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transcension

an exploration of the creative potentials for wearable technology and interactive media art in fantasy worldbuilding

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Technology has long been used for creating what seems to be inexplicable, impossible phenomena, hereafter described as magic. Magic is also present in many forms of fictional world narratives as one of the central elements in worldbuilding, including in the magical girl genre stemming from Japanese anime. The magical girl character(s) that the narratives center around are depicted as seemingly ordinary girls who become immersed in a magical world, overlaying the world that they typically occupy, through a transformation process which morphs them from the ordinary to the extraordinary and grants them magical powers along with hyper-feminine costume changes.

In the production part of this thesis, titled ☆･*:.｡. .｡.:*･ transcension ･*:.｡. .｡.:*･☆, I use new media technology to intersect a fantasy world of my own making with the real world, mimicking the transition which occurs in magical girl anime. The creative part of this thesis consists of an interactive sculpture and three costumes of original magical girl characters, which are enhanced by technology to become wearables. The costumes respond to interactions, while the sculpture provides a means through which participants can experience magic. The combination of these parts makes a form of interactive media art that blurs the boundaries between the real world and a magical world. Through the production process, I explore possible uses of technology and physical computing for physically manifesting a slice of a fantasy world, while investigating my own personal artistic practice as I designed and produced these four art pieces. The research question therefore is how interactive media art, specifically in the form of wearables and interactive sculptures, can be used to obscure the delineations between magic and reality.

The structure of the written part of this thesis first introduces the project and its scope, and then discusses the multitude of disciplines that are touched upon in the inspiration and creation of the artistic production. I then explore in depth the design and production processes for the physical part of this thesis and perform an analysis of my artistic process as well as of the outcomes of the final exhibition. Through the written and artistic parts of this thesis, I demonstrate potential uses of technology in translating magical aspects of a fantasy world into the real world.

Keywords wearables, physical computing, interactive media art, magical girls, mahou shoujo, cosplay, costume design

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Contents

1 Introduction

1.1 Premise and motivations

As a new media artist interested in wearables, costuming, and cosplay, I chose to create an artistic production thesis project, titled ☆･*:.｡. .｡.:*･ transcension ･*:.｡. .｡.:*･☆ (henceforth referred to as transcension). This project sits at the intersection of those interests, and creates an installation featuring three wearables-as-costumes and an interactive sculpture. My project is framed by a narrative through which I explored the possibilities for using wearables and interactive media art to blur the lines between magic and reality. Within this narrative, I created a fantasy world where three magical girl characters, based on aspects of my identity or personality, existed. They were connected by a magical bond, through which they could communicate with each other, and could create magic together with their special powers. For my project, I sought to bring these characters and their magic from the fantasy world into the real world, so people could experience and interact with an instantiation of magic.

Interactive media art is a term fraught with varied definitions and contexts for usage. In the case of my art, I use it to describe artwork which, as defined by Katja Kwastek, “is based on the realization of potentials that are built into systems” (Kwastek, 2013, p. 6). Using physical computing, I created a complex system primarily composed of wearable technology pieces that was ripe with potentials for interaction. I contextualized the workings of the system through the art of costuming and worldbuilding, and established a set of art pieces which interacted with both the audience and each other. I drew inspiration from a multitude of sources, including: the aesthetics of magical girls, the formation of identity through costume, the performativity of wearables, the fragmentation of flesh and the body through networked technology, and my own past work.

1.2 Research question

The objective of this project was to combine costuming with interactive media art to manifest the super-human reality of magical girls into the everyday lives of audience participants.

1.3 Methodology

This thesis approaches the research question through practice-based research. It is structured in two parts: a creative work, and an “exegesis that accompanies the creative work: that knowledge that has remained implicitly within the artist, made explicit and seated within the context of the scholarly field” (Skains, 2018, p. 6). Practice-based research employs auto-ethnography and auto-ethnomethodology in its analysis of the practice in question. In the case of my project, the object of analysis was the design and creation of three costumes and an accompanying installation piece in the form of a magical portal. I analyze both the design process and my creative process by studying the self-notes and documentation made during the creation process in order to develop this knowledge that is implicitly within me and to make it explicit. Skains discusses the “creative analytical processes (CAP) ethnography’ in which the creative process and products, and the analytical process and products are deeply intertwined, offering opportunity for insight and nuance into the creative practice through a necessarily subjective record (L. Richardson and St. Pierre 2008)” (Skains, 2018, p. 7), which I employ in the study of my notes.

2 Contextualizing the project

2.1 Magical girls

A magical girl is a character construct stemming from Japanese fantasy media in which an otherwise ordinary school girl comes into magical powers, which manifest after a physical transformation that significantly alters her appearance (Sugawa, 2015). Some well-known magical girl series include: Sailor Moon (1995-2000), Cardcaptor Sakura (1998-2000), Puella Magi Madoka Magica (2011), and Pretty Cure (2004-2005), and the genre has spread to western animation with series such as the hit Netflix animation She-Ra and the Princesses of Power (2018-2020)[1]. They often are established as a team, following a convention set by "the "super fighting squad" (sūpā sentai) genre of live-action children's television programming, which generally features a five-person team of color-coded warriors, each with his or her own special power and guardian spirit" (Hemmann, 2014, p. 54), such as Power Rangers. This construct has been present throughout my life, as an avid consumer of Japanese animation (anime) and comics (manga), and is a key part of the aesthetics and inspiration for my thesis project.

Perhaps the most iconic trait of magical girls is that they transform.

> "The transformation process itself is largely an exceptionally detailed, lengthy sequence in which the magical girl character loses all the physical trappings of their mortal outfit and uniform, having their body metamorphose into the form of their superheroine self, and don a new outfit suitable for their new identity" (Liess, 2018, p. 25).

The characters that I created have such transformations, as they are all magical girls, and are depicted in their transformed costumes and states, as part of the premise is that there is nothing remarkable about their pre-state. Through this transformation they become magical and thus gain their special powers which are captured in the potential interactions with the costume pieces.

Existing literature on magical girls heavily investigates the genre's relationship to gender roles, gender performance, and adolescent sexuality, especially as pertaining to Japanese culture. Sugawa Akiko describes Sailor Moon characters in "Children of Sailor Moon: The Evolution of Magical Girls in Japanese Anime" as "Japan's symbols of girl power, joining together to battle evil on their own" (Sugawa, 2015). Although they appear at surface to be symbols of girl power, they are often analysed critically as for the nature of their transformed selves: "While powerful, Japan's magical girl warriors also preserve attributes associated with traditional gender roles . . . that make them less threatening to men" (Sugawa, 2015). Kumiko Saito surveys the history of the genre, and claims that "the genre's empowerment fantasy has developed symbiotically with traditional gender norms in society" (Saito, 2014, p. 143). The design of these

[1] Dates obtained from IMDB, often for the broadcasting era for American television exports of anime series. Multiple of the mentioned series encompass large franchises spanning several different anime series, such as Sailor Moon and Sailor Moon Crystal.

transformed girls — for they are always magical girls, and never women — tend towards the hyperfeminine, both in aesthetic and in personality (Saito, 2014, pp. 145–146).

Rather than delving into a critical analysis of the genre, I bring it up as a relevant topic due to its significant influence on my work — specifically the design of the characters and the world in which they occupy. I approach the magical girl genre not as an academic but as a fan, with love and nostalgia built up from a lifetime of background awareness and consumption. When first asked to describe my project, I contextualize it by bringing up the Sailor Moon series. This reference is common enough that it often enables the person to establish a basic set of expectations for my work, explaining the shared-yet-different aesthetic of the costumes. Hemman breaks down the design tropes that I enact in my own designs, referencing anthropologist Anne Allison when she describes the magical girls as "a five-person team of color-coded warriors . . . associated with her own color and celestial body. . . . The personalities of the five girls are similarly encoded" (Hemmann, 2014, p. 54) with their uniforms.

2.2 Costumes and cosplay

Through this thesis, I draw a distinction between the characters which I created — three magical girls — and the costumes which I created. I traverse both sides of the line, where on one side, the characters freely exist in a fantasy world as original characters with actual superhuman aspects and actual magic, and on the other side I drift into the real world, where I made costumes of the characters to materialize an approximation of them, following the tradition of Cosplay. Cosplay, short for 'costume play', is a subcultural activity traditionally practiced by participants of a 'fandom' — fans of a particular piece or collection of media (Lamerichs, 2014, p. 113). The chosen media is limitless in possibilities, and common areas include western franchises such as Marvel, anime such as Sailor Moon, video games such as Overwatch, or even podcasts, such as Critical Role. When cosplaying, an individual chooses a character or concept and creates a costume so as to appear to be that character. The costumes are then often showcased at fan conventions, which may range from hundreds to a hundred thousand attendees (Lamerichs, 2014, p. 114).

As a cosplayer of several years, I have intimate familiarity with the practice and culture around cosplaying, and have participated in many fan conventions where cosplay abounds for varied reasons. Costumes range in skill from beginners, patching together outfits from thrifted clothing, to highly skilled masters of several crafts, utilizing techniques such as leatherworking, embroidery, clothes-making, 3D-modeling, and armor-making. They may even change their appearance using wigs, makeup, contacts, and prosthetics. Similarly, the motivations behind cosplay vary widely — sometimes it's a matter of matching a group of friends in a group cosplay, or it's a test of skill for displaying in competitions, or simply out of a kinship with a character or a character's design.

> "[Cosplay is] a scarcely studied form of appropriation that transforms and actualizes an existing story or game in close connection to the fan

> community and the fan's own identity. . . . Fans actualize characters that are purely mediated, that do not exist in real life and have no embodied original. . . . Costume, then, is indicative of character and can be understood even in isolation from its narrative" (Lamerichs, 2014, pp. 114–119).

In her research, Lamerichs focuses primarily on cosplay as it pertains to existing characters. However, I applied cosplay to cosplaying my original characters — a practice still performed at conventions, though to a significantly lesser extent. She mentions how costumes may act in isolation from narratives, and I find this reflected in my own experience. Due to the lack of possibility for others to recognize the character being cosplayed, the costume is then interpreted through a different lens — that of viewing the unknown at a superficial level. This lens is not exclusive to original characters, as it is also the lens through which an unrecognized costume is viewed. Without recognition, there are significantly less sociocultural reference points against which to draw implicit knowledge and context through which to consume the cosplay and the cosplayer. In this vacuum of knowledge, "the costume can be admired and appreciated as a creative and visual object" (Lamerichs, 2014, p. 119), and the costumes present the pleasurable possibility for viewers' imaginations. Without the context of the fictional narrative, they can attach any kind of meaning and reference to a costume, thereby creating a unique, individualized experience for themselves.

In creating these largely decontextualized costumes of unknown characters, I sought to guide the interpreted experience through visual and other sensory cues, while leaving much of the experience up to the interactor's imagination. I chose to not include descriptive plaques for each costume, instead presenting them without name or reference, with the intent of leaving the experience as open as possible to interpretations. I drew visual influences from the classic Sailor Moon transformation outfit by making white bodysuits with large colored bows on their chests, and Japanese lolita subculture for the cage skirt + cupcake skirt silhouette, which when combined, both directly reference magical girls and also references the over-the-top femininity often associated with transformation costumes. The wigs also reflect the practices of cosplayers, and their novel colors and styling mimic that of magical girls' and other heroine anime characters.

2.3 Wearable technology

The costumes that I created straddle the line between wearables and display pieces. They contain technology that supports functionality only accessible by the wearers, as well as technology for 'performing' on a mannequin, independent of a body. By having these dual states, an analysis of how they function offers the opportunity to examine the ways of being of wearables that act as hybridized wearable technology (bearing embodiment and agency) and interactive art (disembodied and semi-static). Valérie Lamontagne posits "our bodies increasingly become interfaces, mediated through technologies from interactive art, for handheld or embedded devices. This techno-organic epidermis constructs new relationships with technology, which use wearable technologies to blur the traditional limits between object, garments, information and entertainment" (Lamontagne, 2014, p. 156). While Lamontagne focuses on digital displays and networks such as Facebook and email in this context (Lamontagne, 2014, pp. 156–157), my work concerns itself with a more integrated form of interface with wearable technology. The integration of the electronics in the costumes with the bodies of the wearers are so completely embedded to as obfuscate the boundary between garment and information communicated from the garment. At the same time, I consciously designed the costumes to be stand-alone parts of an exhibition, isolated from the body and their mutual interface.

Interfacing between the public and the private body

"Garments are the immediate interface to the environment and thus are a constant transmitter and receiver of emotions, experiences, and meaning" (Seymour, 2008, p. 12). Wearable garments often doubly so, interfacing between the public and the private through both the medium of the garment and the medium of the integrated technology. They connect what is interior to the wearer — body-sensor data and sensory inputs such as material texture, temperature, and stability — with what is exterior, "what [wearables] display, express, and project onto the public" (Lamontagne, 2014, p. 160). Valérie Lamontagne investigates the relationship between wearables and the body, referring to "how the unique mechanical-somatic exchange, created by implementing techno-fashion on the body, proposes new ways of thinking about, moving, and living in the body" (Lamontagne, 2014, p. 160). The mechanical-somatic exchange described here is reproduced in the dynamic between the magical girl costumes and their wearers — the exteriorized costumes enhance and alter the body, while the body supports and drives the costumes. The dynamic thus enables an exploration of the newly created ways of being that Lamontagne discusses.

With this new way of being, wearers are able to experience a heightened consciousness of their own bodies as well as their relationships with others through a combination of sensors and feedback motors. The sensors convert a specific gesture and people-sensing into data, which are then reflected in the exterior of the wearables as visible changes while the interiors react in tangible ways. This promotes communication between the wearer and the wearable as well as between the wearer and both other magical girls and members of the public. The dissemination of data between the magical girls creates a private, collective sort of sensing and awareness of each other.

In addition to connecting the internalized body to the externalized wearable, wearables also serve as an "immediate interface to the environment" (Seymour, 2008, p. 9). They connect the environment to the wearer through sensors, transmitting data such as proximity to others, lighting conditions, and sound, thereby informing the wearer's experience of the world. They act as a "constant transmitter and receiver of emotions, experiences, and meaning" (p. 9), complicating the wearer's relationship with the world that surrounds them. In the case of the magical girl characters, the costumes differentiate the presence of other magical girls, people within the Magical Girl Network, and the others that lay outside of it. They distinguish potential interactors through a complex arrangement of emitters and receivers to create a 'sixth sense' that alternately heightens and disarms their defenses and affects their reactions to stimuli and these other beings. This 'sixth sense', a magical sort of sensing bestowed upon the wearer by the costume, allows magical girls and others within their network to reach out and wirelessly form a connection, invisibly acknowledging the kinship between themselves. This sense is actuated using vibration motors in the costumes, creating a private somatic relationship between the wearables and their wearers, “hidden, almost secret interactions that are directed only at the user” (Guler et al., 2016, p. xxiii), enabling in-group communications and bonding imperceptible to those outside of the network.

2.4 The Magical Girl Network

My magical girls were initially created to embody aspects of my identity and express them through creative physical interpretations. Although they exist as separate beings, each materializing a different part of my identity, they are bound together by their mutual origin: me. They are separated parts of a whole.

To acknowledge this complex relationship between the magical girls, I took inspiration from Stelarc’s conceptualization of “Fractal Flesh”, from his essay “Parasite Visions” (1997). In this essay, he describes a reciprocal relationship between bodies that are “spatially distributed but electronically connected. . . . a multiplicity of bodies prompting and remotely guiding each other” (1997), as a potential future born from the possibilities provided by the Internet. The magical girls act as this multiplicity of bodies, connected in precisely this way — they create an electronic network between themselves to form a collaborative experience of the world. While they are distinct beings, each individually sensing, they communicate what they sense and guide each other through this network to develop a more complex entity than their separate selves.

This network, which I term the Magical Girl Network, uses radiofrequencies to remotely transmit data, thereby allowing the magical girls to use a wireless, node-based mode of communication that does not rely on a local WiFi or Bluetooth connection. This enables them to be connected with each other anywhere, as they create their own internal infrastructure. The data that they share is informed by the sensors within their costumes, which capture information such as the infrared signatures of living beings and the movements of the wearers. Through this network, they build a real-time, shifting landscape of sensorial perception between their collective selves. This creates the “feedback-loops of alternate awareness, agency, and of split physiologies” (1997, para. 2) that Stelarc describes, forming a synergistic meta-body through their mutual, collaborative ‘sight’, while physically occupying separate bodies. By creating this network, they function as symbiotic parts of a larger organism. Their magic is similarly tuned to the frequencies of this network, and manifests physically as the magic portal sculpture. It serves as visualization of their transmitted signals, externalized from the bodies of the magical girls, and they are able to activate it through this networked connection.

2.5 My previous works with wearable electronics

My creative background lies in designing costumes for events and spectacle. Over the years, I learned about the vast possibilities brought about by integrating electronics into costumes and drifted into the field of making wearable technology for fashion. Fashionable wearable technology is In the recent past, I worked on a project entitled Flung Out of Space (F.O.S) (2020), which explored the possibilities for using wearable technology to create and maintain pseudo-physical bonds between people across space. F.O.S was a paired set of wearables in the form of a large collar-style necklace and a cuff-style bracelet (Fig. 01), which primarily allowed the wearers to share their heartbeats with each other over a short distance using a combination of pulse sensors and haptic vibrations. This experience with using radiofrequency modules for short distance (<30 meters) wireless communications, paired with the idea of private haptic feedback, persisted in my interests into this current project.

Figure 01

The two parts of F.O.S.

Hsieh, W. (2020). [A photograph of the two parts of the Flung Out of Space wearables] [Photograph].

I also made Miss(ed) Chimera (2021) (Fig. 02), a fashion wearable in the form of a dress. That project was very much a progenitor to this project, emerging out of a love for monster girls, which, like magical girls, can be found as a type of fantasy manifestation of super-human girlness. The dress featured an iridescent infinity mirror heart on the chest, along with flashing LED patterns under the skirt which revealed the shadows of tentacles underneath the tulle. In that project, I used e-textiles to build a pressure sensor so the wearer could trigger a visual 'startle' response in reaction to their environment, instead of using an external sensor for initializing triggers. The dreamy lightness of the skirt, which was made of several layers of light blue and pink tulle, was belied by the dark shadows of the tentacles underneath. These shadows, when revealed, hinted at the unnatural nature of the wearer's body, suggesting that they were potentially inhuman. The theme of monstrous natures concealed in skirts carried over to one of the designs of the magical girls, which had a similarly people-triggered, perturbing surprise.

Figure 02

Miss(ed) Chimera, inactivated versus activated, revealing the hidden tentacles underneath her skirt

Xie, J. (2021). [Two side-by-side images of the Miss(ed) Chimera project] [Photograph]. Instagram. https://www.instagram.com/p/CMHVYJHDPe-/

3 Describing the project

3.1 The Magical Girl Network ecosystem

My thesis project consists of several interconnected parts which operate on a personal network, henceforth referred to as the Magical Girl Network (MGN). Each costume has a wireless module, as does the central sculpture, and each costume reacts to external stimuli (the approach and proximity of people) as well as personal stimuli (when a transformation sequence is triggered by the wearer). The sculpture detects when they initiate the transformation sequence, which then initiates a visual reaction as they 'activate' their individual magical powers. Participants are invited to engage with the magical sculpture through gestures, where their gestures are mirrored by a generative noise animation that disappears into an infinite tunnel, transforming the mirrored surface into a portal. These interactions are all communicated via the MGN through the wireless modules.

3.2 Worldbuilding

In true magical girl fashion, the characters that I came up with exist in a foreign fantasy world in which 'real' magic exists. Within this world, the girls have an intangible, magical connection through which they are able to communicate by 'sensing' each other, and also able to discern if one another needs assistance. This connection is carried out through the MGN. Although they can act independently of each other, they are stronger when united as a team, which is reflected in their magical powers. Independently, they can summon some magic, but together they unite to create a portal of magic, demonstrating the power of the whole over the partial. They have different personalities, which are reflected in their differing appearances and reactions to the presence and approach of others outside of the MGN. These personalities are derived from aspects of my identity, in an artistic take on self-portraiture, and as such I regard them as both fragmented parts of myself and born out of me, as their creator and originator.

3.3 Introducing the Magical Girls

The three magical girls are informally characterized as Lust, Monster, and Disturbance. Although their costumes share visual themes, with matching foundation garments, they are distinguished by differing colorways and potential interactions, which are facilitated by complementary accessories.

3.3.1 Lust

Lust (Fig. 03) is the most obvious 'portrait' of the three characters — she is a visual portrayal of who I am, distilled to a color scheme that I have continuously returned to for the past decade. Her accessory colors are light pink and blue, done in an alternating harlequin pattern, and she has the most subtle but most sensitive potential interaction. When she detects someone approaching, her skirt lights up in tiers from pink to orange, replicating the colored stripes on the lesbian flag. This reflects my approach to my sexuality and the process of coming out, in that I am continually coming out to those who meet me. Although I am much more relaxed about the process now than I was several years ago, it is not always as legible to others as I would expect. The lesbian flag is depicted subtly, and is in general a lesser known queer identity flag compared to the classic rainbow flag. As a result, while I am literally flagging my identity, only those in the in-circle are able to truly understand this secondary layer of meaning beyond the first impression of the blue-and-pink aesthetic.

Figure 03

Two images of Lust, showing her distinctive pink-and-blue color scheme and light-up skirt

Keppo, S. (2021). [A portrait-style photo of Lust in her activated state next to a closeup of details on Lust's skirt] [Photographs].

3.3.2 Monster

Monster refers to my love of the classic queer-monstrous relationship, as well as my love of folklore. Historically, queerness and monstrosity have been portrayed hand-in-hand, and in approaching the creation of Monster, I embraced that relationship rather than shying away from it. I adore the sensation of being slightly out-of-sync with humanity, as it reflects a sense of otherness that I have experienced my entire life, being a minority in multiple ways. This monstrosity manifests in the design as a tangle of moving black and red tendrils dangling down from underneath her skirt (Fig. 04), inspiring the question of whether they are organically bound to Monster's body, or are they mere accessories? Their reactivity adds a life-like animacy, suggesting a biological connection, but they are a distinctly non-human kind of extension of the body, similar to whiskers or a tail. The jingling bells are a gesture at a common element in folklore, in which faint bells in the distance tempt travelers into darker parts of the wilderness where they are then consumed in some fashion, whether through abduction via faerie circles, or by other malevolent spirits. They also inspire a further sense of animacy, as sound often draws attention and amplifies the effect of the moving tendrils.

Figure 04

A portrait of Monster, with visible ropes dangling out of her skirt

Keppo, S. (2021). [A portrait-style photo of Monster in her resting state, a close-up of details] [Photographs].

3.3.3 Disturbance

Disturbance combines several themes emerging from my relationship with the world and people in the form of the most frightening and inhuman of the magical girls. She wears a mirrored mask that disappears to reveal a tunnel of red-illuminated teeth when approached (Fig. 05), and there is a sonic component where a disturbing distortion of sound, input from her surroundings. The sound is iterated back to interactors with increasing volume to the point where it is near-violent in how unpleasant it is to experience, when someone is very near. At a passing experience, it manifests as a form of indistinct noise derived from the amplification of ordinarily inaudible soundwaves. However, if the interactor makes sound through motion or vocalizations, that sound is similarly distorted and echoed back at them. This reflection mocks the interactor through her refusal to communicate her own comments, choosing instead to act as a malevolent mirror to reality, much as her mask acts. Her transformed form, in contrast to Lust's, rejects proximity by very obviously reacting negatively. The tunnel of teeth is a symbol of self-protecting defense mechanisms that I relate to, as a perceived woman in a patriarchal misogynistic society. While many people approach with the best of intentions, there is enough violence in this world that pre-emptive aggression may be used as a defense mechanism before revealing the more welcoming part of my identity.

Figure 05

Disturbance before and after activation, revealing the tunnel of red teeth in her mask

Keppo, S. (2021). [Two photos of Disturbance in her resting and active states] [Photograph].

3.4 Introducing the magical portal

The fourth part of the installation is the physical embodiment of the magic accessible to the magical girls, made tangible through an interactive sculpture that allows interactors to play with the magic as well. It first appears to be a circular pedestal with a mirrored top and an iridescent, flower-like centerpiece (Fig. 06). However, when someone steps close enough to the pedestal, or gestures over the surface, a colorful, programmatically-generated, animation of light initiates opposite of their movements (Fig. 07). Like Disturbance's mask, the mirrored surface disappears when the interaction starts, but instead of a menacing tunnel of teeth, an enchanting ring of lights emerges and sinks into infinity, creating a magic portal. The dreamy patterns of light, combined with a color palette inspired by the aesthetics of Sailor moon and a disappearing/reappearing twinkling star animation calls to mind and reinforces the magical girl aesthetic.

Figure 06

The portal in its inactive state, with a mirrored surface

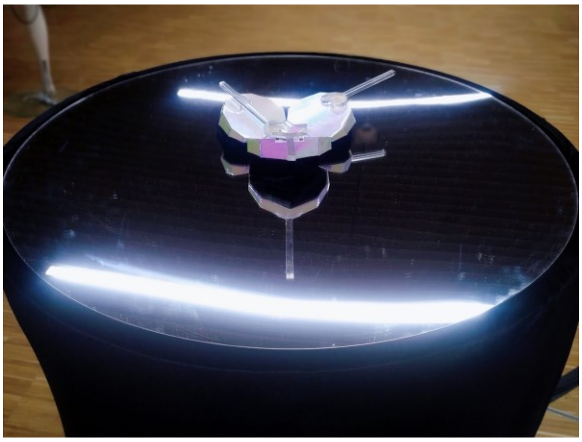
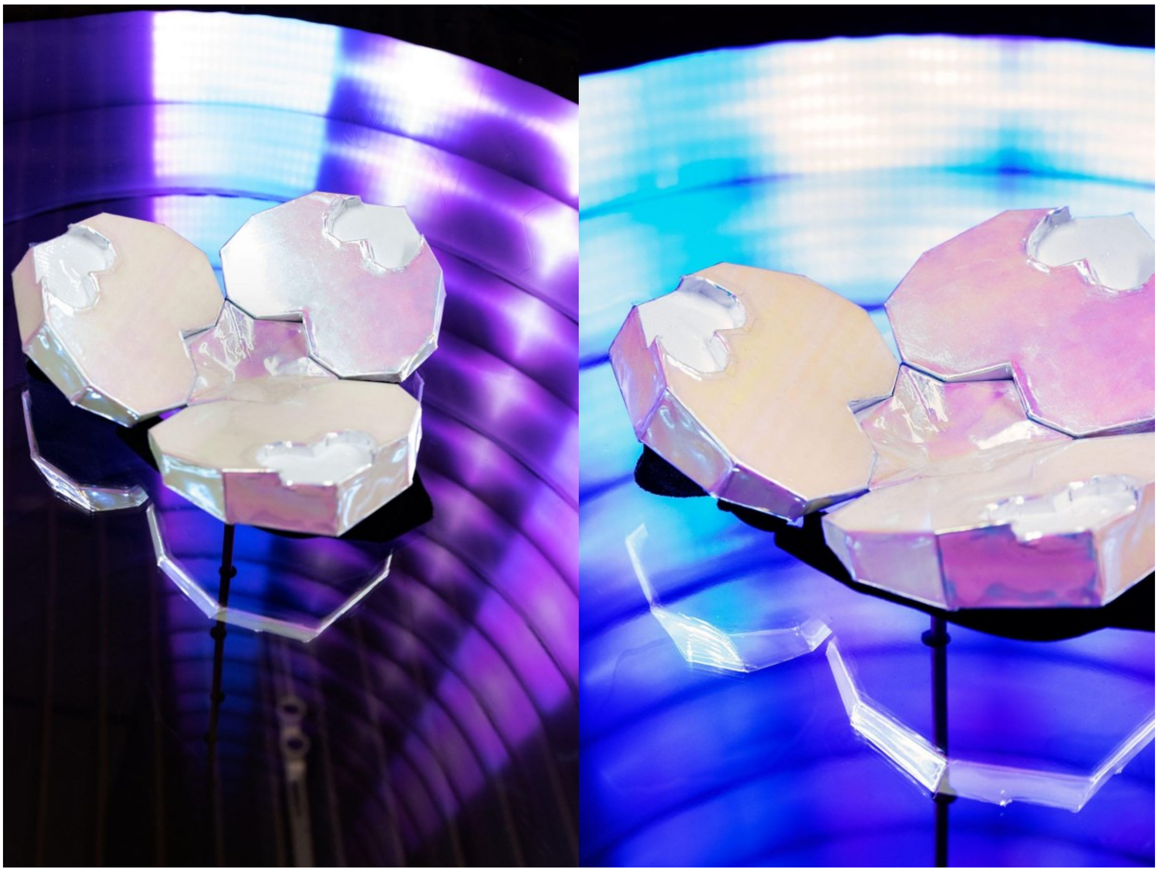


Figure 07

Two photos of the portal in its active state, displaying two different instances of animation



Keppo, S. (2021). [Two photos of interaction with the portal animation] [Photograph].

There was a planned extra interaction, where, when three participants, acting as the three magical girls, took one of the provided wands and slotted them into place in the centerpiece, a special visual effect would occur to reflect the power of uniting their magic. Rather than the patterns of light twinkling into and out of existence, a third of the table would light up with a horizontal 'ring' animation spreading out from the vertical center each time a wand was added. By lighting up a third at a time, it would visually cue participants to try to complete the circle by adding in their own wands. When all three participants had their wands in, a noise pattern, similar to that revealed during the gestural interaction, would be generated but with increasingly randomized parameters. This would have had the effect of referencing the partial magic available with the prior interaction, while enhancing it and adding visual interest, and the variable speed of the movement of the shapes would eventually build to a climax. At the climax, the entire animation would repeatedly fade in and out from view. In addition to the animation visible in the table, the lit-up hearts on the chests of the magical girls would increase in brightness until they too pulsed in tandem with the light of the portal. However, it was removed at the very end of the project due to the lighting conditions of the exhibition space interfering with the interaction. This is detailed more in Chapter 5, where I discuss the implementation of the project.

4 Design

In this chapter, I discuss in detail underlying design decisions which went into the making of the magical girl characters, costumes, and the magical portal. I also overview the functionality of the pieces in more detail than in the previous chapter, but the technological and prototyping details are discussed in the subsequent chapter, Chapter 5: Implementation.

4.1 Magical girl costumes

4.1.1 Designing the aesthetic

As mentioned previously, my visual influences come from the transformed outfits from Sailor Moon (Fig. 08), which themselves are derived from their seifuku (sailor fuku)-style school uniforms, as well as from the general aesthetic trends from other magical girls. These uniforms are depictions of typical girls' junior high uniforms in Japan (Artemis, 2021). The outfits also took inspiration from the Lolita Japanese subculture, which often features doll-like, over-the-top dresses. The 'cupcake' silhouette is directly borrowed from lolita dresses, which utilizes a cage-style hoop skirt to maintain a full, structured, rounded shape, which the ruffle-edged overskirt rests on. The overskirts are made from taffeta, which has a sheen that adds texture and is often used in prom and princess-style costumes. The top is a white spandex bodysuit with a large bow and a heart-shaped gem in the center, which directly references the sailor scout uniforms from Sailor Moon. This design decision was chosen to create a clear reference to a widely known example of magical girls. Frills and ruffles abound in the details, reflecting the hyper-girliness of many magical girl outfits such in Madoka's skirt (Fig. 09). The velvet ribbons on the cage skirts and decorating the gems complement each girl's color scheme, and hides the polyester covering for the plastic bones of the skirt while adding lush richness to the texture of the decorative elements.

Figure 08

Official artwork of the Sailor Scouts in their distinctive uniforms

[Digital artwork of transformed Sailor Moon characters] [Artwork]. Sailor Moon Official Website. http://sailormoon-official.com/

Figure 09

Two examples of visual influences. Left: Madoka from Puella Magi Madoka Magica, Right: lolita style

[Digital artwork of Kaname Madoka's transformation outfit from Puella Magi Madoka Magica] [Artwork]. Zerochan. https://static.zerochan.net/Kaname.Madoka.full.1723307.jpg

[Photograph of a lolita outfit] [Photograph]. Lolita Wardrobe. https://www.lolitawardrobe.com/moonlight-forest-fantasy-castle-open-front-lolita-op-dress_p2813.html

Part of styling the magical girl exhibition also involved giving the mannequins long, full, colorful wigs. This both reflects the 'anime' look of magical girls, where main characters often have vividly colored hair, and also reflects how cosplaying such characters often works: they have otherworldly hair, and so cosplayers use artificial hair to mimic the styles.

I chose to model a low-polygon design for the shape of the central heart to give it a gem-like appearance. The heart truly serves as the 'heart' of the costume, in that it is where a vast majority of the electronics are stored, including the 'brain' and the 'eyes' of the costume. The hearts are covered with iridescent plastic, which is a color choice reflected in the centerpiece of the magical portal, and four-pointed star cutouts mimic the twinkling star animation when the magic is accessed in the portal. A significant part of the design process was oriented around discretion — to create a truly 'magical' effect, I wanted to hide all of the technology, so there was a lot of effort put into concealing wires and components.

4.1.2 Creating the electronic brain

Each element of my project used a version of a Teensy, which is a type of microcontroller used in physical computing to allow users to control electronics through code. The different versions were chosen specifically for each costume as well as the portal, as each had different requirements for processing power and accessory support. While there was some shared code among the costumes, there was also custom code for each one to set up and perform all of the interactions. I designed and milled custom circuit boards for each part of the project, which connected to the Teensys to improve the stability of the circuit and also allowed for miniaturization of the overall electronic components used.

4.1.3 Networked communications

I created a network for communications using wireless modules that operate using radiofrequencies for each part of the project in order to implement the Magical Girl Network. Each part of the ecosystem, including the magic portal, had a discreetly implemented module that allowed all of the parts to communicate with each other. By using these specific wireless modules, I avoided the need for WiFi or Bluetooth connections, as they created an internal infrastructure that effortlessly synced with each other. This removed a dependency that wireless projects often have, and enabled the communications to exist even when these external networks were inaccessible. Thus, the magical connection between the elements of my project could be instantly established and maintained as long as they were powered.

4.1.4 People-sensing versus distance or proximity-sensing

The primary trigger for interaction with the costumes was reacting to what they ‘saw’. I gave the costumes the sense of ‘sight’ by using heat-detecting, thermal cameras to detect living beings approaching, so that they could react accordingly. I considered other types of sensors, which could measure proximity (whether something is within a specific range of distance) or distance (how far or close something is); however, I chose to use thermal cameras to extend the worldbuilding aspect of my project. Thermal cameras allowed the costumes to differentiate between warm, living beings rather than objects, replicating the ability for the actual magical girls to visually differentiate what they saw.

4.1.5 Haptic sensing

Similarly to my past project, Flung Out of Space, I used vibration motors integrated into harnesses that rested against the wearer’s sternum to create a private haptic interaction between the wearer and the (wearable) costume. This materialized a physical output from the networked communications aspect of the project, enabling wearers to experience the invisible, electronic data as if they themselves possessed the magical ability to mentally tap into the Magical Girl Network. The information that was transmitted through the motors conveyed whether the other magical girls were transforming or in distress, allowing a visceral awareness of the state of the other magical girls through the costume. Each girl has her own vibration motor and vibration patterns, so the wearer could differentiate between who was sending the signal. The patterns were derived from morse code — SOS (...---...) meant that both of the other girls were in distress, while individually they were L(ust) (.-..), M(onster) (--), and D(isturbance) (-..).

4.1.6 Transforming

Each costume had a 'transformation sequence', which outwardly translated to the costumes reacting in their most extreme manner (all lights lit, rapid movements, loud sonic reactivity). To trigger this sequence, wearers could cross their wrists over their chest and the costumes would react accordingly. This specific gesture is inspired by other magical girl transformation sequences, which usually involve striking a pose to initiate the process. I attached reed switches, which are a type of sensor that detects magnets, to the inside front of the heart gem, and paired them with simple fabric cuff bracelets that matched the fabrics used in the rest of the costumes. The bracelets had magnets embedded in the inner wrist area, so when the crossed-wrists gesture was performed, the magnets in the bracelets would set off the magnetic switch inside of the heart gems.

I chose to use magnets in creating this simple type of gesture recognition because this allowed the bracelets to be 'passive' devices — they had no electronics inside, and therefore did not need batteries or a controller to function. This allowed the bracelets to be streamlined and appear to be simple fabric bracelets, rather than part of the electronics, and made the electronic connection invisible and thereby more 'magical'. This interaction only worked when the costume was acting as a wearable, as mannequins cannot move, and so was inaccessible when they were displayed as installation pieces.

4.2 Magical portal

4.2.1 Aesthetic goals

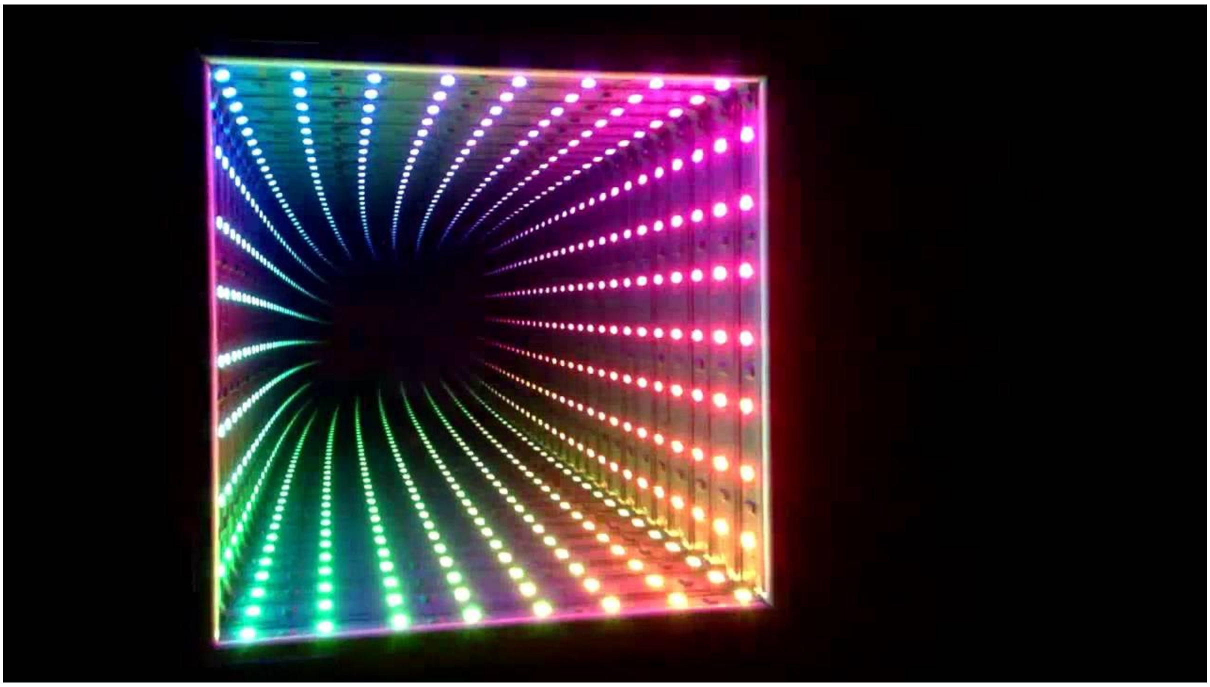
The portal was originally meant to be a wall-mounted piece — a large mirrored wall that, when stood in front of, detected arm movements and reacted by activating LEDs in the shape of a circle to create the effect of opening a void. Over time, the piece transitioned from a vertical surface to a horizontal surface, for a variety of reasons. The overall goal was always to create a transforming mirror that revealed an internal portal through infinity when interacted with, as initial user tests revealed that this simple interaction was very enchanting to people. However, the complexity of the animation, size, and construction increased significantly as I found inspiration from Aidan Lincoln Fowler and his installation "Infinite Reflections" — "an art installation consisting of the first video infinity mirrors in existence" (https://www.aidanlincoln.com/infinite-reflections). The use of black velvet around the portal served to both obscure the housings for the electronics and also added a space-like dark richness in contrast to the mirrored surface and emergent lights.

4.2.2 Designing the portal

I started the design process with a technical goal — I wanted to make an interactive infinity mirror. Infinity mirrors utilize a two-way mirror paired with lights and a one-way mirror to create the illusion of a tunnel leading into an infinite void (Fig. 10).

Figure 10

An example of a classic infinity mirror



Tim Southerton. (2013, March 11). Dreamcolor RGB LED Infinity Mirror [Video]. YouTube. https://www.youtube.com/watch?v=8XaDgpnTyAg

Usually, infinity mirrors are non-reactive, although they may feature interesting animations. I hoped to breathe life into a static installation by adding interactivity, which would also differentiate it from the many infinity mirrors which I had seen. I found the infinity effect beautiful, and had used it in previous projects, but I was also unimpressed with the trick because I considered the technical implementation to be trivially simple and overdone, although it was still dazzling to the public at large. As a primary motivation for the creation of this part of the installation was to generate a sense of joy, awe, and enchantment through 'touching magic' in the interactors, I struggled with the feeling that there were two major groups of interactors that would experience my work: people who were familiar with this technological trick, and people who weren't. For people who weren't familiar with infinity mirrors, I suspected it would be easier to spark these emotions for them, as the interaction potentials constituted novel experiences — this 'new media' installation was truly very new indeed. For the people who were familiar though, I was concerned about them being as unimpressed as I felt.

To combat this concern, I added interaction potentials in the form of motion sensors, which could be triggered by people gesturing over the portal. I wanted the sensors to be discreet and component-based, without relying on the use of Kinects or other forms of computer vision. This was due to a personal preference of mine to exclude computers from my artistic works, opting to use microcontrollers instead, as well as my having minimal experience with computer vision. This also preserved the integrity of the portal as an enclosed project that required no setup aside from providing it with power. To maintain the seamlessly smooth surface of the mirror, I wanted to hide the sensors behind the two-way mirror, which proved to be an interesting technical challenge. Distance sensors, for detecting when an object passed over them, relied on tools such as ultrasonic waves or infrared light, which could not pass through the mirror. I eventually used Light Dependent Resistors (LDRs), which are sensitive to changes in light even under the two-way mirror. This enabled me to detect the shadow of movements over the surface of the portal, thereby giving me the invisibly activated interactivity that I was aiming for.

I chose to multiply the amount of LEDs I was using by seven so I could create significantly more complex animations than on regular infinity mirrors, which have one layer of LEDs. This was inspired by "Infinite Reflections" (Fig. 11), a project which used high-resolution LED screens with 32 layers of LEDS to form video-based infinity mirrors.

Figure 11

One of A. Fowler's video infinity mirrors

Fowler, A. (2021). Tunnel Mirror [Photograph] Aidan Lincoln. https://www.aidanlincoln.com/infinite-reflections

I took inspiration for his innovative use of multidimensional LED screens to improve my own design. Where he used LED matrices to form video panels, I chose to keep mine at a much lower resolution of seven long strips of LEDs, to form a seven layer deep infinity mirror. Instead of streaming video content, I created animated patterns inspired by the magical girl aesthetic present throughout this project. Specifically, I took three main colors from the Sailor Moon anime: pink, yellow, and blue, as well as the twinkling stars present in the backgrounds of her transformation sequences, and used them as the basis for a generative noise pattern that 'twinkled' in and out of visibility in response to direct interaction. While the increase in complexity significantly affected the fabrication effort needed, it also added nuance that helped differentiate the portal from other infinity mirrors.

4.2.3 Designing the centerpiece

The centerpiece went through several design changes — originally, it was meant to be a separate part of the installation. Comprising four pedestals, it would have been a cooperative installation that required four interactors to simultaneously touch the four pedestals to trigger a light-based reaction in the room. However, in the interest of simplifying the scope of my thesis, this interaction was merged with the portal in form and function to add a secondary layer of interaction to the experience.

The design of the centerpiece references the low-polygon design of the heart gems, as well as their iridescent covering and there being three magical girls, and therefore three places to put wands. The three 'petals' of the centerpiece had small heart shapes indented into the outer edges, colored in white, which perfectly fit the tops of the wands that participants were provided with (Fig. 12). They were also tilted upwards to be more inviting for participants to place their wands in from a standing position. The bottoms of the petals were covered with black velvet: adding to visual cohesivity with the outside of the portal while conveniently concealing the otherwise exposed electronics inside each petal.

Figure 12

The iridescent centerpiece with wands inserted

Keppo, S. (2021). [A photo of the centerpiece with two out of three wands inserted into their designated positions] [Photograph].

The wands themselves were transparent, with iridescent plastic covering the heart-shaped top. As a result, when the wands were placed within the designated slots, they visually completed the appearance of the petals. The decision to use clear acrylic for the wands rather than white acrylic was due to user testing, as the unanimous position was that the clear wands were preferable, as their transparency added a jewel-like effect to the end of the wand. Unfortunately, this design decision eventually led to the discontinuation of this interactive aspect of the portal due to technical issues. While the decision was confirmed through positive results when running tests, the lighting conditions at the exhibit were too different from those in the testing environment, and so the sensors had difficulty detecting the transparent wands.

5 Implementation

The implementation chapter details the fabrication process, which invoked much of my background in creating physical computing projects as well as my background in constructing cosplays. I also go over more technical details, including the components used and the decisions made in choosing them, as well as some of the code design.

5.1 Magical girl costumes — soft fabrication

The patterns for the costumes were hand-drafted and sewn using a quilting machine as well as a sewing machine. I used past bodysuits I had made as a template for the white bodysuits; however, a lot of the pattern was newly drafted, as the hemlines and fabric requirements were different from past projects. As the bodysuit was made of white spandex, they were semi-transparent, so it was important to line the front of the suit, which also smoothed out the shape. The harness inside the suit was also a new design to me — it was made out of pink elastic that was sewn into the side seams of the suit, and only in the front half instead of wrapping around the ribs as per a typical body harness to prevent any visible lines across the back of the outfit. The bows were an interesting variation on a standard bow, as there needed to be an empty area in the center where the heart gem could sit flush to the bodysuit. A hole was cut under the gem to allow wires to pass between the gem and the inside of the suit. As a result, each side of the bow is a separate, interfaced piece.

The overskirts were also hand-drafted, and guided by a pattern by Kitty Kanzashi[2]. Each skirt was 280 cm wide at the top and pleated into a 71 cm waistband using box pleats — a reduction of 3.9:1. The ruffles were hand-gathered by my assistants, Katie Ballinger and Natalie Eliassen, and I, from 12 m into a 330 cm hem — a reduction of approximately 3.6:1. I made the decision to use very large reductions, combined with the semi-stiff polyester taffeta fabric, to create structure and volume in the finished skirt (Fig. 13). This was to emulate the dramatic shape of magical girl outfits, and the choice of a satin-finish fabric was to emulate the styling and fabric choices of princess dresses, such as those found at Disney World.

Figure 13

Drafting the overskirt, the final overskirt for Monster

[2] https://kittykanzashi.blogspot.com/2014/03/making-dress-bird-parade-lolita.html

The base for the cage skirts are ready-made and customized with fabric, ribbons, and decorations along with interactive embellishments so each one was custom to its corresponding magical girl character (Fig. 14). Lust's skirt was filled with large roses made from bubble wrap, as a diffusive surface against which the LEDs could bounce, while Disturbance's skirt featured shiny silver ribbon, coordinating with the mirrored surface of her mask. Monster's skirt was the most significant effort, as it involved hand-sewing hand-painted foam ropes into the interior of the skirt, some of which were mounted on custom attachments for the motors. The visible part of the outside of the cage structure was covered with velvet ribbon, which also was ruffled around the edges of the heart gems, which added more lush texture to an already grandiose outfit.

Figure 14

The three different skirts: Lust, Disturbance, and Monster

5.2 Magical girl costumes — prototyping and iterating

The three costumes shared similar base technology — a Teensy, magnetic switches, vibration motors, LEDs, wireless modules, and thermal cameras. However, each costume was personalized according to its interactive reactions, which were developed over four months of prototyping. Certain familiarity with physical computing and microcontrollers has been assumed for this section, as a more high-level summary can be found in Chapter 4.

From past experience with physical computing, I chose to begin the fabrication of the costumes with a focus on the electronic design and implementation. This was to ensure that I had a fully working ecosystem before I designed parts such as the case, to avoid consequences from incorrect assumptions failing me after I had already fabricated to accommodate the used electronics. This proved to be very important, as over several iterations I changed which active components were used and thereby what size and shape requirements were needed from the final design. See Fig. 15.

Figure 15

List of key components

Component	Lust	Monster	Disturbance
Grid-EYE AMG8833 thermal camera	X	X	X
WS2812b LEDs	X	X	X
Pancake vibration motor	X	X	X
nrf24L01+ wireless module	X	X	X
Reed magnetic switch	X	X	X
Stretch sensor	X	X	-
74AHCT125 level shifter	X	-	X
Audio Adaptor Boards for Teensy 3.x	-	-	X
Speaker	-	-	X
Omnidirectional microphone	-	-	X
Audio amplifier	-	-	X
A4988 Stepper Motor Driver Carrier	-	X	-
Stepper motor — bipolar, 48 steps	-	X	-

5.2.1 Networking

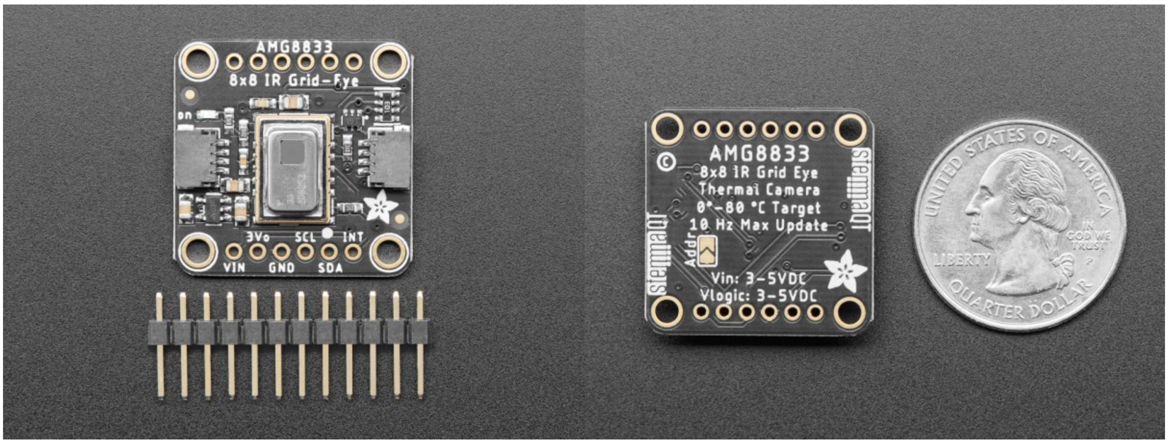
While I had used nrf24L01+ wireless modules before, I had not used them with the complexity that I was planning for this project, so I focused first on this most unfamiliar part of the system. I built three independent circuits that used Arduino Unos, combined with Light Dependent Resistors (LDRs) as the sensors and WS2812b LEDs as indicators for when data was successfully transmitted between the Arduinos. With the way that the modules sent data, I chose to create structs which contained several values, so I could transmit the ID of which sensor was being activated as well as the value of the sensor and other data. Data is transmitted using a preset rate of transmission (how many bytes per second) and a preset channel that is shared by all of the transmitters. Within the channel, there are READ and WRITE pipes, which allow the module to send and receive data.[3]

5.2.2 People detection

The criteria for people detection had two parts: a reasonably accurate ability to detect people approaching and a discreet form-factor. I performed distance and proximity measurement experiments using a HC-SR04 ultrasonic sensor, a Time-of-Flight sensor, and a Passive Infrared Sensor (PIR sensor), but found all dissatisfactory, due to unstable or inaccurate readings and difficult to conceal hardware. I eventually moved to using heat detection via a thermal camera — the Grid-EYE AMG88xx series of 8x8 pixel resolution thermal cameras, which came in a very small form factor and various breakout boards[4], all of which I considered reasonably-sized enough to conceal (Fig. 16). The Grid-EYE also supported the worldbuilding aspect of the costumes. The magical girl characters would be responding to living beings, not moving objects, and so being able to differentiate using the sensors allowed the costumes to more closely emulate the 'sight' of the characters.

Figure 16

The front and back of Adafruit's Grid-Eye breakout board, next to a U.S. quarter coin for scale



[Two photographs of Adafruit's AMG8833 Grid-Eye breakout board] [Photograph]. Adafruit. https://www.adafruit.com/product/3538

The Grid-EYE camera provided an 8x8 array of temperature measurements, ranging from 0°C to 80°C, and I was able to calibrate the code to detect people (and other living or particularly warm things) by first averaging out the temperature readings from an empty room and then comparing that to the current temperature of the room to see if

[3] https://tutorial45.com/arduino-with-nrf24l01/

[4] I used three different breakout boards due to availability, but the code is identical across the boards:
Sparkfun: https://www.sparkfun.com/products/14607
Adafruit: https://www.adafruit.com/product/3538
Grove: https://www.seeedstudio.com/Grove-Infrared-Temperature-Sensor-Array-AMG8833.html

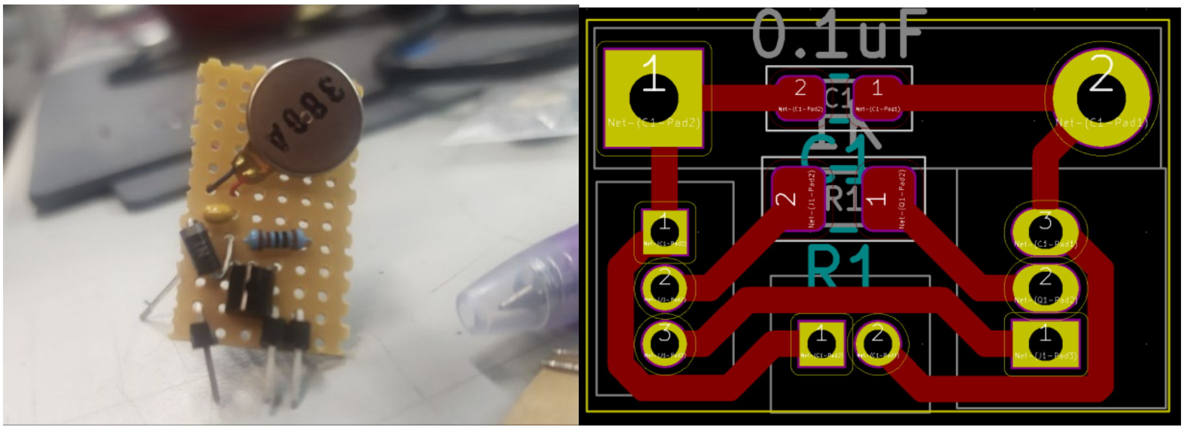
it the current room had enough heat in it to suggest the presence of people. I set a threshold of 1.5°C, so if the room was 22°C, the person-detection-threshold would be 23.5°C. This value was chosen after testing in both the lab room and in the exhibition space, as external factors such as clothing and lights and sun in windows all affected the readings, so 1.5°C was determined to be responsive enough. Because the Grid-EYE provided a grid of readings, I could then count how many pixels were warmer than the threshold value and extrapolate a general sense of person density within 'sight' of any given camera. The values from counting the warm pixels were then compared against custom, predetermined thresholds in the code to scale the level and type of reactivity that the costume would perform in response to people approaching or gathering nearby.

5.2.3 Haptic feedback

I integrated haptic feedback by attaching a pancake vibration motor to an elastic harness to the inside of each costume. The harness held the motor against the sternum of the wearer, so vibration patterns could be easily detected and discerned from each other. I have used this circuit before for my Flung Out of Space project, so I was familiar with it and miniaturized it for the purpose of this project (Fig. 17).

Figure 17

Left: the initial prototype of the vibration circuit, made on protoboard. Right: the schematic for the miniaturized vibration circuit



5.2.4 Gesture detection

To detect when the wearers performed the 'transformation' action (crossing their wrists in front of the heart gem), I embedded flat disc magnets into fabric bracelets to act as passive triggers. I glued an arrangement of three reed sensors, which are magnetic switches, to the front inside wall of the heart to act as the target sensor pad. By placing three reed switches in parallel with each other, I was able to create a larger sensing area, approximately 35x35mm, rather than the 26x12mm area that would result from using one reed switch.

5.2.5 Lust-specific technology

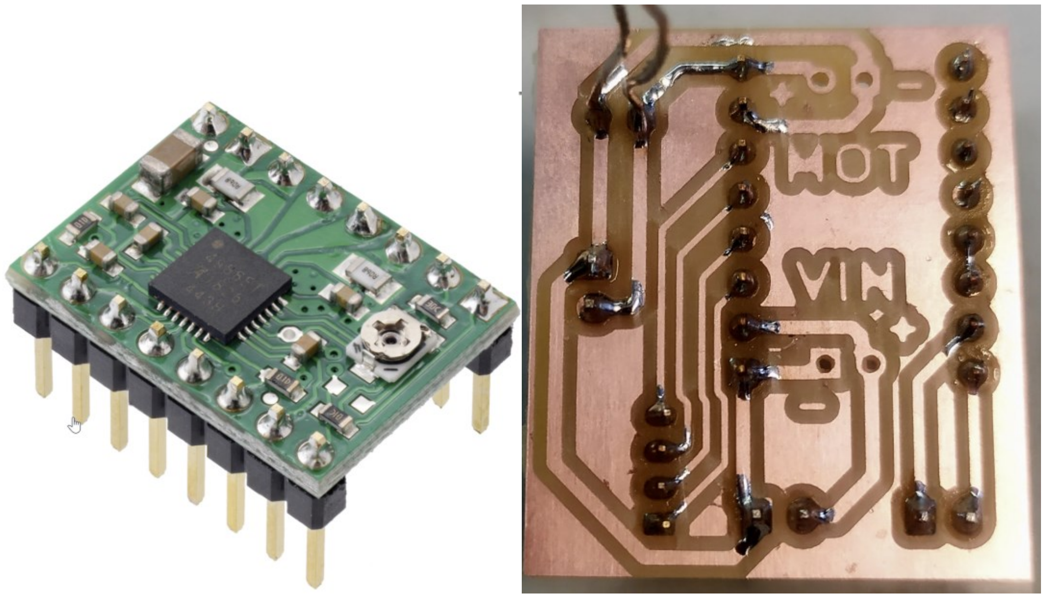
Lust's reaction utilized four strips of WS2812b LEDs wired in series to form one long strip, which was then sewn onto the inside of the four horizontal hoops in her cage skirt. A gentle diffusion effect was achieved by folding the excess fabric over the LEDs. The majority of the hand sewing was done by Natalie Eliassen, one of my assistants. Lust used a Teensy LC, which is a 3.3v board but has one pin for driving LEDs on a 5v logic level, paired with a logic-level shifter to provide 5v on another pin for driving the skirt LEDs.

5.2.6 Monster-specific technology

Monster's reaction involved the use of bipolar stepper motors in conjunction with custom mounts to connect foam ropes and threads of jingle bells to the motion of the motors. Monster's base was a Teensy LC. To drive the two motors, I used two A4988 Stepper Motor Driver Carriers[5], which I attached to two custom PCBs (Fig. 18). Although I tried Silent-Step-Sticks[6] as drivers, I found them unnecessarily complicated and the motors were inaudible inside the skirt so I opted for the more common A4988 drivers.

Figure 18

Left: A4988 Stepper Motor Driver Carrier. Right: The custom-designed board for interfacing the A4988 drivers with the rest of Monster's electronics



5.2.7 Disturbance-specific technology

Disturbance's reactions were the most complex to fabricate — the mask required extra LEDs, which necessitated adding a separate logic-level shifter to the circuit, while the audio required a special Audio shield for the Teensy 3.2, an audio amplifier board, a microphone, and a speaker. Working with the audio shield was difficult for me, as I

[5] https://www.pololu.com/product/1182

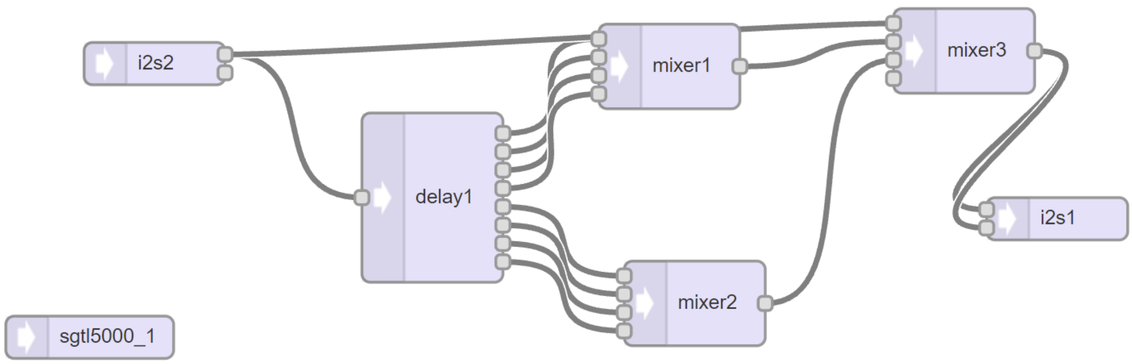
[6] https://learn.watterott.com/silentstepstick/

had very little experience working with audio, but I was able to use the Audio System Design Tool's graphical interface (Fig. 19) to manipulate the audio coming from the microphone. Preventing feedback was very difficult, as the microphone I used was omnidirectional and the speaker relatively nearby, but I eventually solved it with a combination of delay commands and a function that scaled the volume according to a person's proximity. This enabled the volume to cut off when the person stepped back in response to hearing the beginning of feedback, so it could never fully play through the characteristically painful squeal of feedback.

When I moved the circuit from a protoboard to a custom PCB, I discovered a strange humming sound that radiated from the speaker, regardless of microphone input. After consulting with my advisor, Matti, we concluded that it was probably due to the noisiness of the electrical signal for sending data to the LEDs, and so I put some capacitors in the circuit and accepted what remained as part of the system.

Figure 19

The graphical diagram of the circuit in the Teensy Audio System Design Tool



https://www.pjrc.com/teensy/gui/index.html?info=AudioControlSGTL5000

5.2.8 Physical fabrication challenges

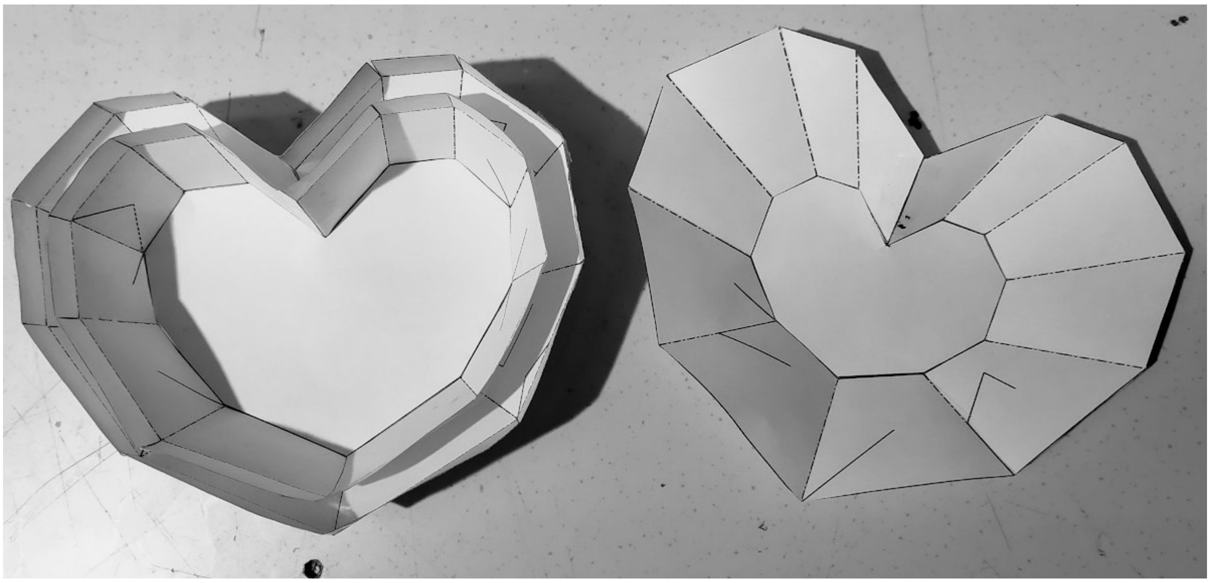
Following the magical girl aesthetic, I designed a gem-like heart-shaped container for housing the electronics that were located outside of the skirt, to sit on the chest as a decoration for the bow. These included the Teensys and their respective PCBs, as well as the thermal camera. As the camera needed a hole to look through, I included four-pointed star cutouts in the front of the design, similar to the star animations in the portal. I used Autodesk Fusion 360, a Compter-Aided Design software, to make 3D models of the container. The models went through multiple iterations, both during design and during physical fabrication, where I added elements such as support for heat-set thread inserts[7] so the parts could be connected by screws, or changed dimensions to better accommodate the PCBs and electronics for each costume.

[7] https://markforged.com/resources/blog/heat-set-inserts

After my initial design was made, I used Pepakura Designer, a software I had familiarity with from using it in past projects, to unfold the model into a 2D net. I then cut and assembled the paper prototype (Fig. 20) — a simple, fast method of testing the dimensions of low-poly 3D models, that yielded less material and time waste than if I had 3D-printed every iteration of my model.

Figure 20

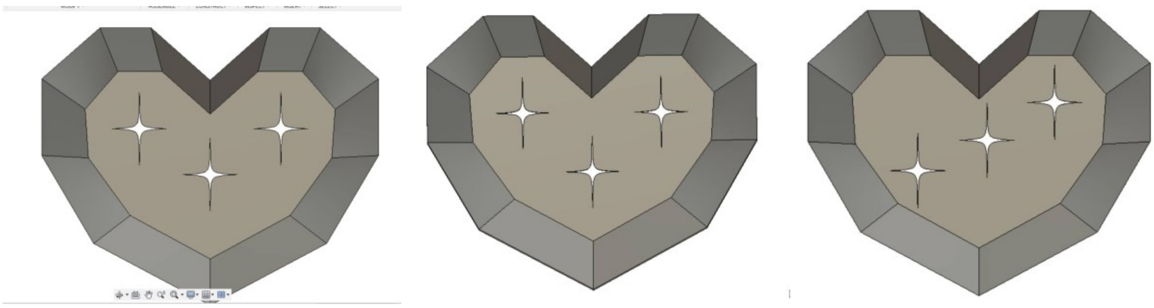
A paper model of the first iteration of the heart case



I made multiple versions of the front of the heart and gathered opinions from friends and coworkers (Fig. 21). The first design won out, with comments on how it evoked the suggestion of a face, perhaps containing the 'real' soul of the costumes.

Figure 21

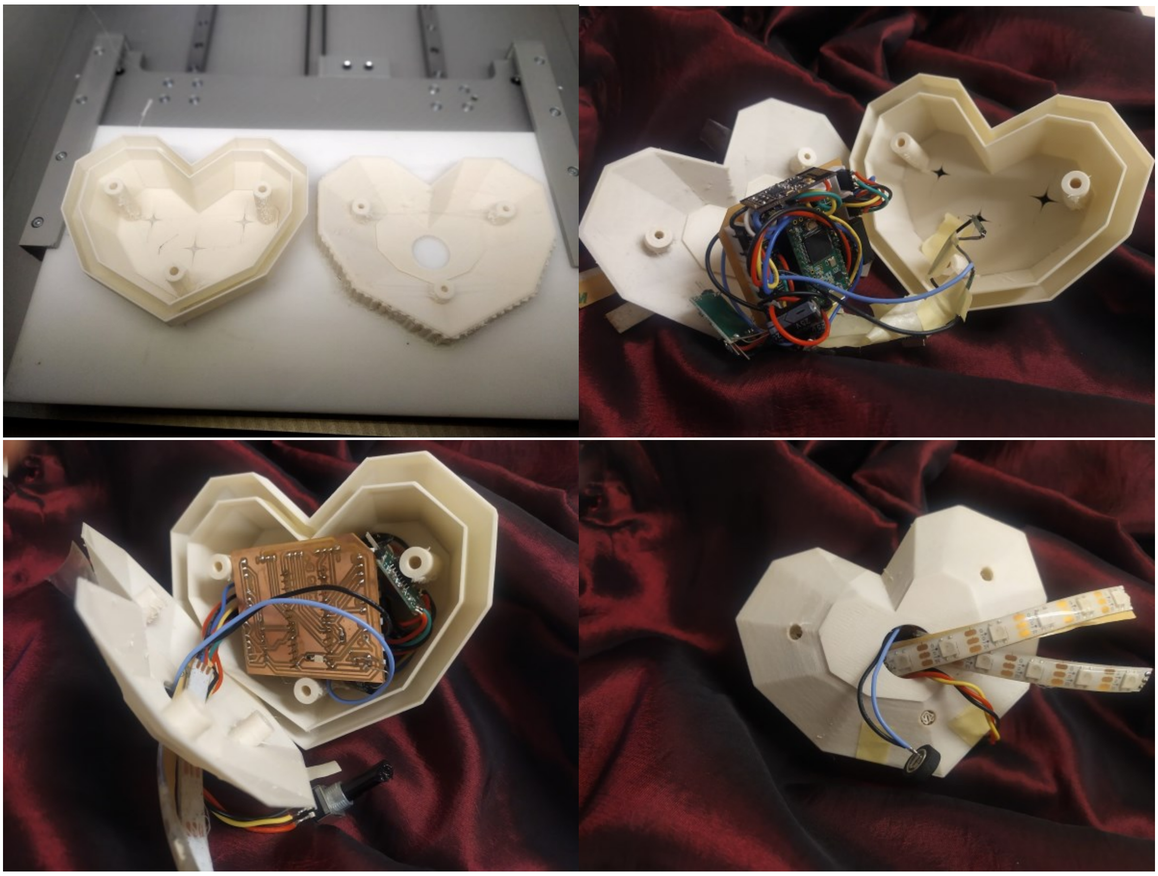
Three potential designs; the first design was chosen after gathered feedback



Multiple iterations of the heart had to be printed to perfect the sizing to accommodate all of the electronics and to improve structural stability (Fig. 22).

Figure 22

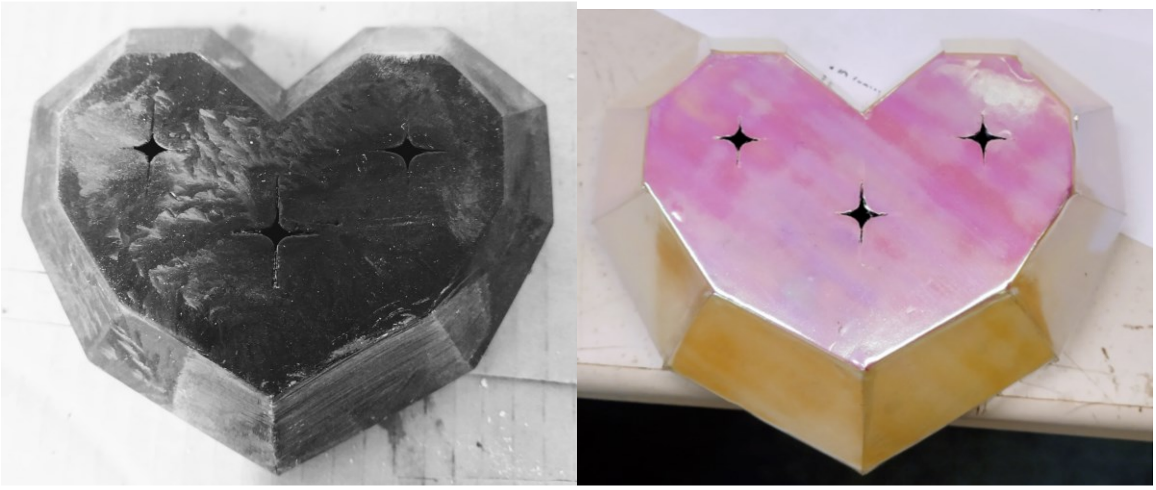
First 3D print of the heart container and testing the fit of Disturbance's PCB and electronics inside



When working with the actual 3D models, I experienced significant problems with the lines of layers ever-present in Fused Deposition Modeling (FDM) 3D printers. To smooth out the surface of the models, I tried sanding, coating in wood filler and sanding, and eventually settled on covering them with an iridescent vinyl, which helped hide the lines (Fig. 23). Given a future iteration, I would consider printing them using a resin 3D printer, which does not create the lines that FDM printers do.

Figure 23

Testing various ways of finishing the surface of the hearts. The following two images are of when I tried painting it them black and added a 'frost' finish with a special spray paint, and then the final trial using an iridescent vinyl cover



5.3 Magical portal

The first version of the portal was intended to be a wall-like installation piece. Over time and testing, it was rotated to be parallel with the floor, but the underlying planned interaction was always the same. Interactors would gesture on top or in front of a two-way mirrored surface, which would reactively turn on LEDs following the gesture that were hidden behind the mirror, revealing an infinity mirror, portal-like effect. By setting up an unexpected interaction, I aimed to invoke the sense of enchantment that I associated with creating a magical moment.

5.3.1 Iteration 1 - proof of concept

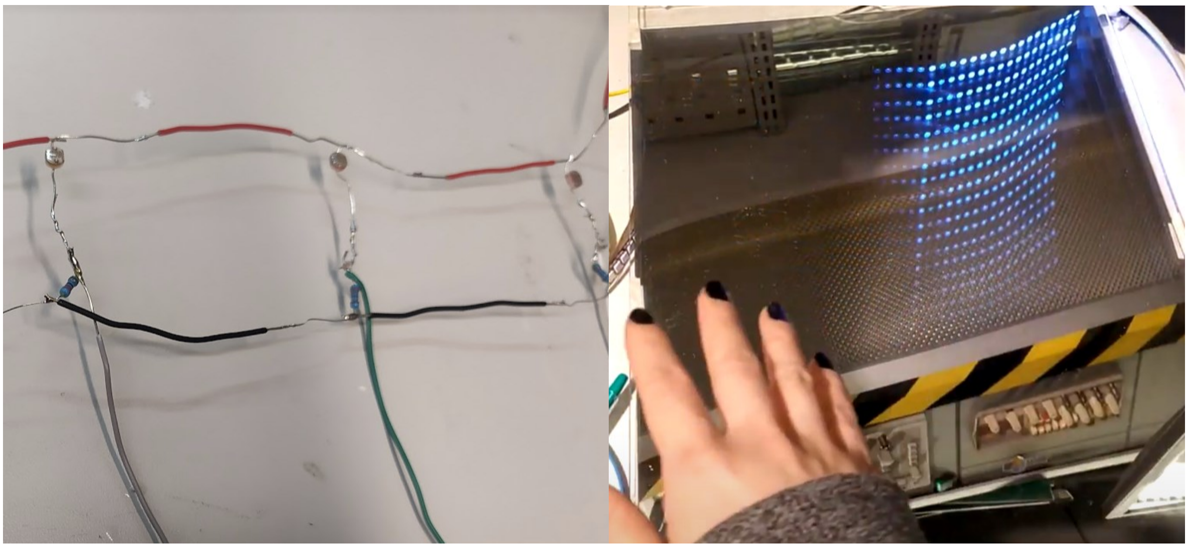
Iteration 1 focused on feasibility — were Light Dependent Resistors (LDRs) able to sense movement through two layers of two-way mirror? The original design had the LDRs under the two layers of the entire mirror setup instead of under one layer, which was a challenge for the other movement-related sensors that I tried as the mirrored or acrylic surface interfered with the relevant types of waves that they relied on. To my surprise, the LDRs were sensitive enough, although of course when I later moved to a one-layer mirror setup, their readings were much more reliable. I was able to program an addressable LED strip to light up responsively following hand movements over the concealed LDRs — thereby making a successful proof-of-concept for the basic electronic mechanism that the portal was based on (Fig. 24).

During the testing for iteration 1, I found out that my plan for having the mirrored surface be a wall and perpendicular to the floor was not feasible. This is due to how shadows are cast differently when light is adjacent to a surface versus when the light is shining down on a surface — when on a wall, the shadows are cast at a downwards angle, so the one-to-one accuracy of LEDs to LDRs was not possible. When the light was pointing down over the surface, it cast shadows directly under the hands, so the relationship between where the LDRs were sensing and where the corresponding LEDs were was aligned. A solution could have been to have a light installed across from the wall, so it would cast a shadow directly behind the interactor and therefore their gestures; however, I opted instead to rotate the portal as I did not want the added complexity of having to set up an additional light source wherever the portal would be exhibited. By making the portal self-contained, I hoped to make setup and portability easier, as well as to conceal the mechanism behind the 'magic' as much as possible.

Similarly, I chose to not use a Kinect or other type of technology for using computer vision (CV) to detect gestures. This was both a practical choice, as I had very little experience with CV and would have needed to learn a whole new type of new media technology, and also would have needed additional equipment and setup requirements, and also a conceptual choice, as again I felt it would reduce the immersiveness to have a Kinect or other device visible. This decision also reduced the complexity of the system, as LDRs worked well with using just microcontrollers that I was familiar with, instead of having to network communications between some kind of computer and a microcontroller.

Figure 24

Left: A prototype of the voltage divider circuit used when using LDRs; Right: A prototype of syncing LEDs with hand movements over the LDRs under an infinity mirror setup



5.3.2 Iteration 2 - initial prototyping

Iteration 2 was dedicated to prototyping the portal in miniature. I made a 10cm diameter 3D model in Autodesk Fusion 360 of a proposed structure for the portal and then 3D printed it in white PLA (Fig. 25). I also designed the first iteration of the PCBs for the LDRs, with connection points so I could chain them together (Fig. 26). Most importantly, I switched from using an Arduino Uno for prototyping to a Teensy 3.5. The

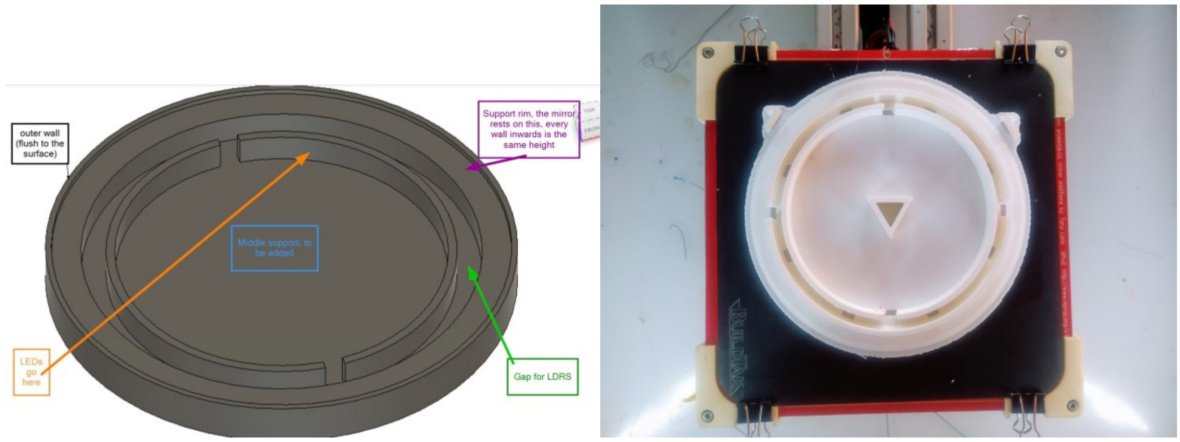
Teensy 3.5 was chosen because it was compatible with the OctoWS2811 Adaptor[8], which is a special board that attaches to the Teensy to enable it to control thousands of LEDs in a more efficient manner than how a basic Teensy would be able to by utilizing eight pins to send data simultaneously, rather than using only one pin. The Teensy 3.5 also has the most analog input pins of all of the Teensys, at 27 inputs compatible with measuring LDR readings, which was important for the original design of the portal which had as many LDRs as possible, to improve the resolution of sensing.

The original design for the portal was 1.2 meters in diameter. This dimension was due to material availability - the two-way mirror acrylic was initially planned to be sourced from China, as I could not find a supplier in the EU that fit in my budget. Therefore, I was limited to the sizes readily available using AliExpress, with 600mm x 1200mm being the maximum size. I planned to use two sheets to form a 1200mm diameter circle, which would then have a center seam, so I reflected this design decision when I laser-cut the acrylic mirrors for the prototypes. A central object was also added to the design because of this segmentation, so that the two sheets could be stabilized and rest on something in the center.

In later discussions, I was able to receive funding from Design Factory to order a 3mm thick, 1220mm x 2440mm large sheet of two-way mirror acrylic from Etra, a Finnish plastics supplier. This then removed the need for a center seam, which was aesthetically much more pleasing than with the seam. The total size of the portal also changed over time.

Figure 25

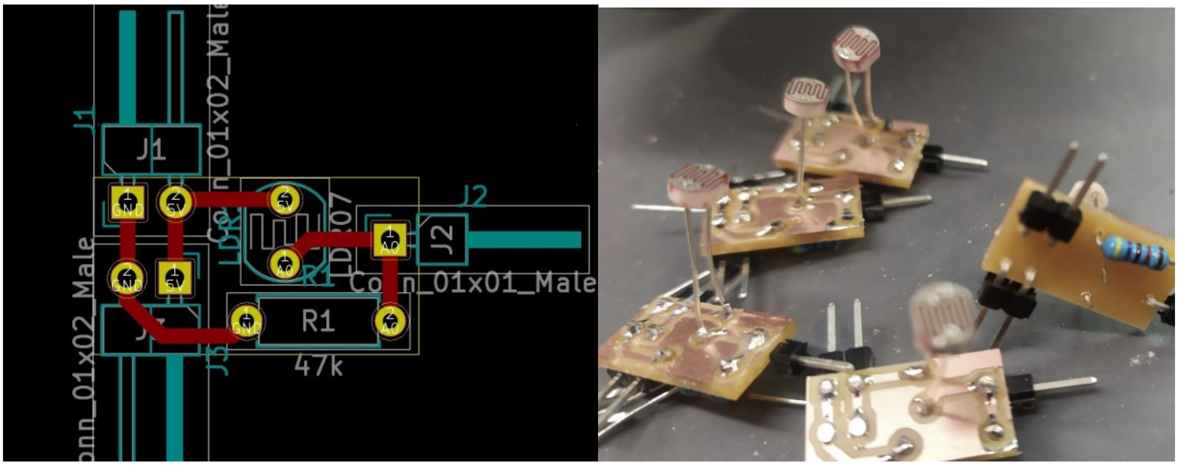
Left: a draft of the 3D model used for printing the portal. Right: the first printed prototype, 10cm



[8] https://www.pjrc.com/store/octo28_adaptor.html

Figure 26

Left: the PCB design of the LDR breakout boards. Right: the milled and assembled PCBs

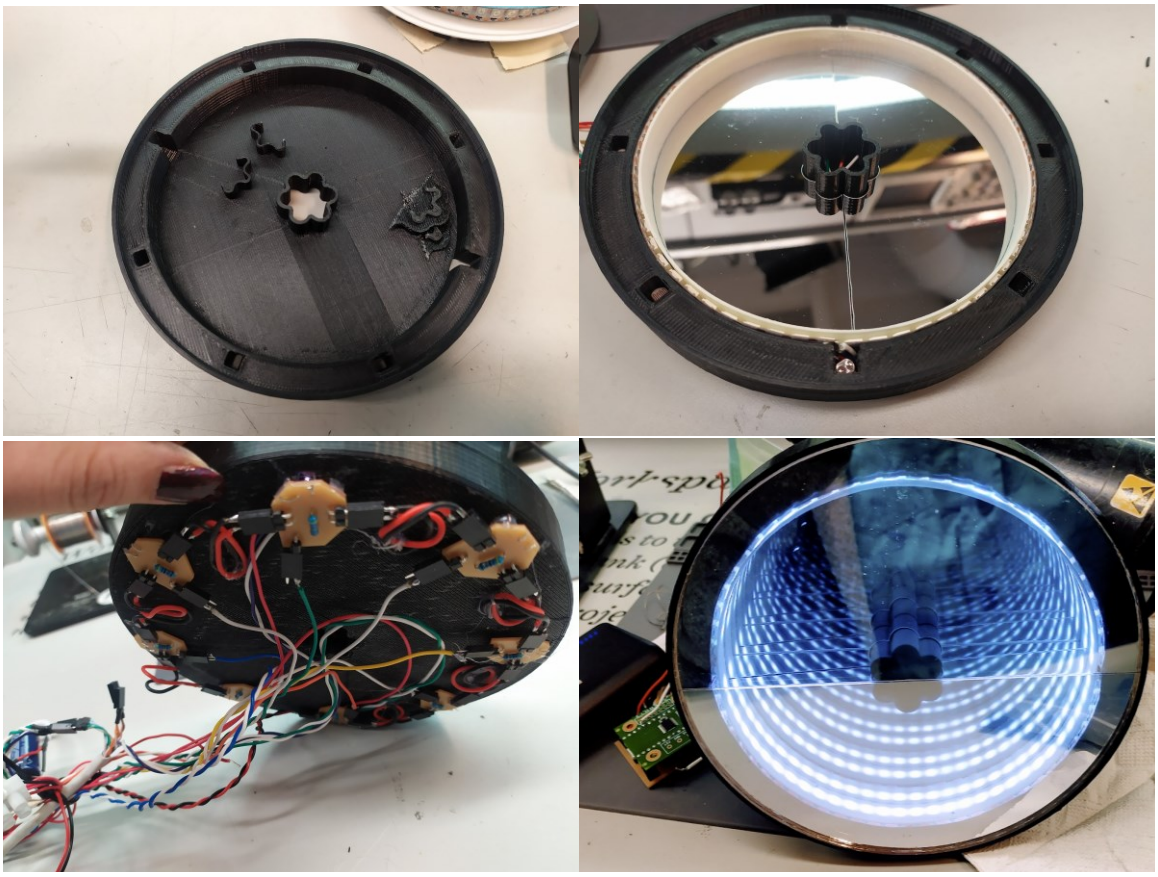


5.3.3 Iteration 3 - prototyping round two

Iteration 3 was a direct revision of iteration 2 to test potential improvements to the overall structure. The 16cm version featured many improvements on the 10cm version, the most important of which was creating deep, walled holes within which the LDRs were nestled. The high walls prevented the light from activated LEDs shining on the sensors, which was previously affecting the responsiveness of the sensors, and using black plastic instead of white which also improved the absorption of errant lightwaves (Fig. 27). I used iteration 3 for most of my future tests as the LDR sensing setup, even when I shifted from using the LEDs in the structure to using separate, external LED strips.

Figure 27

Four photographs of the construction details and activated appearance of the second prototype, 16cm in diameter, black PLA



5.3.4 Iteration 4 - multiplying the LEDs

Iteration 4 reflected a significant increase in complexity and depth of interaction for the portal. As mentioned earlier, I took inspiration from Aidan Fowler’s use of LED screens in creating infinity mirrors, and decided to use seven strips of LEDs instead of the single strip I was using earlier. Seven strips was chosen as the ‘height’ of my portal because it neatly fit within the native support on the OctoWS2811 Adaptor for eight strips, and I planned to make an animation that would be easier to code and more aesthetically pleasing if rendered on an odd number of strips. I connected seven strips of 72 LEDs to the adaptor for the majority of the time spent prototyping the code, and connected this makeshift 7x72 LED panel to the sensors on iteration 3, the 16cm diameter portal.

I experimented primarily with two methods of adding animation to the panel (Fig. xx). First, I tried using a Processing sketch, which is a software implementation of the Processing coding language[9], combined with a Raspberry Pi to stream videos, reduced to a seven-pixel tall resolution. This was an exercise in learning how to use a Raspberry

[9] https://processing.org/

Pi, discovering unexpected hardware and software conflicts, and traversing obscure questions on forums in an attempt to solve the conflicts. I ended up having to switch from a Raspberry Pi 4B, which is the latest version of the Raspberry Pi microcontroller[10] that I chose to maximize processing speed, to a Raspberry Pi 3B+ because a fundamental way of processing videos was changed in the upgrade from 3B+ to 4B, which made running the Processing program work incorrectly. When I finally had all of the parts working: the Arduino IDE, Teensyduino IDE, Processing IDE with support for video, changes in configuration files for the Raspberry Pi, and communication between the Raspberry Pi and Teensy microcontroller, I experimented with short video clips downloaded from YouTube[11].

Although the effect of compressing the video down to seven pixels in height yielded interesting animations, I decided to instead use generative patterns created using the Teensy directly, instead of maintaining the connection and reliance on the Raspberry Pi. As with many of my decisions during this project, this was decided to reduce complexity and improve stability — having an entire miniature computer added to the existing ecosystem would have added another potential point of failure. I also was unsure of how to decide which videos would be appropriate for compression and display, how to manipulate them to create endless animation possibilities, and how to manage proper crediting of creators.

The second method of creating animations was rooted in a tutorial on LED Programming with Arduino & FastLED[12], which covered how to use the Perlin noise generator in FastLED (a library for programming addressable LED strips)[13] and how to map the pattern on two-dimensional LED matrices. Perlin noise is an algorithm used to generate a pseudo-random sequence of numbers. Rather than using a purely random sequence, using the Perlin noise function smooths out jumpiness between values and is often used to generate organic shapes, such as cloud patterns (https://natureofcode.com/book/introduction/). In Figure 28, a Perlin noise sequence of numbers is graphed in comparison to a random sequence of numbers, demonstrating the difference in how values are determined between the two types of sequences.

[10] https://www.raspberrypi.com/products/

[11] https://www.youtube.com/watch?v=N_Z8-HVXGGo, https://www.youtube.com/watch?v=ye0IuAZgy50

[12] https://hackaday.io/course/174150-led-programming-with-arduino-fastled

[13] https://github.com/FastLED/FastLED/wiki/

Figure 28

Two graphs comparing Perlin noise (left) versus Random (right) number generating algorithms

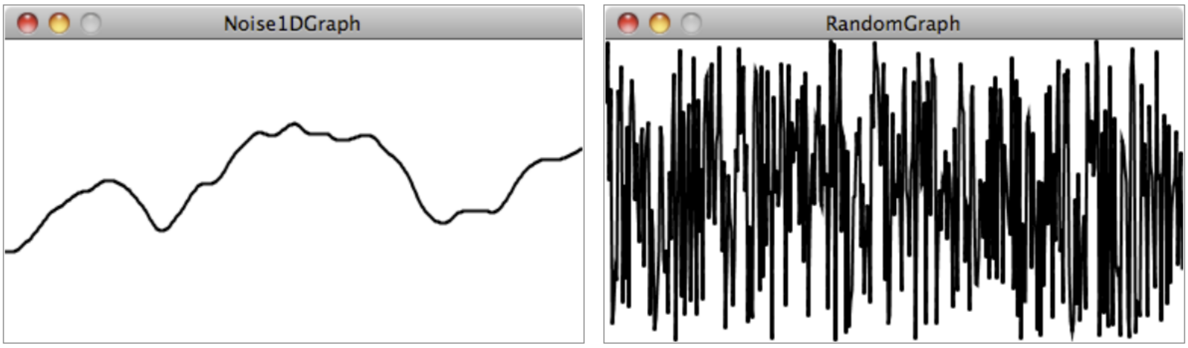


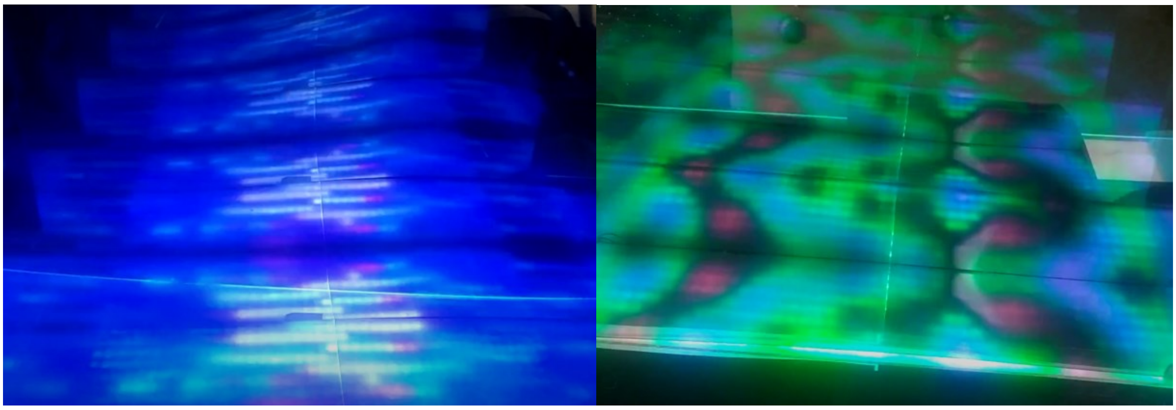
Figure I.5: Noise Figure I.6: Random

Daniel Shiffman. (2012). The Nature of Code: I.6 Perlin Noise (A Smoother Approach) [Graph]. The Nature of Code. https://natureofcode.com/book/introduction/

By adapting Hackaday's tutorial to my own code, I was able to experiment with using Perlin noise as a means of generating animation, which I found more visually pleasing than using pre-made animations (Fig. 29). The generative nature of the animation also meant that I did not need to concern myself with repetition, which furthered the concept of 'creating magic' that I intended for the portal — visitors would never experience a 'loop', so their experience was truly unique to them and their interactions.

Figure 29

Two photos of animation tests: on the left, a compressed video of Sailor Moon transformations that was processed on the Raspberry Pi 3B+ and streamed to the OctoWS2811 board; on the right, a Perlin noise pattern generated on the Teensy 3.5



I created a 'twinkling star' responsive animation to be applied on top of the existing noise pattern, which masked and controlled which parts of the pattern were revealed in any given moment. The stars were four-pointed, referring to the twinkling stars from the Sailor Moon transformation sequence, and the color palette for the noise pattern was also derived from three main colors from the Sailor Moon aesthetic — pink, yellow, and blue. The star animation function relied on a complex algorithm that I came up with to calculate brightness values for each pixel and manipulate them in conjunction with a lifespan function, which determined the speed at which the stars would fade in and out. The brightness values would then be blended with the colors of the underlying noise pattern, creating animation both through the stars revealing and concealing the pattern and through the organic, ever-changing pattern of generated Perlin noise, applied to a predetermined color palette.

5.3.5 Iteration 5 - finalizing electronics

Iteration 5 was the final iteration of the electronic side of the portal project. I upgraded the microcontroller from a Teensy 3.5 to a Teensy 4.1, which is faster, has more flash memory and more RAM, and generally is a more powerful microcontroller. I added a PSRAM chip as well to expand the available RAM by 8 MB. These upgrades were because I noticed a conspicuous slowing of the animation frame rate as I increased the amount of LEDs — I suspect that my code was too resource-heavy for the 3.5, as it worked speedily after the upgrade.

However, the upgrade reduced the available number of analog pins from 27 to 18, meaning I could detect up to 18 LDRs if I had no other analog sensors. Due to some changes in the physical dimensions of the portal, the number of LDRs and LEDs were reduced from 25 LDRs and 2975 LEDs to 18+3 LDRs and 2394 LEDs, which would be more than I would be able to detect using the available pins. To solve this analog pin shortage, I used a SparkFun Analog/Digital MUX Breakout - CD74HC4067[14], which contains a 16-channel multiplexer; essentially, I was able to read 16 different analog readings while using only four digital pins and one analog pin. By using this multiplexer, I was able to expand the amount of LDRs that I could use and also have extra pins for other analog components, such as a potentiometer.

I redesigned the schematic of the LDR PCBs to be a different shape and also to have a surface mounted resistor instead of a through-hole, to reduce the height profile of the PCB. The new design also had 2-pin JST receptacle connectors for Power/Ground, Ground/Power, and Ground/Signal. I made six custom-length Cat 6 cables crimped on one end with RJ-45 connectors[15] (commonly used for Ethernet cables) and split into four twisted pairs of wires, each of which was terminated by the 2-pin JST header connector that could connect to the receptacle connectors on the LDR PCBs. I chose to use Cat 6 cables for connecting the LDRs to the main PCB (and therefore to the Teensy 4.1, to be processed) because they could be used for up to four Signal/Ground connections, and the way that the twisted wires were physically intertwined reduced potential noise and crosstalk in the transmitted data[16].

The final main PCB (Fig. 30) supported connections to: a Teensy 4.1, an NRF24L01+PA+LNA Wireless Module (a larger version of the nrf24L01+ wireless

[14] https://www.sparkfun.com/products/9056
[15] https://www.wikihow.com/Crimp-Rj45
[16] https://electronics.stackexchange.com/questions/221642/using-ethernet-cables-cable-for-sensor-wiring

modules located in each costume, with amplified power and an antenna for improved signal transmittance)[17], RX/TX for Serial communication to the centerpiece's Pro Mini controller (retired due to a later change in what components were being used in conjunction with the centerpiece's sensors), a potentiometer (used for adjusting the sensitivity of the sensors), the Sparkfun CD74HC4067 breakout board, and six Ethernet jacks, as well as multiple power connectors. Due to the complexity of designing the PCB, I opted to make it a double-sided PCB and have the 'top' side, where the majority of the components would sit, act as a 'Ground plane'. A ground plane is generally "a large area of metal connected to the circuit ground" for a variety of reasons, including to reduce electrical noise (The PCB Ground Plane and How It Is Used in Your Design, n.d.). This simplified the circuit by permitting me to place PCB rivets throughout the design that acted as Plated Through Holes (PTH) that could connect an existing trace to Ground.

There was much trial and error in discovering which settings were needed to create adequate holes for the rivets to fit in, while also creating adequately large pads for them to be soldered to. In KiCad, I discovered that the following settings worked best for the rivets available:

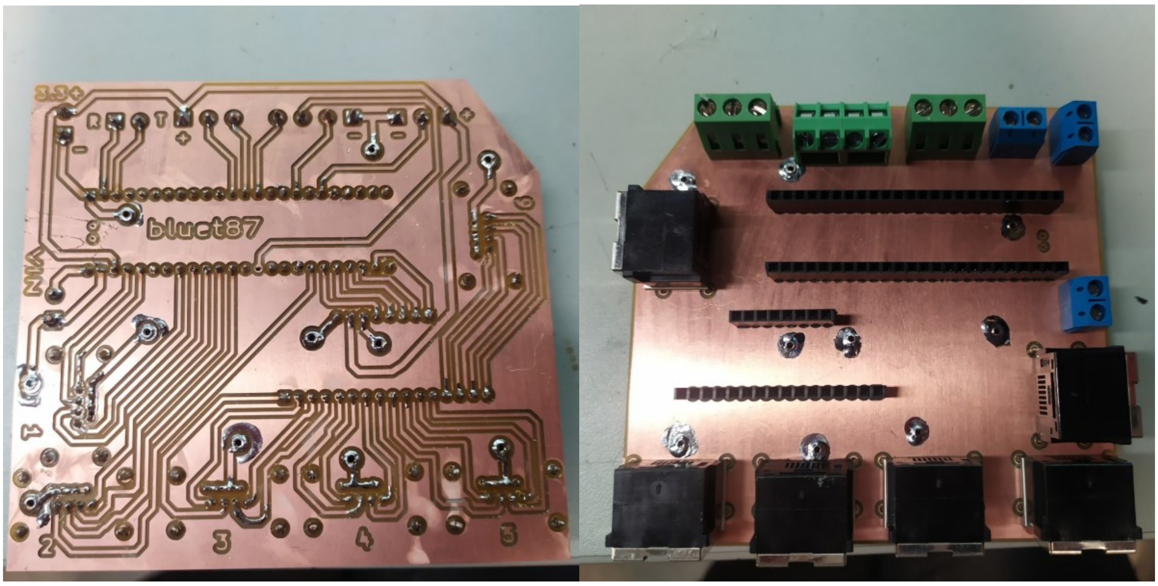
Rivet Outer Diameter (OD)	**Via Size**	**Via Drill**
1.5mm	3.4mm	1.7mm
0.8mm	2.0mm	1.0mm

[17] https://www.elecrow.com/nrf24l01palna-wireless-module-1100-meters-p-556.html

Figure 30

Left: The 'bottom' side of the final PCB for the portal, where all of the traces are visible. Labels for determining polarity and component placement have been engraved throughout the design, and my instagram username, bluet87 is prominently featured as a signature. Each Ethernet jack has a designated number, 1-6, to reduce mistakes when connecting the LDRs to the PCB. The silver-colored donut-like holes are one side of the PCB rivets.

Right: The 'top' side of the final PCB, where all of the screw terminals and headers for connecting to components are located. The silver-colored patches are the other side of the PCB rivets, connecting them directly to the large copper coating on this side that served as the 'Ground' plane

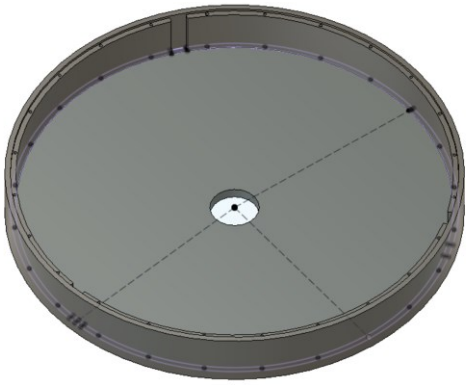


5.3.6 Iteration 6 - building the portal

Iteration 6 is the final iteration of the making of the portal, in which it was transformed from a network of electrical components into a physical structure. I built the portal with the assistance of Petteri Haverinen, a coworker at Aalto Design Factory and a student at Aalto University, and Katie Ballinger, a first-year New Media student. The original construction plan was to CNC an 84-centimeter-diameter circular structure (Fig. 31), very similar in design to the miniature 3D-printed prototypes that I made in earlier iterations. This size was determined by evaluating potential configurations for the star animation, and settling on 24 sections of 15 LEDs each, controlled by 24 LDRs. This determined the size of the table, as its inner circumference encompassed precisely 360 LEDs, or 2.5 meters of material. After adding the space for sensors and support outside of the LED circle, the table was determined to be 84 cm in diameter, and to contain 2,520 LEDs total. It would have two parts - an upper layer, where all of the LEDs and acrylic layers rested, and a layer underneath that would conceal all of the electronics such as the sensors, PCB, and power supply. However, the actual construction process deviated significantly from the plan both in methods and in design due to extenuating circumstances.

Figure 31

The initial 3D model of the top layer of the portal — there are holes embedded in high walls for the LDRs, and there is a wide support wall for the seven strips of LEDs



Construction:

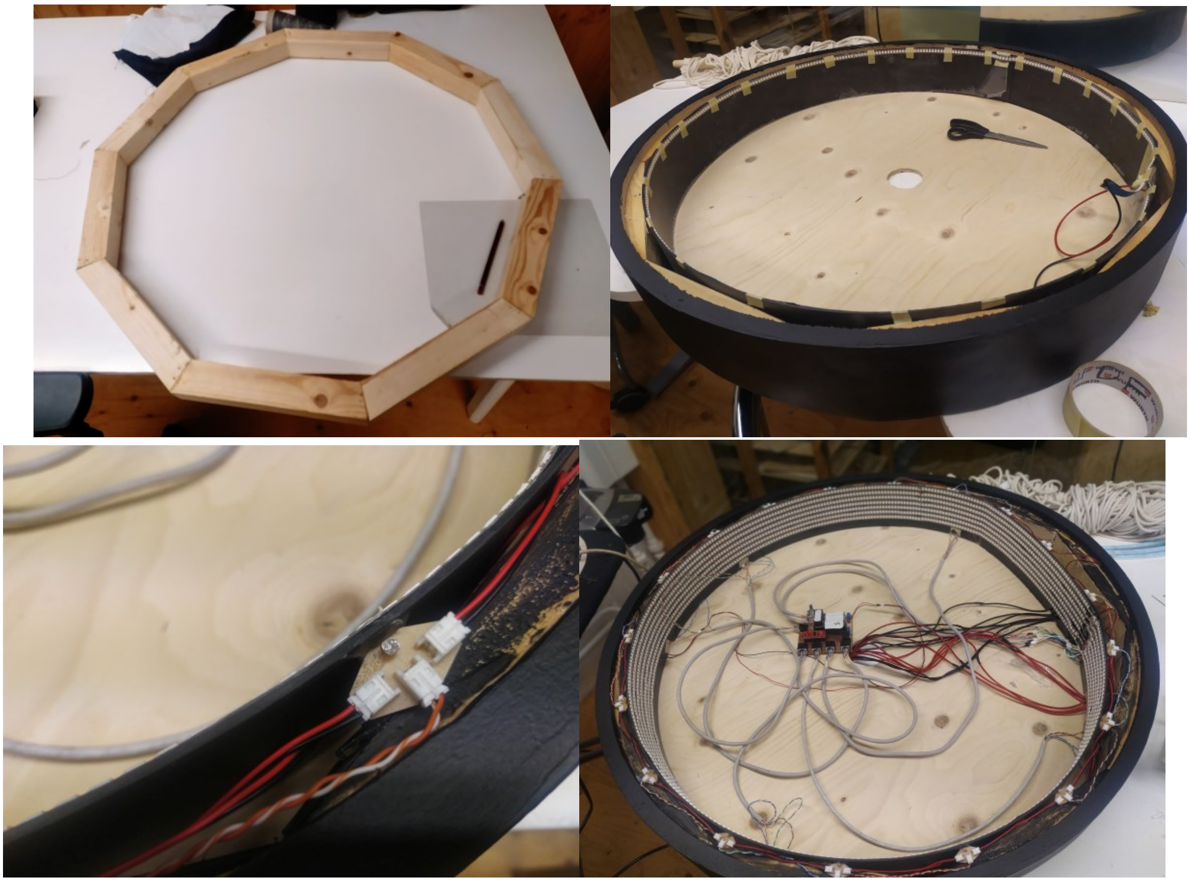
Due to a miscommunication regarding when the wooden part of the structure was needed, the CNC-driven method of fabrication had to be put aside. Instead, Petteri cut and nailed together ten segments of wood, roughly in the shape of a regular decagon (10-sided), and then carved and sanded off the majority of the segmentation on the outside so as to make the outside of the portal circular. It was then covered in wood filler, sanded, and painted black. A large 2mm thick strip of flexible black plastic was cut to size to act as the backing for the LEDs, wrapped around the inside rim, and glued in place (Fig. 32). The basic structure of the portal was changed to keep the majority of the wired connections and LDR PCBs within the main structure, hidden in a secret chamber underneath the base mirror plate.

An infinity mirror is constructed by layering a single-way mirror, LEDs, and a two-way mirror, with the two-way mirror being the surface or top of the apparatus. We constructed the height of the portal to therefore accommodate not only the top protective layer of clear acrylic (2mm), the first two-way mirror acrylic (3mm), the seven rows of LEDs (84mm), and the second two-way mirror acrylic (3mm), but also to harbor a space between the bottom of the structure and the bottom mirror. In this space, all of the cables leading to the LDR PCBs and to the LEDs for data and power/ground were stored and routed through a hole in the base. The cables were then connected to the main PCB and the power supply, which were supported in a plastic basket that we sprayed black and attached to the bottom of the portal by using heat-set insets (the same type used in the heart containers).

Instead of the LDR PCBs being mounted underneath the structure, with the LDRs pointing upwards through vertical channels in the walls, they were moved to be suspended immediately adjacent to the top of the LED wall, on the other side of the LEDs. The signal/ground wires were clustered in groups of four sets and routed through notches in the bottom of the LED wall.

Figure 32

Left: One of the base decagons. Right: The base of the portal after building, with black LED support strip taped inside. Bottom left: A closeup of an LDR PCB which was hot-glued to the top outside of the black LED support strip. Bottom right: All of the LED strips have been glued in. The Cat 6 cables for transmitting LDR data are all connected to the main PCB, as are the Cat 6 cables to the OctoWS2811 adaptor for controlling the LEDs.



Powering the LEDs:

As detailed in the seminal “Adafruit NeoPixel Überguide” (Adafruit NeoPixel Überguide, n.d.), in the section “Powering Neopixels”, users are advised to estimate the LEDs to consume 60mA at maximum, but closer to 20mA in regular usage (that is, not at full white at maximum brightness). Using these numbers, I was able to estimate power needs for the LEDs to be between 50.4A-151.2A — much higher than any other project that I had done before. For perspective, a standard phone charger provides 2-3A. Therefore, I had to use a switching power supply instead of my usual portable power banks, which I traditionally used in my wearable projects. The size of the portal was reduced over the course of construction, from 24 sets of LEDs (360 LEDs/strip) to 18 sets of 19 LEDs (342 LEDs/strip), and I reduced the maximum power requirements estimate to approximately 32A. The reduction was accomplished by reducing the total number of LEDs used and by limiting the maximum brightness setting from a potential value of 255 to a more modest 145. This number was determined through testing and comparing brightness settings versus desired aesthetic effect. Due to the way that human eyes perceive the brightness from the LEDs, we perceive brightness non-linearly in comparison to the coded value. This conveniently supports using a lower brightness value, combined with gamma correction, to create a perceived brightness much brighter than the numerical brightness (Sipping Power With NeoPixels, n.d.). In addition to these changes, I limited power consumption through the code by using colors and animations which had variable levels of brightness.

Figure 33

Initial testing of connections, as well as the impromptu use of a soldering iron for tricky repairs. During testing, the protective film was left on the sheets of acrylic, so much of the test results were muted and blurry.

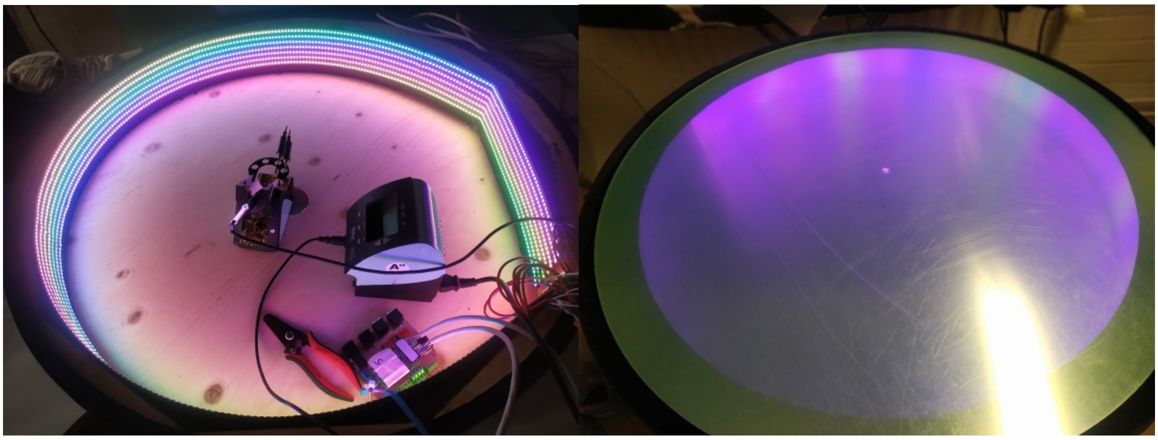


Figure 34

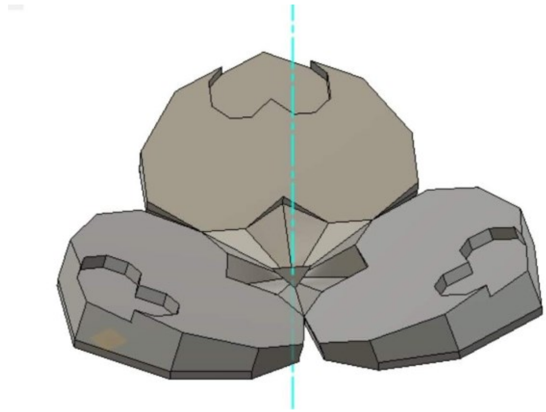
The portal after the protective film was removed, when inactive and active

5.3.7 Iteration 7 - building the centerpiece

Iteration 6.2 covers the complete fabrication of the centerpiece, which was a structure initially included in the design of the portal to add a complex interaction potential. The plan was for there to be laser-cut, vinyl-decorated small wands that visitors would receive upon entering the exhibit, which could be placed into the centerpiece as a way to trigger a new animation in the portal. While it was fully fabricated and integrated into the electronic system of the portal, it was eventually disabled and rendered inert due to unexpected difficulties with the exhibition setup, as well as for time limit reasons. Similarly to the construction of the heart gems, the centerpiece was first modeled as a four-part low-polygon structure, composed of three flat hearts with smaller heart-shaped cutouts and a geometric shape in the center. The design for the hearts was modified from the model of the heart gems, as were the cutouts (Fig. 35). The hearts were modeled at an angle for a more ergonomic interaction. The parts were all 3D printed in white PLA, covered in hand-cut white vinyl to cover layer lines, and then covered in iridescent vinyl, like the heart gems. The wands were laser-cut from 6mm transparent acrylic — initial testing showed significant preference for transparent acrylic versus white acrylic — and decorated with a vinyl-cutter cut heart, also made from the iridescent vinyl.

Figure 35

The 3D model of the centerpiece, next to a fully decorated heart from the centerpiece, with a version of the transparent wand



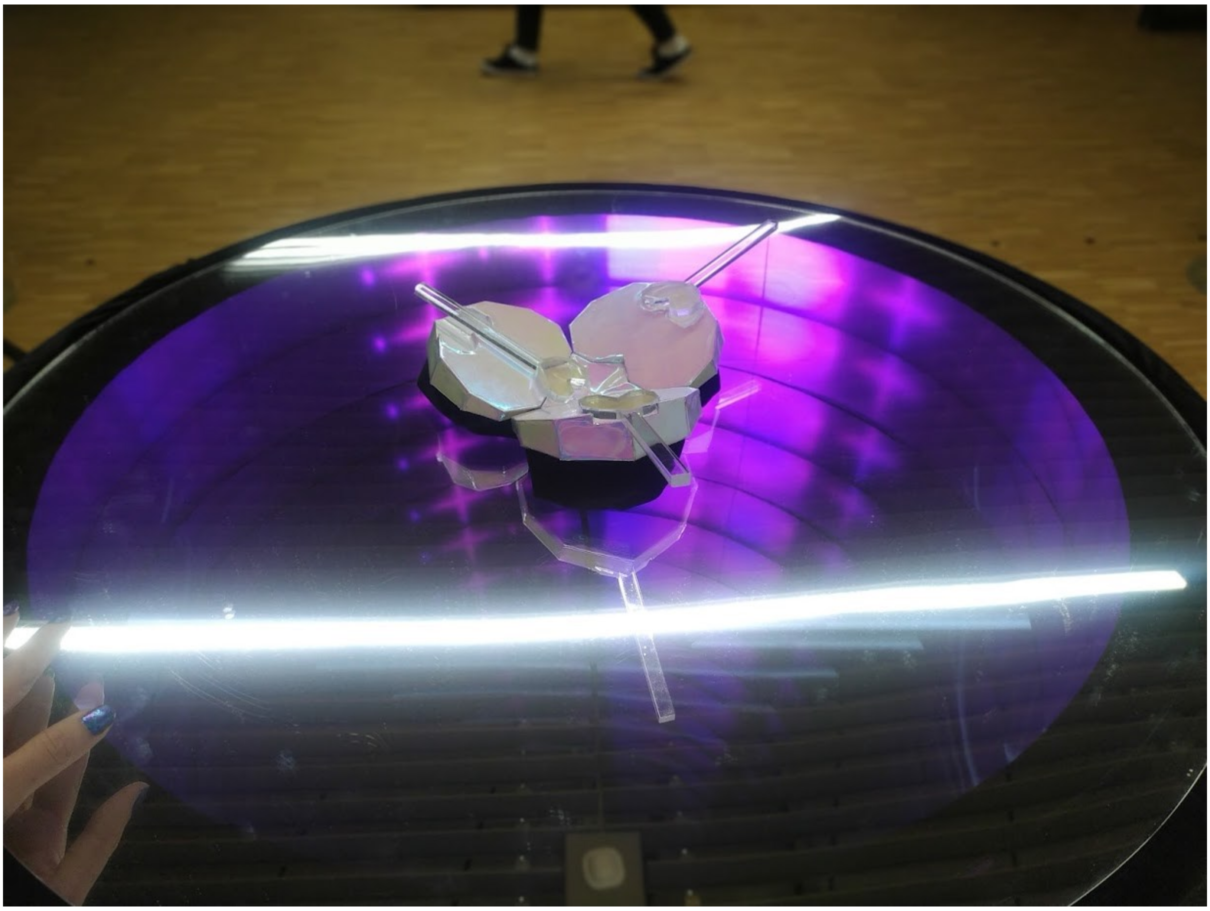
The electronics for the centerpiece was based around using LDRs to ‘see’ through the white vinyl heart slots, to detect when the wands were placed down. I facilitated this by cutting a hole for the LDR in the plastic base, and then covering it with the white vinyl. Testing was performed to determine if the wands could be detected, as I was concerned that, because they are tinted but otherwise transparent, they would not block enough light to be sensed by the LDRs. I detected small changes of 5-10 in the readings, on a scale of 0-1023, but it was enough to be detectable. I added a filter to prevent the centerpiece from being triggered when a larger shadow was cast (e.g. if someone moved their arm over the centerpiece) so it would only react to the placement of the wands. As the wands are transparent, it is near-impossible to make them ‘active’ parts of the interaction — magnets or RFID tags cannot be concealed. This made for a much more delicate electronic setup, but had the potential for creating a more ‘magical’ experience, as there was no obvious technological trigger. The LDRs were made on a freehand, flattened circuit, and were attached to wires that went through a narrow copper pipe which fit in a hole through the center of the table. The wires then attached to another Cat 6 cable that fit with the main PCB for processing the data.

However, I tested the sensitivity of the LDRs in the Electroshop in Aalto Design Factory, and not in the exhibition space. The readings in Electroshop were relatively stable, tending to shift +-2 when not interacted with, but the readings in the exhibition space did not behave in the same way. They reflected a sine wave pattern, so their values steadily oscillated +-20. A theory for why this happened, as the lighting itself seemed stable to the human eye, is because of light banding — a phenomenon where some light sources flicker at a rate equal to the frequency of AC mains power (50 Hz), which is not visible to the eye but visible to things such as cameras. This can be detected on a cell phone camera if anti-banding is not turned on in the settings, as consistent ‘bands’ of darker and lighter lighting shift across the image (What Is Anti Banding in Cameras and How Is 50hz Different from 60hz?, n.d.). Although this was problematic, I was able to solve this problem with the code to some extent by using a low-pass filter and some averaging.

The point of failure for this setup was then the placement of the overhead lights —at Electroshop, I had very bright direct overhead lighting, so shadows were cast directly downwards. In the exhibition space, there were two bright lights offset from the top of the portal. This had the unfortunate effect of causing shadows to be unevenly cast if someone stood at a certain position around the portal, so that their shadow would be cast over the entire structure rather than just their wand's shadow being cast. I surmised that this would inconsistently trigger the reaction of the centerpiece, even when wands were not involved, so I removed the feature entirely to prevent confusion in the normal interaction. The centerpiece was still physically included with the final presentation of the portal though (Fig. 36).

Figure 36

A photo of the final presentation of the table, with partial activation and the centerpiece installed



6 Discussion

In this chapter, I discuss the results of the exhibition and their relation to my research objective. I also analyse my approach to my research, in the spirit of practice-based research, and examine my creative process using my notes and the documentation generated in the course of this project from the distance of being at least three weeks past the production stage. Finally, I offer questions and ideas that arose out of the course of this project that serve as interesting avenues for future work.

6.1 The exhibition

transcension was exhibited in the LQ Lobby at Väre, Aalto University from October 18th-26th. I had a minimalist approach to the exhibition setup, and provided one sheet of text to explain and contextualize the different aspects of the project. This had the effect of leaving the audience to freely interact with the pieces without guidance and expectation. I noticed that people tended to swiftly realize the expected action-reaction interaction pattern when interacting with the different costumes, but behaved somewhat differently than I had intended when interacting with the portal.

The interactions with the costumes were very linear - given a certain distance from a costume, the costume would be activated and perform generally repeatable coded reactions, whether they be motors moving or LEDs lighting up. A common sequence of interactions would start with a person noticing a costume reacting, and then experimenting with various actions to determine the constituative rules for 'how' each costume worked. This particular sequence falls much in line with observations by other artists on their own work, such as Rokeby observing his Very Nervous System. He notes that recipients, or interactors, first tentatively perform an action, and when they become sure of their grasp of the system's reactions, repeat the action with confidence and "a commanding attitude" (Kwastek, 2013, p. 128). I specifically quote his use of the word 'commanding' because it captures certain interactions that I observed — on more than one occasion, someone would determine (correctly) that there was some sort of sensor in the heart gem, and then hold out their hand deliberately in front of the gem while approaching it. This explicit demand for interaction surprised me, and contrasted with how people tended to interact with the portal.

My observations regarding interactions with the portal were less regular, I suspect due to the lack of a clear goal. In the iteration of the portal that was at the exhibition, there was no particular embedded goal to achieve, no clear end at which an interactor would have gained a sense of completion from. If the centerpiece would have been functional, then a simplistic game would have been present — place item A in slot B, repeat with two other people, then a reward in the form of a new interaction would emerge. However, as the portal did not have this functionality, recipients did not have a specific game to 'play'. In my ideation behind how to conjure a sense of magic or enchantment through the portal, I focused on the visual impact of a mirror transforming into an animated void. I expected participants to act in what I thought of as a very common way when confronted with seemingly static new media works of art: by waving their arms in front of it. As the portal faced upwards, I therefore planned for people to gesture over it, which would then trigger the interaction.

From my observations, there seemed to be approximately three kinds of interaction when confronted with the portal:

- a lack of interaction, wherein someone would walk past or stand around the portal but not manage to trigger the LED animations, thereby rendering the portal to simply be an elevated mirror;
- a simple fascination which fell in line with my intended interactions, wherein someone would notice that reaching over the portal initiated the reaction and seem to (aimlessly) play by experimenting with movement and location; and then
- an implicit or explicit attempt to 'solve' the interaction, much like how the costumes were linearly interactive. This interaction, though visually similar to the prior kind of interaction, was noticed through some feedback from when I discussed the portal with participants, wherein I would be asked if there was a specific goal or 'correct' way to interact, or if there was a point to the wand-centerpiece interaction.

The last type of interaction reflects Ken Feingold's experiences with recipients interacting with his Surprising Spiral (1991), although his recipients expressed more disappointment than I noticed with mine. I suspect this is in part because although the structure of the portal hinted at the possibilities of an additional achievement to be had, through the presence of the centerpiece, it still offered participants a degree of control over the work — a desire that can often drive the motivation and satisfaction that a recipient receives from the interaction (Kwastek, 2013, p. 129).

6.2 The objective

The objective for the production of transcension was to use interactive media art and costuming to bring the magic of magical girls, in the form of enchanting encounters, into the lives of recipients. Based on my observations at the exhibition, along with the comments in the guestbook, the objective was achieved to an extent. A large part of the intended overlapping of magic and reality was based in the seamless integration of technology with the costumes by concealing the electronic components, so that there was not an immediately obvious means of interaction. In an ideal situation, the simple concealment of sensing components would be enough to render any sense-based interaction mysterious and magical. However the audience that interacted with transcension was largely familiar enough with interactive media art to understand interaction tropes, such as the arm-waving mentioned in the previous section, and proximity-based reactions are similarly hardly new. Having an optimal experience of transcension therefore benefited from either a temporary suspension of one's existing familiarity with interactive media art, or an actual unfamiliarity (observed most notably in a one-year-old child that visited, but also in older visitors).

Despite the unlikelihood of an 'optimal experience' happening, recipients seemed to find some kind of magic in the interactions, even if they had some idea of how the interactions worked on a technical level. Magic has many definitions, one of which is things that give a feeling of enchantment, as if under a spell (Merriam-Webster, n.d.). Unlike the work of traditional magicians, where there is seemingly no explanation for how something impossible happens, the magic offered by the costumes in transcension is the joy and enchantment emerging from novel, satisfying interactions.

After making my observations, I would have liked to improve transcension, for the purpose of boosting the 'magic' brought about by the interactive media art. I would have liked to improve the staging of the exhibition by including more descriptive texts for priming recipients with context for each costume's interactions and appearance. While I had chosen to not provide texts out of concerns about over-priming, I now believe that the benefits of providing framing would have outweighed that concern. I realized after interacting with various visitors passing through the exhibition that knowing the intentions of the artist was particularly desirable, rather than being left to draw their own conclusions. This makes sense when one considers the urge to perform an interaction 'correctly' (Kwastek, 2013, p. 129) — recipients to a piece of art, even in a minimally interactive sense, often want to 'complete' their experience, which involves knowing how the artwork is meant to be understood.

6.3 The process

In reflecting on my process, now having had a break of several weeks from the production itself, I am able to notice a few significant aspects for commenting on. The intended effect of this post-production analysis is so that I can "identify patterns in the creative process and narrative artefacts that may not have been apparent while the activity was underway" (Skains, 2018, p. 88). In discovering the patterns, I am then able to extrapolate the results of my research, which are otherwise very interior to a study of the self, to a more widely applicable set of circumstances, inspiring directions for future study.

My creative process is very production-driven and technology-driven. For transcension, I started prototyping the electronics long before developing the finer details of my designs, focusing on researching what possible tools and interactions were accessible to me before beginning to assemble them into concepts. As a result of this approach, several aspects of the designs are derived from what I considered doable, given the materials, skills, and time that I had. This approach is practical, as it increases the feasibility of a project being completed by limiting it to known building blocks. However, this approach is also limiting — by relying heavily on my own research, and therefore the boundaries of my own imagination and knowledge, I find it difficult to break out of the 'box' built up by my existing knowledge. While my notes indicate continued growth and learning through overcoming problems, coming up with novel solutions, and pushing the limits of my skills, the design process and end result would have been very different if I had collaborated with others. In an environment outside of a COVID-19 pandemic-bound isolation, more collaboration, even on the level of sharing knowledge and ideas by sharing a lab, would have been possible.

In the specific case of my research objective, my pursuit of a magical interaction could have afforded a more flexible approach to what 'magic' constituted, or involved a different scale of work. I had wanted to explore more light art, to reference the dramatically spotlit nature of a classic magical girl transformation; however, I could not figure out how to fit it within the scope of this project, so I chose to set it aside. I had also considered Pepper's ghost and other hologram-style effects, as well as projection mapping, all for creating a more ephemeral 'magical' interaction.

6.4 Suggestions for the future

Beyond the technical areas for improvement, of which there are several — re-building and fully implementing the centerpiece-wand interaction, adding auto-calibration to the code, making networked communications more tangible — lies a particular avenue for research that sparked my interest after the exhibition of transcension. In Chapter 2, I discuss the dual function that my costumes serve — as wearables and as display pieces — and touch on the disembodiment of unworn wearables. After reflecting on the actual execution of transcension, in looking at the 'lived experience' of the costumes, I come across the question of: if a wearable is never demonstrably worn, is it truly a wearable?

Off of the body, the functionality of the costumes transform — they are no longer part of an embodied experience. They lose the presence of the wearer and the performativity inherent to the act of wearing, instead becoming 'purely' interactive art. The way that I designed the costumes meant that they still possess a simulacrum of animacy, despite being disembodied, in that they still provide a form of interactivity that participants may experience and play with. Harkening back to the earlier discussion of cosplaying original or unknown characters, without the experience of seeing the costumes on bodies, viewers are given the suggestion but not the verification of them being actually wearable. Any connection that would emerge between the wearer and the wearable is invisible in the context of the installation. Therefore, there is a lot of room for imagination regarding the potential of the costumes — how do they act on a body? Do they have any additional functionality, or is their response as predictable as the currently experienced interactions are? Is there any added benefit to being embodied, or is the so-called wearable fine being unworn, unwearable?

While the costumes in transcension were designed as wearables, intended to be wearables, and entirely wearable in a physical sense, they were not necessarily self-evidently presented as actual, wearable costumes. I had sourced models for staging a photoshoot in the costumes, both for the sake of documentation and for an opportunity to bridge the gap between the hypothetical and the material experience of the costumes as being wearables. However, due to a lack of time, the costumes were never put on bodies before the exhibition. The meaning of performance changes when bodies are no longer involved. We become removed from the performative turn of theatre that Lamontagne discusses and reinstated in the aesthetics of interaction, as written about by Katja Kwastek. "The interaction and thus the aesthetic experience are determined not only by the actual potentials of the interaction system but also by their interpretation and by the meanings ascribed to them by the recipient" (Kwastek, 2013, p. 29).

Action potentials are built into the interaction system through the technology embedded throughout the costumes, but further interpretation is necessary to capture the full aesthetic experience. As with the reception of unfamiliar cosplays, the depth of meaning ascribed by the recipient to the experience is unpredictable, being dependent on too many factors to account for. As the artist, I instead hope to provide enough supportive 'potentials' to facilitate the 'experiencing of magic' that I desired to induce for participants.

Due to how the costumes are designed, the threshold for engagement is very low. A person merely needs to be within direct 'sight' of the sensor on the costume to begin triggering the potential interaction. This has the effect of making nearly all spectators into participants at some point when they are observing my art — even if one's focus is on something else in the room, one's proximity to a costume may make it begin reacting, therefore starting an interaction between the art and the recipient. This "action-related experience of the recipient [is] a basic component of an aesthetics of interactive art" (Kwastek, 2013, p. 48). Through this relationship, the costumes are able to transform themselves from wearables to interactive art, and in the context of the exhibition and what was shown to the public, they acted solely as interactive media art.

It would be interesting to further explore the dynamic of dual-existence wearables and determine what meaning-making is happening, as oftentimes they already intersect categories such as wearable art, functional wear, and fashionable technology. While it is out of the scope of this project, the question of unworn wearables and other alternative modes of existence for wearables is an interesting one for future consideration.

7 Conclusion

My proposed research objective was to explore the use of interactive media art for manifesting a version of magic into reality. The concept of overlaid, blurred worlds borrows from the magical girl genre of anime. transcension is at heart a love letter to the magical girl genre, manifested in a combination of different forms of interactive media art. In determining what form transcension would take, I defined magic loosely as "having seemingly supernatural qualities or powers" and "giving a feeling of enchantment" (Merriam-Webster, n.d.) and sought to find mediums that resonated with my artistic background through which I could evoke this form of magic.

The influence of the genre is directly visible on the design of my magical girl characters. I use the construct of a magical girl as a template through which I can present my original character designs and concepts, and borrow heavily from aesthetic tropes to create cohesivity between the different characters. They have matching base costumes, partially inspired by Sailor Scout uniforms and lolita-style dresses, but are color-coded and their design reflects their differing personality characteristics. They react with different interactive aspects, such as motorized ropes, light-up elements, or a responsive mask depending on their visual theme.

The eventual form that transcension took — three technologically enhanced costumes of original characters and one interactive mirrored portal — was heavily influenced by my past works both as a new media artist and as a costume maker. Elements which I find enchanting emerge throughout my work as motifs: secret haptic communications integrated into wearables, exaggerated fantasy styling, gestures at bridging the line between the unreal and the real, and infinity mirrors and other forms of light-based art, for example, and this project is no exception. I created three fantasy magical girl characters: Lust, Monster, and Disturbance, and combined these elements into the fabricated costumes and the portal to share enchanting, magical interactions with others.

In creating and exhibiting transcension, I was able to experience the making-of and receiving-of 'magical' interactions from the perspective of the artist. Through discussion with recipients, I could reflect on what I considered enchanting and magical, versus what others' did, and from that stem perhaps possibilities for even more means of magic-making in the future.

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