Processing sketch, port 8000 was declared in *void setup()* command as *puredata = newNetAddress("127.0.0.1",8000);* and received its data from the Processing port 12000 declared as *oscP5 = new OscP5(this,12000);* (table 6). Messages from Processing were then parsed to Pure Data's assigned port, this was achieved by declaring the function *void serialEvent(Serial myPort)* and by declaring the command *new OscMessage* on the Processing sketch, there the individual message values from the assigned variables *Lchange* and *Rchange* were included in the *OscMessage* and were then sent as a package by declaring the command *oscP5.send(msg, puredata);* (table 7). The netreceive -u -b 8000 object was used to receive a long list of numbers (fig 22). From the unpack object in Pure Data the numbers received were listed as 0, this created outlets on the unpack object. From the list of numbers sent, there were only two numbers that represent the sensor data, these two values were then separated by connecting them to Number objects where the values were used to control other objects in this case the phasor~ object, whenever a sensor value was detected (fig 21).

Table 8 : Create Serial Event on Processing to communicate with Pure Data, (Lchange) and (Rchange) are sent to Pure Data

```
void serialEvent(Serial myPort) {

OscMessage msg = new OscMessage("/test");

msg.add(Lchange);

msg.add(Rchange);

oscP5.send(msg, puredata);

}
```

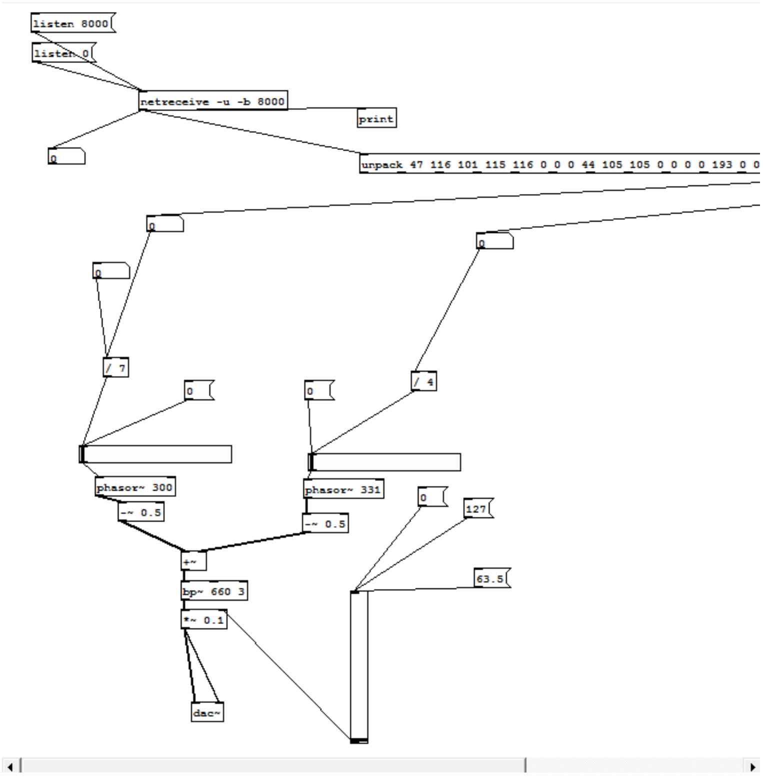

Figure 20: phasor~ objects receiving data messages from the unpack object

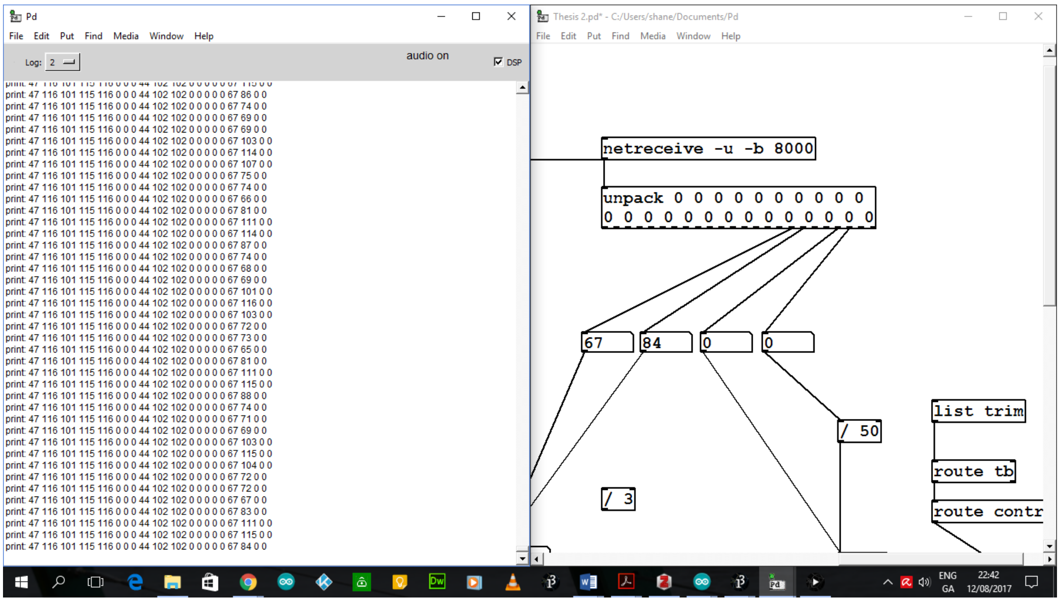

Figure 21: Pure Data, netreceive -u -b 8000 object receives messages from Processing to create audio

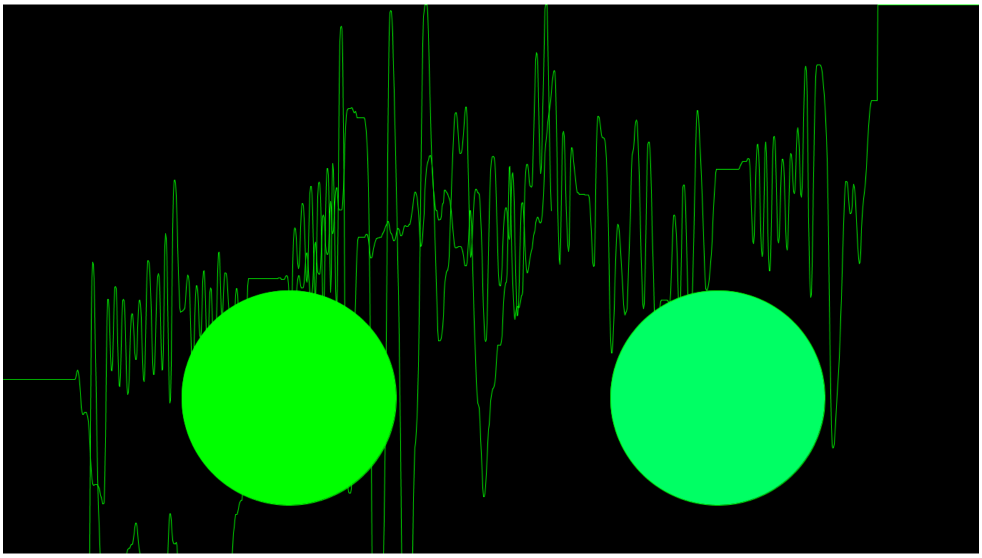

Figure 22: Processing sketch on a monitor

3.4.5 Projection Mapping

The choice to use projection techniques to display the graphical user interface was partly a technical decision but also because of the ephemeral nature of projecting light onto a surface acts as an analogue to the ephemeral nature of using off-the-shelf materials to explore the interactive potential of embedding capacitive sensing technology into everyday objects. As this work was displayed as part of the DAWN exhibition, I personally felt that using a projection to display the graphical user interface made the work more presentable while also placing an emphasis on the overall context of the project, the installation may have been perceived as a hi-tech artefact but in truth it had been constructed from basic materials. Due to the technical setup of the project, the projection had to be shone from above, there was no real possibility of projecting onto a translucent surface from underneath due to the positioning of the electronics, also my preference for the project was to use everyday objects and by constructing a special table just for presenting in an exhibition would be a contradiction. The projector that was used for the project was a Sony VPL-EW226 Data Projector. The projector's setup involved placing the projector roughly at ceiling height, then positioning a mirror in front of the projector's lens at a 45 degree, reflecting a reverse image on to the table top, this was reversed by using the flip control in the projector's settings. (see Appendix A pg. IV-IVV)

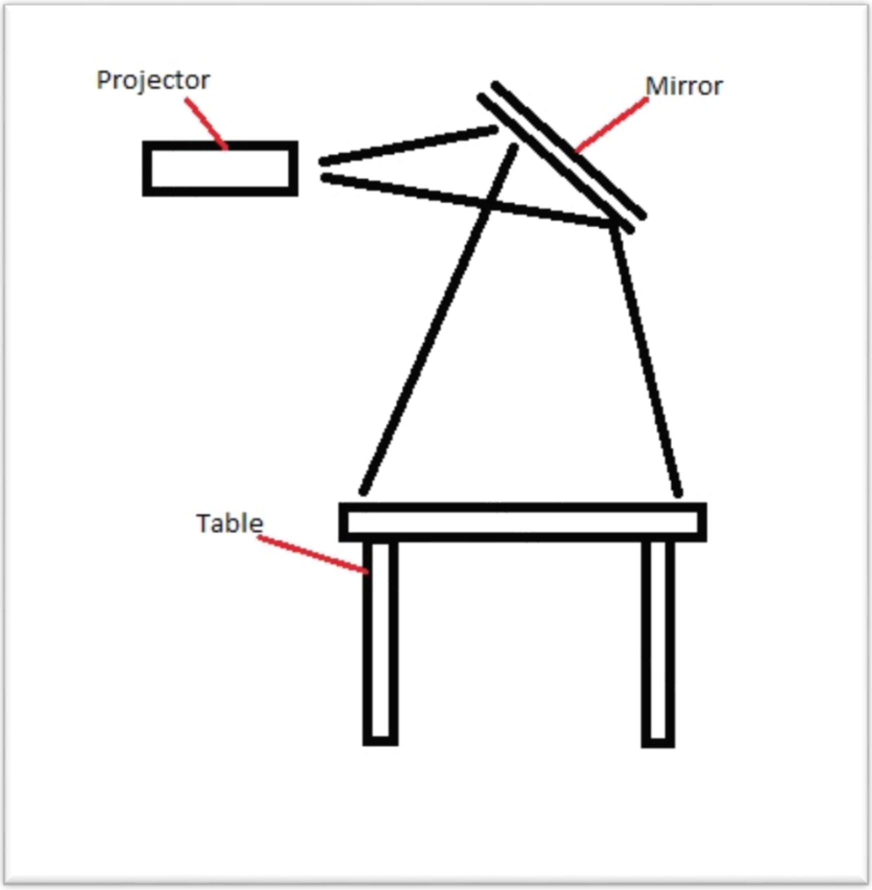

Figure 23: Diagram of Projector setup

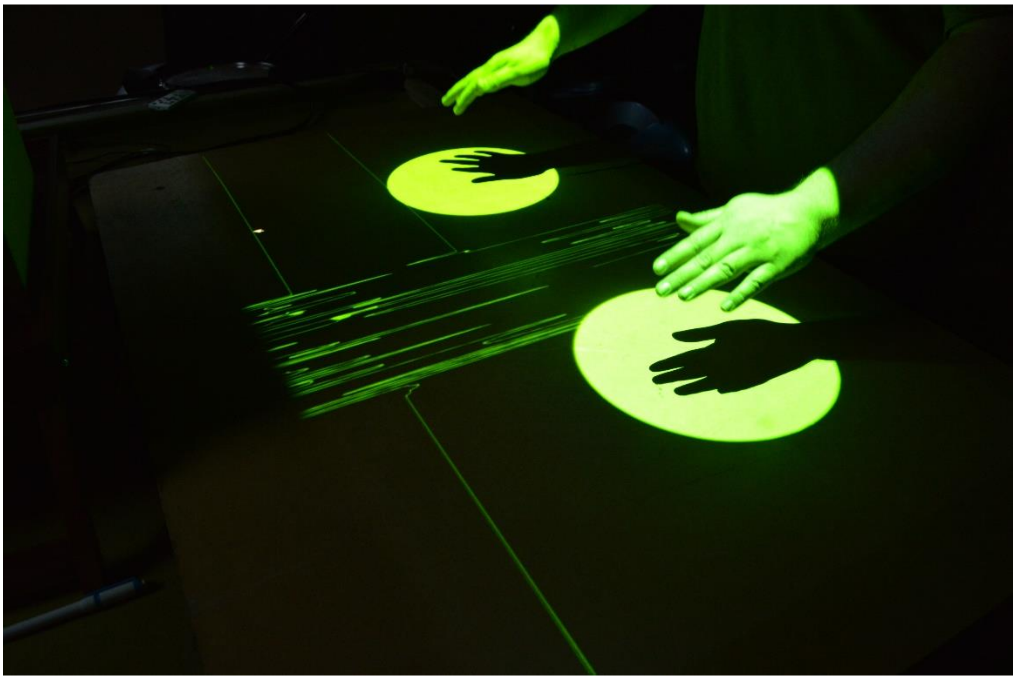

Figure 24: Projection Test for Installation

3.4.6 Technical Issues

Many of the technical issues that arose from this project came mainly from the programming, particularly from attempting to initiate a communication protocol between Processing and Pure Data. Being a novice to certain aspects of programming, most of the time was spent on learning and researching how to initiate these protocols. Processing and Arduino to their credit had plenty of online resources and up to date tutorials, but many of the tutorials for Pure Data are still using the outdated and abandoned version of the software Pd extended, which had a broader library than the original version of Pure Data. A lot of time was spent downloading libraries used in the tutorials that did not work with the current version of Pure Data. The main problem was figuring out how to receive messages from Processing and unpack the messages in Pure Data. I attempted to use the objects from mr peach, OSCx and zexy libraries for Pure Data as these were predominantly used in the online resources and tutorials, but I did not have much success. In the end, it was the netreceive and unpack objects included in the original software that worked successfully. Other issues arose from calibrating the capacitive sensors, as they tended to produce inaccurate readings due to unwanted electrical influences in the environment.

Chapter 4: Conclusion

4.0 Conclusion

This thesis began by introducing the conceptual and contextual framework of the project by first analysing the different design concepts and methodologies that had informed my practice which was established in the literature review section. This section, through the findings of Sanders and Stappers and Fischer (2008a, 2002a) explored the pitfalls of end-user development and how there is a tendency to dichotomise the different expert user groups into the roles of consumers of technology who are not truly experts of the tools they use. Sanders and Stappers and Fischer (2008a, 2002a) believe that the practice of design is evolving from the user centred approach where the focus is towards the idea that the designer or developer determines what the potential user needs, to a co-designing methodology that includes the potential user and involves them in the design process. The work of Fischer and Ishii (2010a, 2008) calls for a paradigm shift from the production techniques of the past and instead to look towards ways of collaborating and sharing knowledge between the IT developers and the greater population, who are marginalised into the role of the consumer and to explore collaborative reflection in action. The ideology of meta-design and related methodologies are further explored in the literature review through the findings of Fischer, Ishii (2002a, 2010a, 2008) who explore a solution to end-user development by the means of collaborative reflection in action. By introducing digital interactive tabletops that include users of various backgrounds and skill sets, groups could work together on design projects and remove the dichotomies of certain skillsets, shifting towards a more multi-disciplinary approach. The second section of the literary review explores how this methodology has been implemented into current practices. Resnick and Silverman (2005) explore the methodology when testing collaboration techniques with children to which they believe that it is through expression of creativity that conversations about the design begin to emerge, from which pertains to Schön's (1983) methodology of reflection in action, where the situation "talks back" to the practitioner. The rest of this section is concerned with how these methodologies have informed another and how they have highlighted the importance of Schön's (1983) methodology of reflection in action to expand on the creative aspects by being more hands-on with materials and the process of making, to create conversations with the material to enhance the design process.

The second section of this chapter was concerned with related projects and inspirational material that had an influence on the conceptual framework of this thesis. The focal point of the inspiration for this project was more concerned interactive artefacts and the technologies involved with them to which coincided with topics raised in the previous section of the first chapter and with the concluding chapters of this paper. This section explored emerging interactive technologies that allow for the experimentation and development of new interaction methods to augment the experience of human-computer interaction, from embedded products such as Microsoft's Kinect, the Leap Motion controller and electronic toolkits such as the Makey Makey, whereby the uses and limitations were explored and compared to a different approach, exploring prototyping techniques from a minimal perspective that involved conjoining craft techniques with technology . Furthermore, the second section of chapter one explored practical solutions for creating touch and gestural based interactive interfaces firstly through Harrison and Hudson's (2008) acoustic-based Scratch Input gestural controlling device, then concludes by exploring the practicalities of capacitive sensing technology. The work of Grosse-Puppendahl (2015) highlights the versatility of capacitive sensing technology as it can potentially be integrated into any non-conductive object, and due to its low power consumption, its low cost, along with the technologies touch sensing and proximity sensing capabilities makes it very applicable for interactive prototyping. Paradiso, Gershenfeld(1997) and Smith et al (1998) emphasise how electrical field sensing by means of capacitive technology should be explored to enhance user experience for creating gestural controlled graphical interfaces, they believe that the answer for exploring natural gestural expression can be found in musical performance.

Chapter two sets out a clear and concise outline for my contextual and conceptual framework that informs my design methodology for this thesis. This methodology is evident in the user testing whereby empirical data was documented through qualitative research techniques and it was from these findings that collaborative practice between the participant and the designer was explored. The topic of creative gestural control was also explored in the low-fidelity prototypes when documenting how the participants reacted to the idea of using a table as an interactive sound instrument. As previously mentioned, one of the users had an adept knowledge of various musical instruments, and found that using a performative audio based application was an interesting and immersive way of exploring gestural control as it would provide more of a challenge for the user, it could be something that the user could develop new skills and techniques with. The majority of the participants found that the prototype gave an insightful introduction to meta-design and by getting involved in the design process they questioned their own relationship with technology by exploring how an everyday object such as a table could be transformed into an interactive interface by relatively low-tech means. The empirical data gained from the user test proved to be more informative than expected. Setting up the low-fidelity mockup took very little time and labour but provided a vital insight into how the actual project would work in a real-time setting. The prototyping process was crucial in defining how potential users could possibly interact with the technology and it conveyed to them the potential of transforming any non-conductive surface into a touch and gestural interface. A further iteration of this project has taken the form of a DIY online tutorial on the hobbyist and maker site Instructables.com, where the concept of using off-the-shelf materials to explore interactive prototyping has been shared with fellow enthusiasts (see Appendix C). As previously mentioned, considering this work was part of the DAWN exhibition, I personally felt that using a projection to display the graphical user interface made the work more presentable while also placing an emphasis on the overall context of the project, the installation may have been perceived as a hi-tech artefact but in truth it had been constructed from basic off-the-shelf materials, therefore the user contemplates their own relationship with technology, this was the message that was conveyed in the final outcomes of this project.

Appendices

Appendix A

Figure 25: Plinth 2 LDR testing

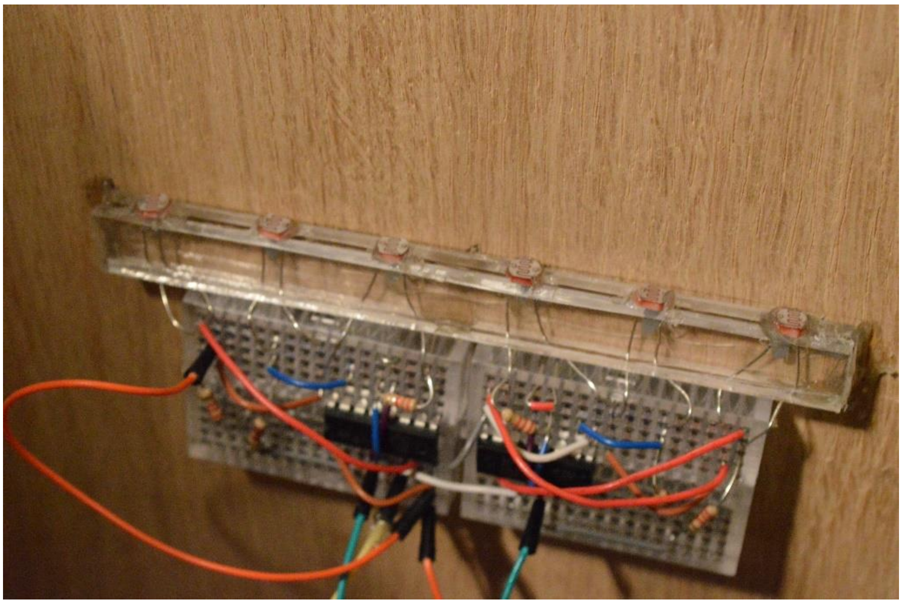

Figure 26: Plinth 2 Light Dependent Resistors connected to L293D motor drivers that trigger the motors when a laser is not shining on an LDR

Figure 27: The public interacting with my work at the Plinth2 exhibition

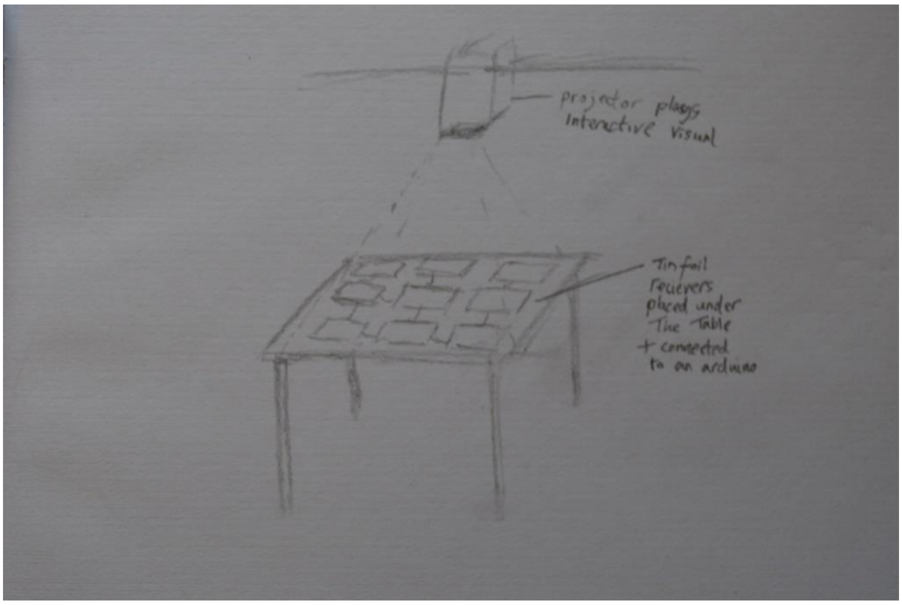

Figure 28: Sketch of project

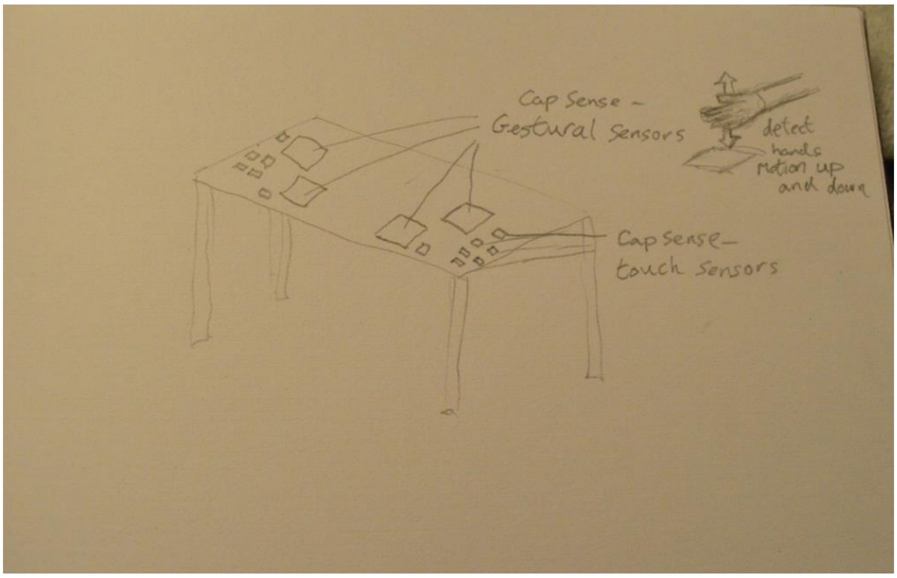

Figure 29: Sketch of project

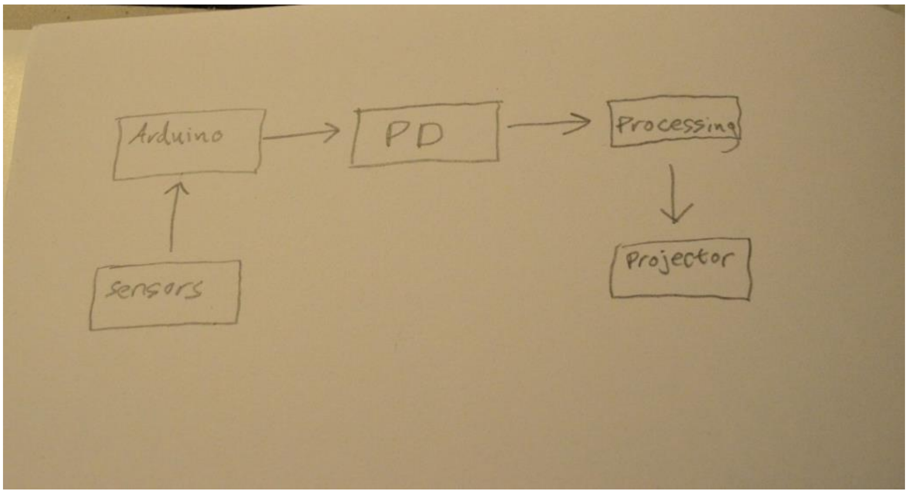

Figure 30: Sketch of project

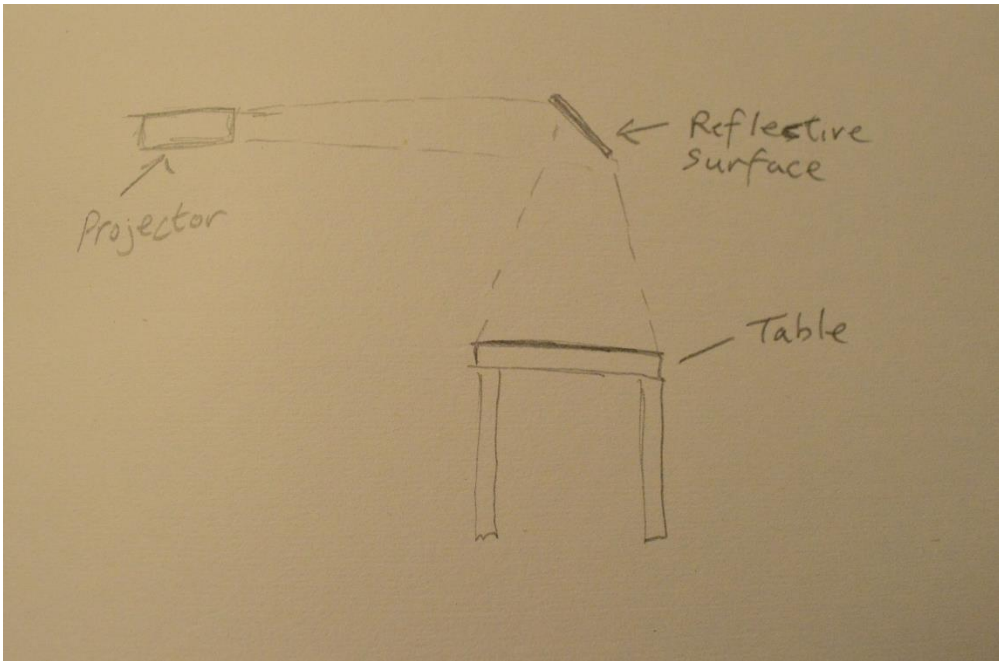

Figure 31: Sketch of project

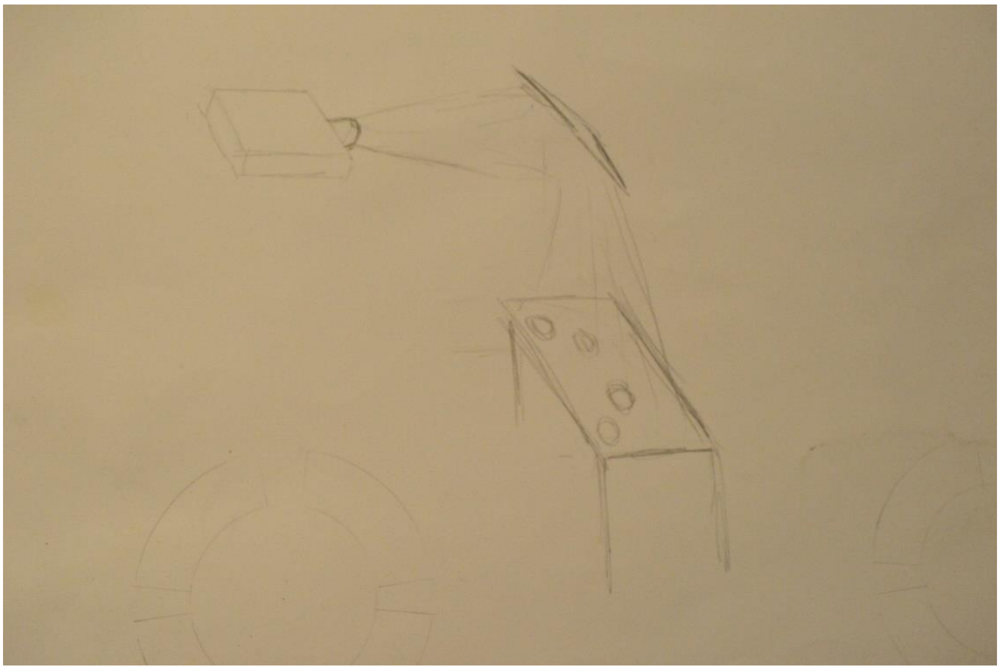

Figure 32: Sketch of project

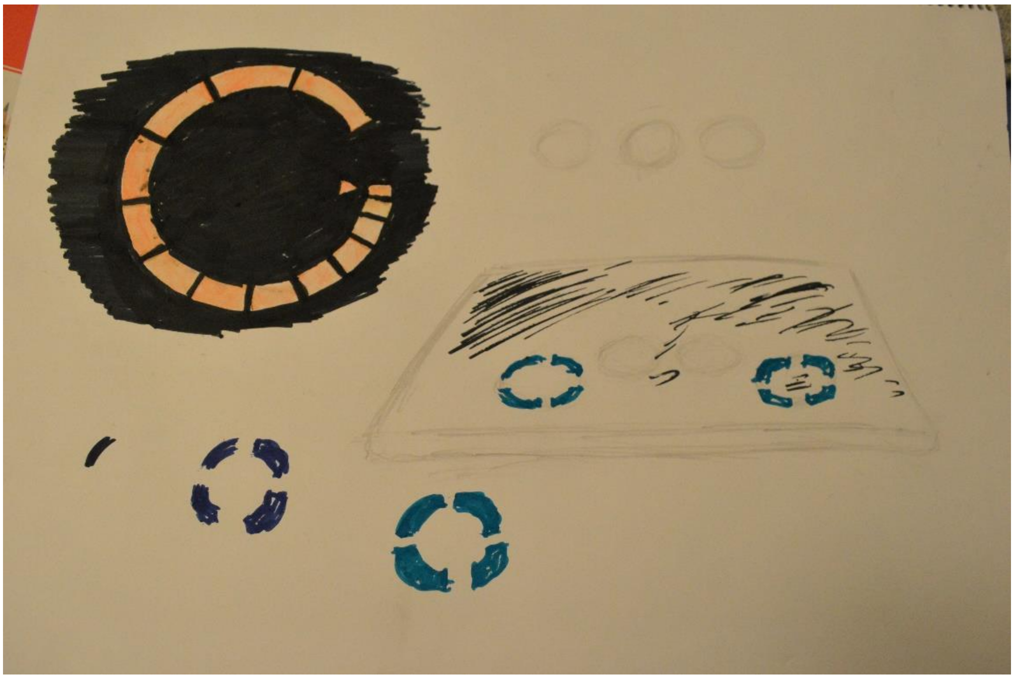

Figure 33: Sketch of project

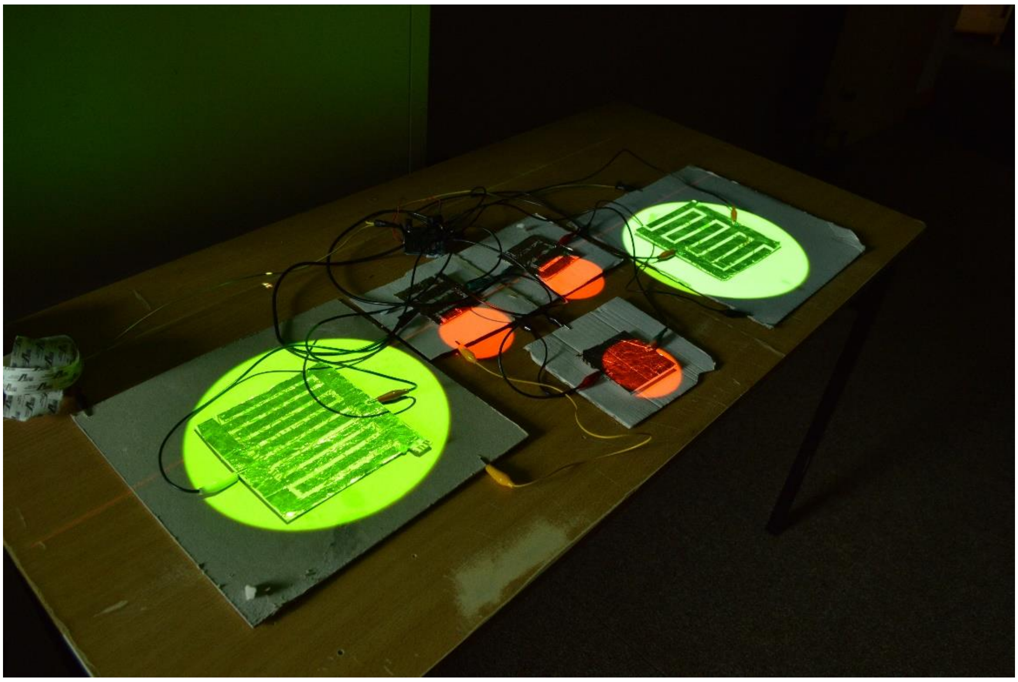

Figure 34: Setting up project for DAWN 2017

Figure 35: Setting up projector for the green light meeting

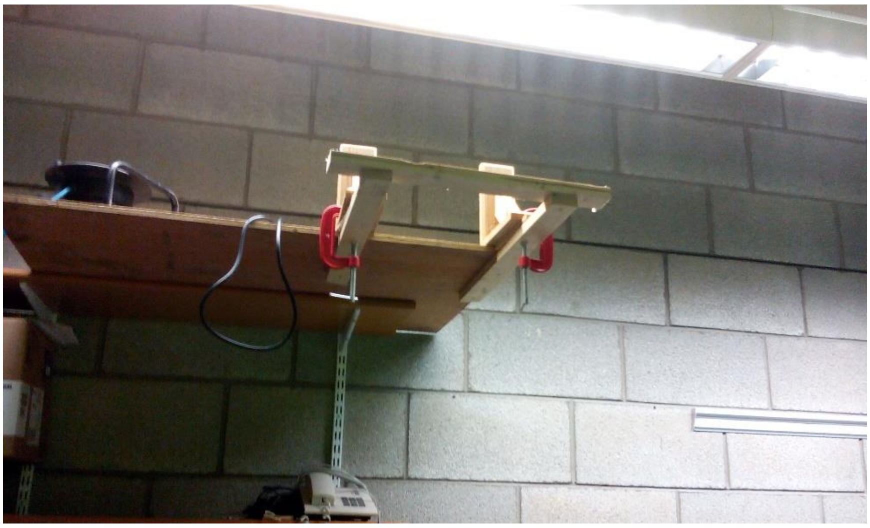

Figure 36: Setting up projector for the green light meeting

Figure 37: Setting up projector for the green light meeting

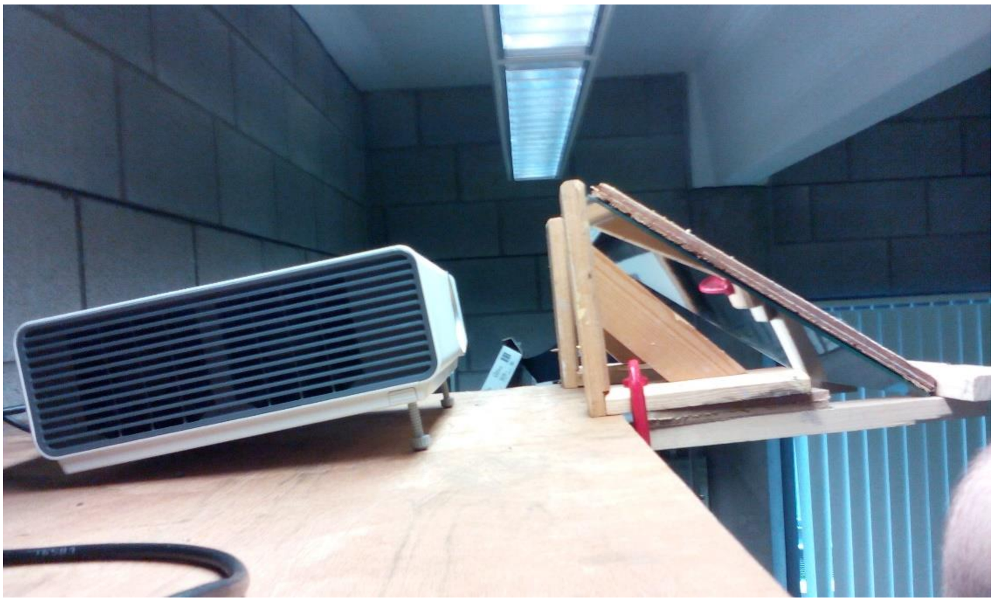

Figure 38: Setting up projector for the green light meeting

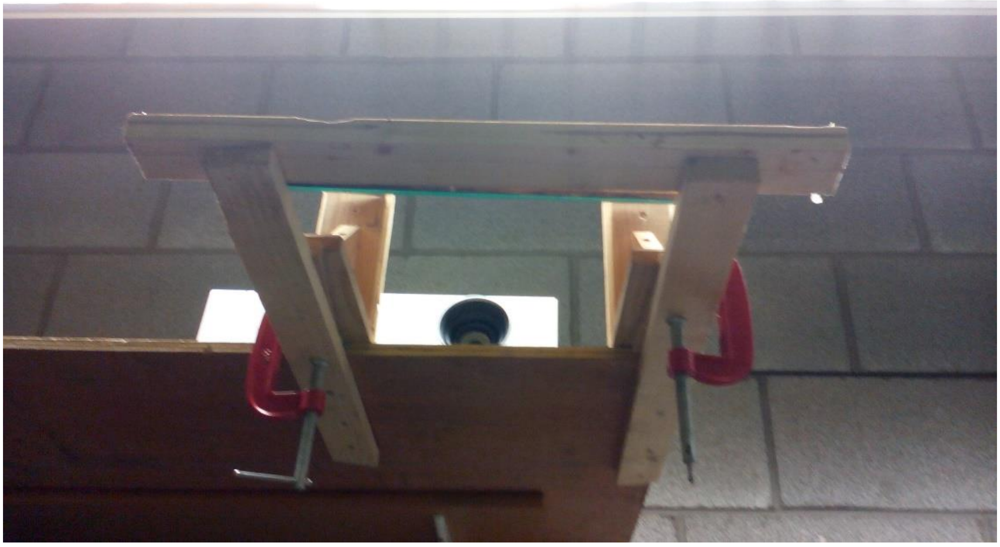

Figure 39: Setting up projector for the green light meeting

Appendix B

UNIVERSITY *of* LIMERICK

OLLSCOIL LUIMNIGH

CONSENT FORM

Consent Section:
I, the undersigned, declare that I am willing to take part in research for the project entitled "*Crafting with technology: an exploration into low-tech solutions for high-tech issues*".

- I declare that I have been fully briefed on the nature of this study and my role in it and have been given the opportunity to ask questions before agreeing to participate.
- The nature of my participation has been explained to me and I have full knowledge of how the information collected will be used.
- I am also aware that my participation in this study may be recorded (video/audio) and I agree to this. However, should I feel uncomfortable at any time I can request that the recording equipment be switched off. The recordings will be destroyed once the study is completed.
- I fully understand that there is no obligation on me to participate in this study
- I fully understand that I am free to withdraw my participation at any time without having to explain or give a reason
- I am also entitled to full confidentiality in terms of my participation and personal details
- I declare that I am between the ages of 18 and 65

______________________________ ______________________

Signature of participant Date

TASK LIST AND SET OF SURVEY QUESTIONS FOR USER TESTING
User Task List

1. Select Volume Icon.

2.Turn volume up.

3.Turn volume down.

4.Control Pitch of Sound.

5.Control Tempo of Sound.

6.Add Audio track.

7.Add Delay to track.

8.Switch between tracks.

Survey Questions:

1. What did you feel was the best thing about the prototype?
2. Was it easy or difficult to use?
3. Were there any major difficulties in exploring the prototype?
4. Was the layout of the interface user-friendly or problematic?
5. Was the layout of the interface easy to understand?
6. How could the layout of the interface be improved?
7. What other functionalities could have been included?
8. Did you find the motion sensing accurate?
9. Did you feel the gestural sensing was natural or forced?
10. What did you not like about using the prototype?
11. Did the prototype seem professional, if not why?
12. What features did you feel needed to be improved upon the most?
13. Were the tasks of the user test easy to follow?
14. Were the aesthetics of the prototype appealing?
15. What was your overall feeling about the devices functionality?
16. Was this a suitable toolkit for prototyping with gestural based interfaces, if not, why?
17. Do you have any further suggestions for improvements?

Appendix C

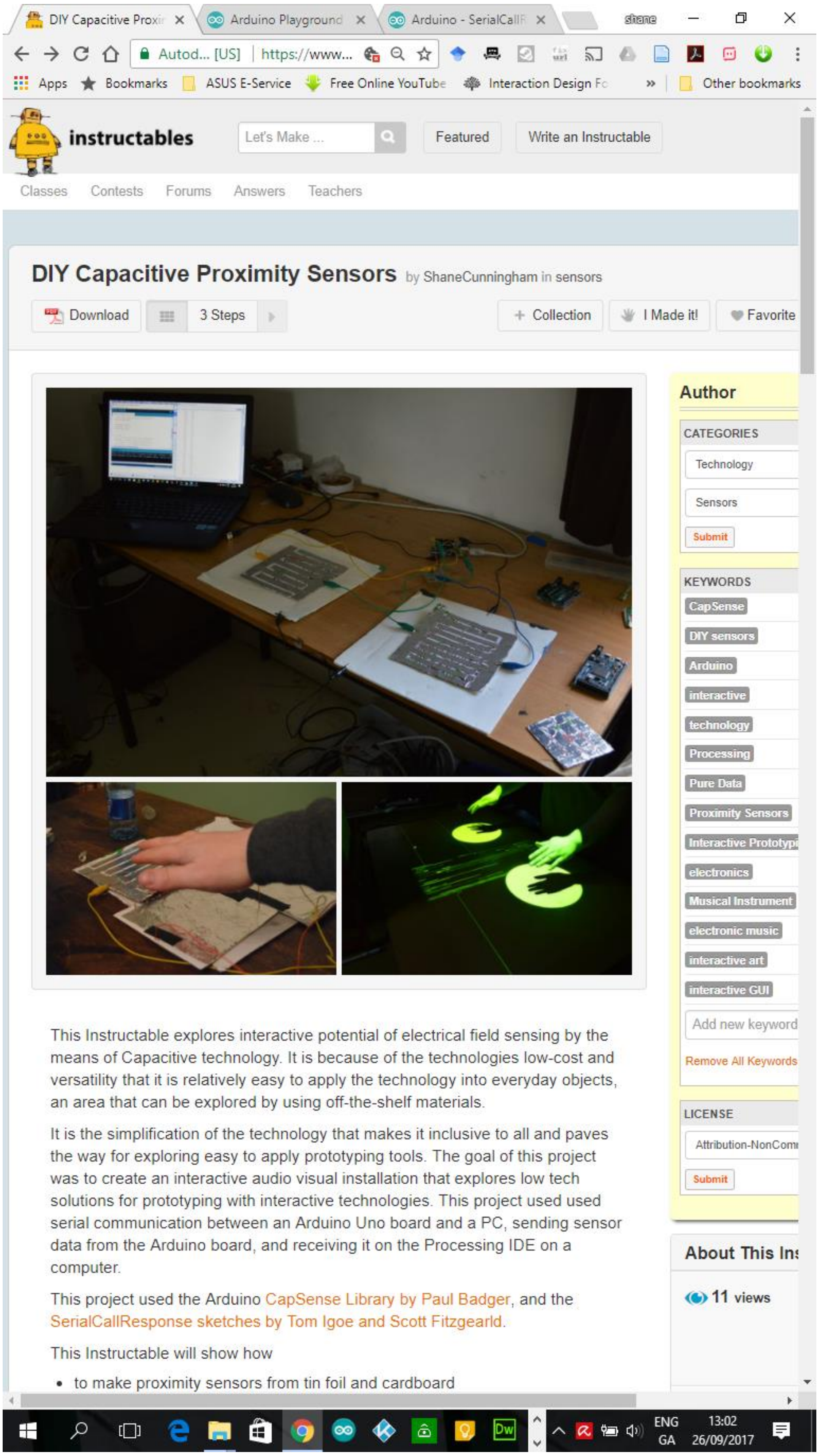

Figure 40: online DIY walkthrough of my project on Instructables.com

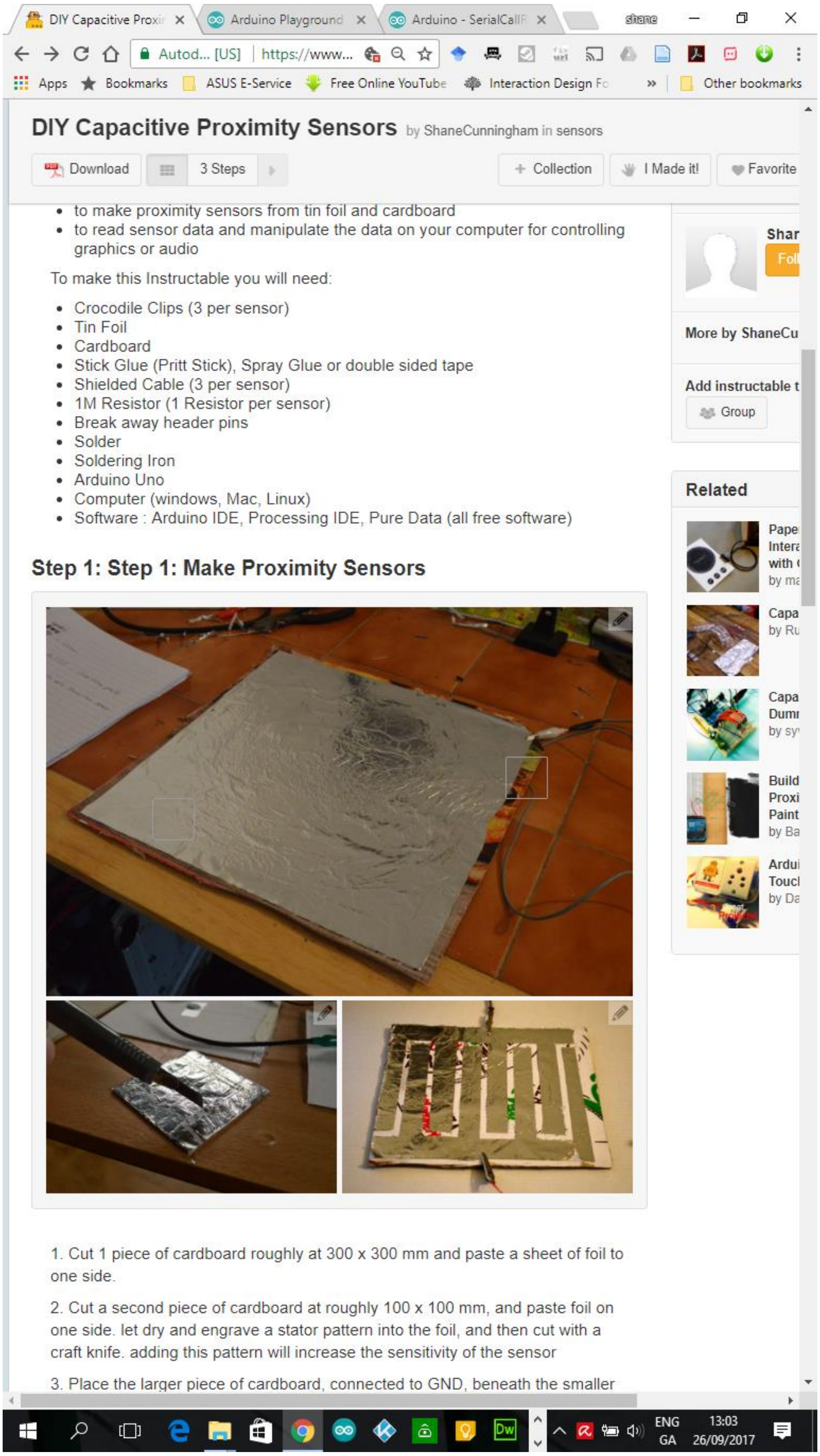

Figure 41: online DIY walkthrough of my project on Instructables.com

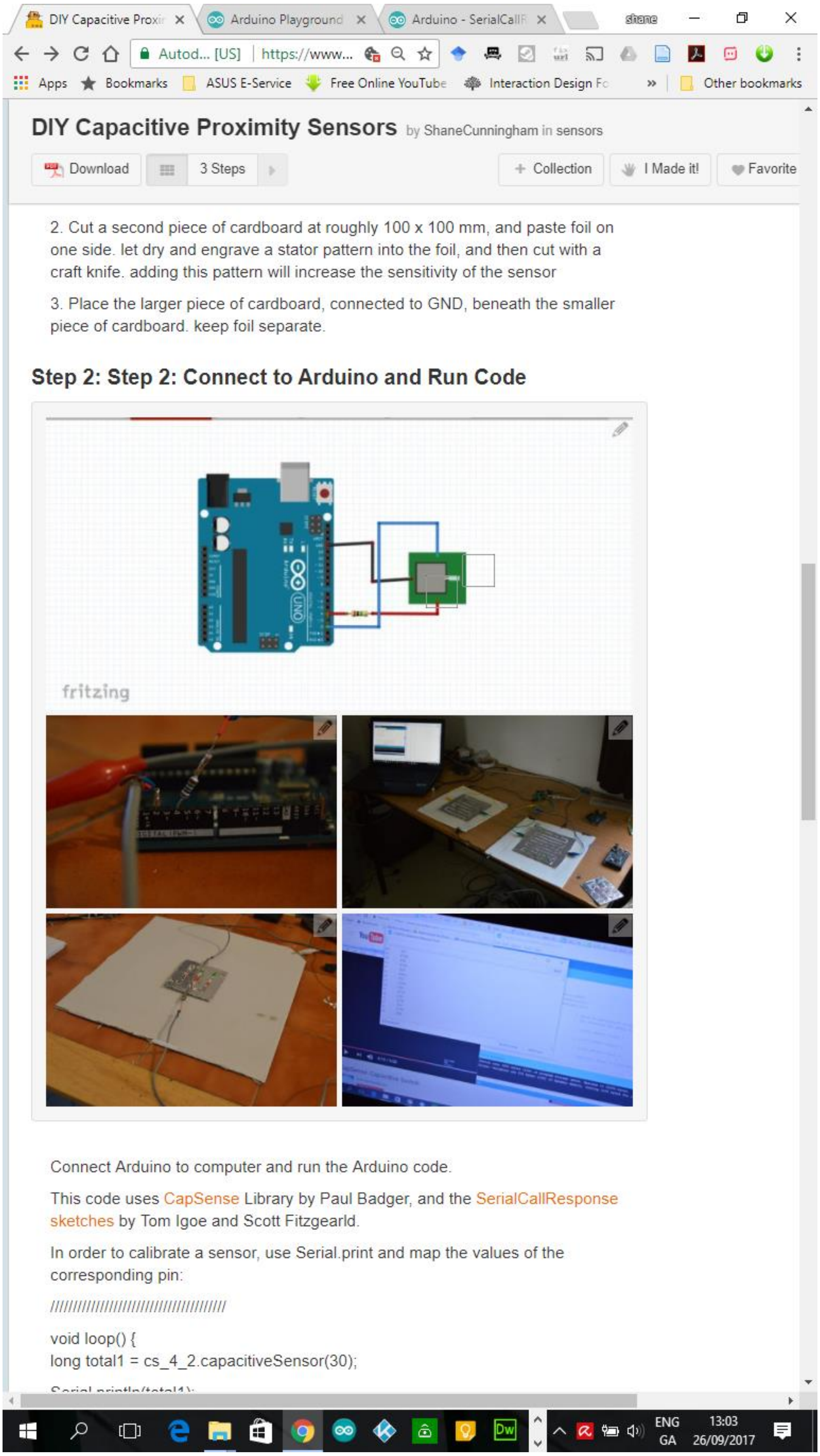

Figure 42: online DIY walkthrough of my project on Instructables.com

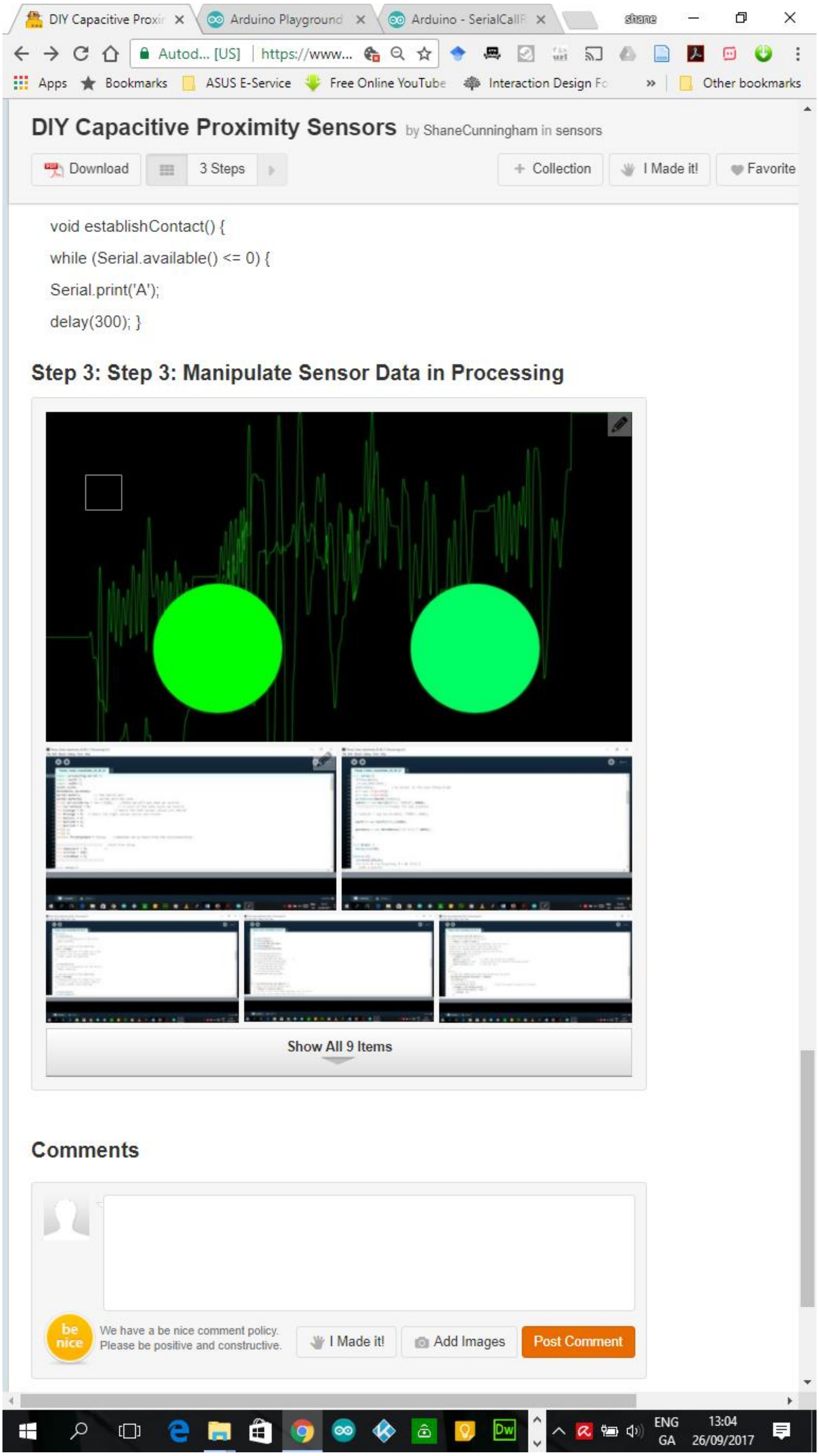

Figure 43: online DIY walkthrough of my project on Instructables.com

References

Baxter, L., 2000. Capacitive sensors.

Beringer, J., 2004. Reducing Expertise Tension. Commun ACM 47, 39–40. doi:10.1145/1015864.1015885

Biswas, K.K., Basu, S.K., 2011. Gesture recognition using microsoft kinect®, in: Automation, Robotics and Applications (ICARA), 2011 5th International Conference On. IEEE, pp. 100–103.

Cabreira, A.T., Hwang, F., 2016. How Do Novice Older Users Evaluate and Perform Mid-Air Gesture Interaction for the First Time?, in: Proceedings of the 9th Nordic Conference on Human-Computer Interaction, NordiCHI ’16. ACM, New York, NY, USA, p. 122:1–122:6. doi:10.1145/2971485.2996757

Chen, C., Cai, J., Zheng, J., Cham, T.J., Shi, G., 2015. Kinect Depth Recovery Using a Color-Guided, Region-Adaptive, and Depth-Selective Framework. ACM Trans Intell Syst Technol 6, 12:1–12:19. doi:10.1145/2700475

Chris Harrison, n.d. Scratch Input (Chris Harrison, Scott Hudson) - UIST ’08.

De Roeck, D., Stappers, P.J., Standaert, A., 2014. Gearing up!: a designer-focused evaluation of ideation tools for connected products. ACM Press, pp. 521–530. doi:10.1145/2639189.2639204

Evans, M., 2012. Hack everything: re-purposing everyday devices - Matt Evans, Linux.conf.au 2012 -- Ballarat, Australia. Ballarat, Australia.

Fischer, G., 2010a. End User Development and Meta-Design: Foundations for Cultures of Participation. J Organ End User Comput 22, 52–82. doi:10.4018/joeuc.2010101901

Fischer, G., 2010b. Extending Boundaries with Meta-design and Cultures of Participation, in: Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries, NordiCHI ’10. ACM, New York, NY, USA, pp. 168–177. doi:10.1145/1868914.1868937

Fischer, G., 2002a. Beyond “Couch Potatoes”: From Consumers to Designers and Active Contributors. First Monday 7.

Fischer, G., 2002b. Beyond" Couch Potatoes": From Consumers to Designers and Active Contributors, in: Computer Human Interaction, 1998. Proceedings. 3rd Asia Pacific. IEEE, pp. 2–9.

Freed, A., Wessel, D., 2015. An Accessible Platform for Exploring Haptic Interactions with Co-located Capacitive and Piezoresistive Sensors, in: Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction, TEI ’15. ACM, New York, NY, USA, pp. 317–320. doi:10.1145/2677199.2680571

Gorman, M., 2013. Leap Motion controller review [WWW Document]. Engadget. URL https://www.engadget.com/2013/07/22/leap-motion-controller-review/ (accessed 7.11.17).

Grosse-Puppendahl, T., 2015. Capacitive Sensing and Communication for Ubiquitous Interaction and Environmental Perception. Technische Universität.

Grosse-Puppendahl, T., Dellangnol, X., Hatzfeld, C., Fu, B., Kupnik, M., Kuijper, A., Hastall, M.R., Scott, J., Gruteser, M., 2016. Platypus: Indoor Localization and Identification Through Sensing of Electric Potential Changes in Human Bodies, in: Proceedings of the 14th Annual International Conference on Mobile Systems, Applications, and Services, MobiSys '16. ACM, New York, NY, USA, pp. 17–30. doi:10.1145/2906388.2906402

Grosse-Puppendahl, T., Herber, S., Wimmer, R., Englert, F., Beck, S., von Wilmsdorff, J., Wichert, R., Kuijper, A., 2014. Capacitive Near-field Communication for Ubiquitous Interaction and Perception, in: Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing, UbiComp '14. ACM, New York, NY, USA, pp. 231–242. doi:10.1145/2632048.2632053

Grosse-Puppendahl, T., Holz, C., Cohn, G., Wimmer, R., Bechtold, O., Hodges, S., Reynolds, M.S., Smith, J.R., 2017. Finding Common Ground: A Survey of Capacitive Sensing in Human-Computer Interaction, in: Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems, CHI '17. ACM, New York, NY, USA, pp. 3293–3315. doi:10.1145/3025453.3025808

Harrison, C., Hudson, S.E., 2008. Scratch Input: Creating Large, Inexpensive, Unpowered and Mobile Finger Input Surfaces, in: Proceedings of the 21st Annual ACM Symposium on User Interface Software and Technology, UIST '08. ACM, New York, NY, USA, pp. 205–208. doi:10.1145/1449715.1449747

Hruska, J., 2016. Can we finally admit that Kinect is dead? - ExtremeTech [WWW Document]. URL https://www.extremetech.com/gaming/230252-can-we-finally-admit-that-kinect-is-dead (accessed 9.28.17).

Ishii, H., 2008. Tangible bits: beyond pixels, in: Proceedings of the 2nd International Conference on Tangible and Embedded Interaction. ACM, pp. xv–xxv.

Jana, A., 2012. Kinect for Windows SDK programming guide: build motion-sensing applications with Microsoft's Kinect for Windows SDK quickly and easily, Community experience distilled. Packt Publ, Birmingham.

Kosner, A., 2013. leap-motion-second-generating-hand-tracking.jpg (800×449) [WWWDocument]. URL https://bi.forbesimg.com/anthonykosner/files/2013/11/leap-motion-second-generating-hand-tracking.jpg (accessed 9.28.17).

leapmotion.com, 2017. Leap Motion [WWW Document]. Leap Motion. URL http://leapmotion.com/ (accessed 7.11.17).

Löwgren, J., 2016. On the significance of making in interaction design research. interactions 23, 26–33.

makeymakey.com, 2017. Makey Makey | Buy Direct (Official Site) [WWW Document]. URL http://www.makeymakey.com/ (accessed 7.20.17).

Mellis, D.A., Jacoby, S., Buechley, L., Perner-Wilson, H., Qi, J., 2013. Microcontrollers As Material: Crafting Circuits with Paper, Conductive Ink, Electronic Components, and an "Untoolkit," in: Proceedings of the 7th International Conference on Tangible, Embedded and Embodied Interaction, TEI '13. ACM, New York, NY, USA, pp. 83–90. doi:10.1145/2460625.2460638

Paradiso, J.A., Gershenfeld, N., 1997. Musical applications of electric field sensing. Comput. Music J. 21, 69–89.

Pinch, T.J., Bijker, W.E., 1984. The social construction of facts and artefacts: Or how the sociology of science and the sociology of technology might benefit each other. Soc. Stud. Sci. 14, 399–441.

Resnick, M., Silverman, B., 2005. Some Reflections on Designing Construction Kits for Kids, in: Proceedings of the 2005 Conference on Interaction Design and Children, IDC '05. ACM, New York, NY, USA, pp. 117–122. doi:10.1145/1109540.1109556

Rogers, Y., Paay, J., Brereton, M., Vaisutis, K.L., Marsden, G., Vetere, F., 2014. Never Too Old: Engaging Retired People Inventing the Future with MaKey MaKey, in: Proceedings of the 32Nd Annual ACM Conference on Human Factors in Computing Systems, CHI '14. ACM, New York, NY, USA, pp. 3913–3922. doi:10.1145/2556288.2557184

Sanders, E.B.-N., Stappers, P.J., 2008a. Co-creation and the new landscapes of design. Co-Des. 4, 5–18.

Sanders, E.B.-N., Stappers, P.J., 2008b. Co-creation and the new landscapes of design. Co-Des. 4, 5–18.

Schön, D.A., 1983. The reflective practitioner: how professionals think in action. Basic Books, New York.

Silver, J., 2009. Awakening to Maker Methodology: The Metamorphosis of a Curious Caterpillar, in: Proceedings of the 8th International Conference on Interaction Design and Children, IDC '09. ACM, New York, NY, USA, pp. 242–245. doi:10.1145/1551788.1551841

Silver, J., Shaw, D., Rosenbaum, E., 2012. Makey Makey: Improvising Tangible and Nature-based User Interfaces, in: Proceedings of the Sixth International Conference on Tangible, Embedded and Embodied Interaction, TEI '12. ACM, New York, NY, USA, pp. 367–370. doi:10.1145/2148131.2148219

Silver, J.S., 2009. Nature As Interface: MacGyver’Ing and Martha-Stewart’Ing Interactivity with Trees, Pencils, Grandpa, Even the Kitchen Sink, in: Proceedings of the Seventh ACM Conference on Creativity and Cognition, C&C ’09. ACM, New York, NY, USA, pp. 483–484. doi:10.1145/1640233.1640367

Smith, J., White, T., Dodge, C., Allport, D., Paradiso, J., Gershenfeld, N., 1998. Electric Field Sensing For Graphical Interfaces. IEEE Computer Graphics and Applications, pp. 54–60.

Weichert, F., Bachmann, D., Rudak, B., Fisseler, D., 2013. Analysis of the Accuracy and Robustness of the Leap Motion Controller. Sensors 13, 6380–6393. doi:10.3390/s130506380

Weiser, M., 2002. The computer for the 21st Century. IEEE Pervasive Comput. 1, 19–25. doi:10.1109/MPRV.2002.993141