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Introduction

With this essay I aim to explain the planning, building and execution of my instrument 'The Mallowtron.' I'll begin by discussing my initial research for the instrument, the choices in design or planning that occurred with different tests, the adaptations I made throughout the project, my desired user journey and experience, the place of the project in business terms, its final execution, evaluation of the outcomes, and finally the changes I am planning to make to allow me to use the instrument for multiple future projects.

Research and Influences

My research began broadly on the topic of electronic instruments and their impact on traditional music. Whilst there are countless examples of pioneers in this field that could be touted as influences for my work (Leigh, 2020), I will focus on the hugely revolutionary theremin for its relationship between gesture and sound. At the time, in 1920s Europe, its inventor Leon Theremin had hoped that it would compete with traditional musical instruments, or even usurp them (Oliver, 2018). Theremin toured and gave concerts with his new instrument which demonstrated a previously unseen relationship "between sound and action through the dissociation of power, effort, sound, interface, and gesture, all of which could be easily scaled and combined modularly into new configurations." It was a large step away from instruments that required mechanical energy to operate and therefore did away with the "ancillary noises of air blowing, bow friction and the mechanisms of keys and hammers."

The apparent detachment between the action of playing and the source of the sound brought an ethereal element to this new style of instrument. It's unsurprising that Theremin's first name for the device was the 'etherphone.' Although it did not instantly supersede the traditional orchestra and its instruments, it did begin a slow burgeoning of electronic experimentation. Such technology is now broadly accessible, to the extent that we could make a theremin from cheap and widely available electronic components and an aluminium can (Hobson, 2020).

The continued dissemination of technology has furthered the disconnection between source and sound. A keyboard can sound like a drum kit, a string section, or a church organ, when used as a MIDI (Music Instrument Digital Interface) controller. Performers such as the musician and producer Imogen Heap will use software instruments and filters on stage through the use of gesture-controlled gloves (Heap, 2017). In this sense, I consider my instrument an opportunity to participate in the topic of form and expectation for the user. It is a chance to exploit their understanding of musical instruments, and the explosion of gesture-controlled and touchscreen technology in their daily lives.

Planning

Inspired by this research, I moved on to the planning stage of my device. I had the opportunity to alpha-test several circuits of different materials, microcontrollers, breadboards, components and sensors. This led me to the basic concept of my device 'The Mallowtron': an 'interactive sweet shop' where users will hear a sound or musical motif whenever they take a sweet from a selection of jars on shelves in front of them. In order to take this from a one-line concept to a fully-functioning device I have broken this essay into key stages: design, execution, business plan and evaluation. Testing of the device occurred consistently throughout the process and so I have detailed it as and when it occurred- rather than detailing it a separate stage of build.

Design

Design was by far the most important aspect of this project. To make the topics more manageable, I have broken them down further into subsections:

- Practical Design (Hardware / Software)
- Sound Design (Recording / Sampling / Mixing / Music)
- Aesthetic Design (Look / Feel / Sound / Cultural References)
- User Journey (Expectations / Intuitiveness / Interactivity)

Practical Design

Microcontroller

I called upon my alpha testing to inform the practical design choices of my initial concept. It was especially edifying for my choice of microcontroller, circuitry material, and software. I had the opportunity to first test a BBC Microbit as an input device which delivered simple one-button or gesture input. I also tested the suitability of the “Makey Makey” board as a microcontroller but found it to be less appropriate because of an inability to access the code to reprogram the device, a maximum of six inputs, and no proximity sensing.

The final device I tested was the Bare Conductive Touch Board (BCTB) which is an incredibly powerful and adaptable microcontroller and the best choice for this project. It has 12 capacitive touch and proximity electrodes for input. Capacitive sensors are able to “detect and measure anything that is conductive or has a dielectric different from air.” (Touchboard Workshop Manual - Bare Conductive, 2015). This meant that I could consider both direct contact or proximity-sensing inputs, whereby the sensors would detect the higher permittivity of a human hand.

I planned to use glass jars full of sweets as input sensors and this early testing made me consider how best to ensure that the user of the device would consistently trigger an input. As the BCTB is an Arduino-based board, it can be programmed using the Arduino IDE software. This software provided a “sketchbook” of code templates including codes that allows for adjustment of the sensitivity threshold of the capacitive electrodes, alternate button or switch input, and the ability to program MIDI note assignments to each input / output (Banzi, Cuartielles, Igoe and Mellis, 2019).

Adjusting this code could allow users to trigger a MIDI note by touching the outside of one of the glass jars. Therefore my next step was to experiment with the sensitivity threshold by changing the values in the supplied code. The default touch sensitivity is 40, and the release sensitivity 20. I experimented with different ratios in order to find the ranges for: direct touch, touch through an insulator such as glass, and proximity touch from a distance of a 3cm - 5cm.

In the end, I settled on using the sweets themselves as the material to complete a “direct touch” to the input rather than a wide proximity field, which may have caused too much overlap between inputs. Certain sweets, such as ‘giant strawberries,’ seemed to work better than others, for example candy floss, when extending the proximity sensor. This could be related to the strawberries’ better conductivity as a dense, gelatinous material which likely contains more moisture. This testing lead my to add a layer of tin foil at the bottom of each jar to create more contact area for the sweets and make it more likely for them to conduct an input.

Circuitry

The options for circuitry material included impermanent solutions such as crocodile clips or conductive tape, as well as more fixed solutions like cold-soldered “electric paint” or soldered wires. (How to cold solder - Bare Conductive, n.d.) In my initial testing phase I used crocodile clips for ease of adjustment. I found them to work well for speed of testing different MIDI note configurations, and changing I/Os on the BCTB easily. However, when lowering the threshold of sensitivity for the electrodes, I considered them less practical for the final product because of the apparent ‘crossover’ between proximity fields which lead to two or more inputs being triggered at one time.

After this I moved on to testing copper tape instead and found it to respond well to touch, be flexible enough to run from the BCTB to the jars of sweets, and run along the inside of the jars with ease. I found it to be responsive over a range of at least 30cm and compatible with several other types of sweets such as strawberry laces and cola bottles. Testing with copper tape and jars informed me to try to limit the height of the jars so that I could better apply copper tape in a controlled manner.

Software

When researching other MIDI instrument builds I discovered that Arduino is already a popular choice for a hardware controller - due in part to the large libraries of code available online, besides the example codes that are included in the IDE software. Arduino hardware is often used by YouTubers such as 'William Osman' and 'Look Mum No Computer,' to interpret MIDI information from hardware to software or visa versa.

I used the Arduino IDE's sketchbook 'Touch Board Examples' to load the 'MIDI_Interface' code (Dzisiewski-Smith, Krige, Loose and Kaliski, 2016). I used this as the basis for my Mallowtron code. I left the MIDI behavioural SWITCH_OFF at the 'false' value in order for the electrodes to act as buttons and not switches. I was able to change the MIDI value for each electrode by using a standard conversion table from note name to MIDI. (Wolfe, n.d.) This allowed me to experiment with chromatic scales as well as testing out more ambitious intervals. However, ultimately, I decided that the MIDI assignments would only be used to trigger my own samples so it was more important to be able to locate each MIDI note on a software synthesiser rather than designate the exact pitches that I wanted them to play.

The Arduino IDE also allowed me to change the 'setTouchThreshold' value from the default 40, and the 'setReleaseThreshold' value from 20. This is the crucial code I needed to change the BCTB from a capacitive touch board to a proximity sensor, and to determine the size of the detection field for each threshold. For example, through experimentation, I found that having the ratio set to 8:4 for Touch:Release allows the board to detect input through the glass jars. The final ratio that I used for the project was a Touch:Release of 50:20 to prevent the circuitry from registering false input- something that I will return to later.

For my composition and instrument execution software, I decided to use Logic Pro X. This would allow me to compose and loop an ambient backing track when the instrument is in use, while the BCTB outputs would trigger a MIDI sample to play from Logic's EXS24 sampler instrument over the top. I composed the backing track to create a minimalist ambience and the notes themselves were made up of elements that I recorded at home.

Sound Design

The most important part of sound design was finding a way to link each sweet to a particular image that I could create in the user's mind. It was my goal to create each sound from scratch, by recording a combination of musical samples and foley-type sounds. The overarching goal was to create an experience that carried nostalgic undertones by offering a reimagining of an experience that a vast majority would have participated in during their childhoods- visiting a sweet shop, and the element of adventure that comes from perusing a shelf of unknown flavours. These ideas lead me to choose sweets that already carried a clear link to certain sounds, such as "fizzy cola bottles" being perfectly represented by the sound of a soft drink can opening and the drink being poured into a glass.

The process informed my selection of 12 'classic' sweets. In order to design the experience that I wanted to impart and help my sound design process, I listed descriptive words for each sweet that ranged from denotive to abstractive. The sweets and their descriptors were:

1. Marshmallows

Chewy, rubbery, plodding, fluffy, pale, classic, melting, dusty, joyful, opaque, bouncy.

2. Giant Strawberries

Chewy, sticky, sweet, indulgent, green and red, oval, flat, translucent.

3. Cola bottles

Tangy, fizzy, sour, sugary, rough, brown and white, translucent.

4. Jelly hearts

Red, soft, squidgy, loving, uplifting, passionate, two-tone.

5. Fried Eggs

Frying, greasy, yellow and white, soft, unexpected (looks savoury but tastes sweet).

6. Liquorice Allsorts

Bittersweet, multiplicituous, tricolour, striped (broken up), geometric, savoury and sweet.

7. Candy Floss

Colourful, light, airy, bright, soft, melting, fuzzy, cloud-like.

8. Strawberry Laces

Long, thin, stretchy, playful, bright red, strand-like, strawberry smelling, spaghetti, hair.

9. Mint Humbugs

Starts hard and becomes chewy, fresh, minty, striped, tough, dated, wrapped,

10. Foam Bananas

Plump, soft, yellow, banana smell, simple, miniature, monkeys, exotic.

11. Sherbert Lemons

Hard, bobbled, sour, citrusy, fizzy, tart, tangy,

12. Candy Apples

Big, crunchy, sticky, juicy, chunky, fairground, fruity.

Once I had the choice of sweets and a list of descriptors, I searched for a pitched sound to act as a 'note.' I recorded the sound of the glass jars being hit in order to create a bell-like attack and I then used the software plugin 'Little AlterBoy' by Soundtoys (Little AlterBoy, 2019) in order to pitch the jars to the correct notes for a C Major scale. The backing track is written in C Major as well, which allowed me the freedom to create sounds which would always be in tune.

I recorded my own samples for the majority of the sounds but could only use six of them for the final instrument, due to issues which I will detail later. The sound of 'candy apples,' for example, was made of the jar being struck and several different bites of a real apple echoing on the left and right sides. I repeated this process for every instrument, exported the samples and placed them within an EXS24 Sample instrument of my final Logic project.

Aesthetic Design

The housing for my instrument is a bookcase which measures 86 x 35.7 x 9 cm and weighs 6.72kg. When considering the size and number of jars I chose this housing to create a sense of the miniature, but without compromising much on the look and feel of a traditional sweet shop. Crucially it still offered me enough room to navigate the wiring for each jar but keep a clear idea of each circuit path. I used a random collection of glass jars which I recycled from household goods and glued them in place with superglue. Their unevenness in size and placement is intended to add to the unique look and feel of the instrument.

The look of the 'exposed' copper tape and BCTB on the back of The Mallowtron, besides being easier to leave uncovered, speaks to the roughshod style of homemade or one-off instruments that can be seen in creations like Wintergatan's Marble Machine (Wintergatan, 2016) as well as the 'crazed inventor' image of fictional characters like Willy Wonka. I further considered the cultural recall that my design could evoke in the user. The two main influences that seemed most relevant were Alice In Wonderland and Charlie & The Chocolate Factory. Both stories involve characters ingesting mysterious foods or elixirs with magical properties, especially sweets in Charlie & The Chocolate Factory, which have surprising or exciting effects. The fantastical style of these stories inspired me to lean into the surrealist elements of the sound and music which I designed for the piece.

User Journey

Most users will have had lots of experience with Human-Computer Interaction (HCI) in their daily lives, and these user experiences need to be considered for designing a new musical interface (NMI) to meet or challenge their expectations. In “User Driven Techniques for the Design and Evaluation of New Musical Interfaces,” (El-Shimy, Dalia and Jeremy R. Cooperstock, 2016) the typical journey of user-driven design is outlined. It is a process “closely involving target users throughout the lifecycle of a project [which] can vastly improve their experiences with the final system.”

Fortunately there are ways in which we can predict the expectations of the user without needing them to be closely involved in the design process. For example, in their project “The World’s Deepest Bin,” Volkswagen relied upon the predictability of their user’s predicted experience and expectations (Volkswagen, 2009). By adding interactivity and new sensory feedback to a rubbish bin, they encouraged far more engagement than is typical. As El-Shimy et al go on to say: “within the context of performance, the importance of creativity and enjoyment naturally supersedes that of efficiency.”

When beta-testing the instrument with users I saw an intuitive understanding of the touch controls and would consider this an indicator that the user journey does not have to rely solely upon experience with the instrument itself, but can extend to their previous experience with other technology such as touchscreens or interactive installations.

Execution

The Mallowtron was ultimately a mixed success. From a software and coding point of view, it was a very successful experiment in creating and coding the necessary elements to run this instrument as intended. The hardware was successful in some elements and not others. The main issue I encountered was a very significant problem when attempting to use all 12 of the electrodes on the BCTB, with copper tape as circuitry. The copper tape was Kitronik 5mm tape with conductive adhesive. When testing with up to five inputs, the sensors were stable and responded to inputs without issue. From six inputs upwards, I had problems with false triggers as well as simultaneous triggers for no obvious reason. Some triggers would occasionally stop working altogether and some would trigger constantly.

In terms of circuit length and signal strength, I tested to confirm that the copper tape would carry a signal from the topmost jars to the BCTB which was around 90cm and had recorded no issues. I believe the problems could have been caused by the cluster of the copper tape circuitry being too close together in the 15cm or so above the board, which could have caused problems with tape triggering the adjacent inputs. The BCTB was plugged into my Mac in order to use it in conjunction with Logic Pro X which would have provided grounding.

My first response was to halve the number of inputs from 12 to six and to alternate those electrodes being used as inputs, so there would be the maximum possible of space between each one. This solved some of the issues with false triggering but not all, and the connections were not reliable enough. As the project went on they seemed to become less stable which could be related to wear and tear or jostling of the instrument. I relaid each copper tape connection on the back panel, removing them from the board electrodes and starting again, but had the same issues.

Ultimately I decided to try and use a different circuitry material and had crocodile clips which I had purchased in case of issues. I found them to be a far more reliable circuit material and I was able to place crocodile clips on each of the six electrodes and then strip the opposite end of each wire before taping it onto the remaining copper tape or even placing it inside of the glass jars. For some of the inputs, I eschewed the copper tape entirely and ran two crocodile clips to the glass jars. By increasing the distance between any two parts of copper tape circuitry, and holding the wires in place with electrical and duct tape, I was able to successfully run and trigger all six of the instrument ‘keys’ that remained.

Business Plan

From a business perspective, this project could be approached in several ways and it's important to first identify whether it is an 'infrastructure-driven,' 'scope-driven' or 'product-driven' business - as proposed by Alexander Cowan in 'The 20 Minute Business Plan.' (Cowan, 2016)

According to Cowan, If The Mallowtron was adopted as an infrastructure-driven business, then the key resources would need to include "various types of physical or virtual infrastructure." The most achievable for this project would be a virtual infrastructure. One which would allow the end user to either interact with the project from a remote location, a digital audience through which content could be monetised, or a virtual storefront through which a product could be bought. In that sense it could compete with popular tech YouTube 'hackers' such as Mark Rober or Look Mum No Computer. The latter is particularly relevant as it offers music-specific tech builds.

If instead we were to consider The Mallowtron as a scope-driven business, it would need to solve specific needs for a key market, which would involve possessing knowledge about a specific segment, as well as "a repeatable set of processes, and sometimes infrastructure." The most obvious segment for this business would be music hardware and it would need to fulfil multiple needs of that particular customer. For example, it could be grown into a business which offers one-off MIDI controllers with completely custom designs.

Finally, as a product-driven business, The Mallowtron would offer a "differentiated product of some sort." This product could be copies of, or the only working prototype, of The Mallowtron. Both products would bring different value to the 'end user.' One represents an inclusive user experience, whereas the other is a completely exclusive user experience.

A good example of the difference between an 'exclusive' and an 'inclusive' product offering within an infrastructure-driven business would be the difference Wu Tang Clan's album *Once Upon A Time in Shaolin* and Radiohead's album *In Rainbows*. Wu Tang Clan pressed a single copy of their album and then auctioned it to the highest bidder. "This included a legal agreement with the purchaser stipulates that the album cannot be commercially exploited until 2103, although it can be released free or played during listening parties." (Christ, 2015). The album ultimately sold at auction for \$2m.

Radiohead, on the other hand, offered their album for download from their website and asked consumers to pay whatever they felt the album was worth. *In Rainbows* succeeded in making more money from digital 'pay what you feel' sales than their previous album made in its entirety. (Garland, 2009)

I believe The Mallowtron would work best as a combination of part of a much bigger infrastructure and product-driven businesses, set on different timeframes. A product-driven model would be the first step to delivering value to the end user, by selling the product itself with immediacy, or offering customers a commissioned 'one-off' MIDI controller to their brief. A virtual infrastructure could concurrently be built through social media channels in order to provide different opportunities to monetise in the future. Parallel channels which would also arise from a strong virtual infrastructure include branded merchandise sales, live demonstrations, workshops and other appearances.

Evaluation

The project didn't achieve all of the aims that I had intended, but it is a large step towards a finished build which could ostensibly run the maximum 12 inputs if all of the correct circuitry is completed. The 'shell' of the instrument was successful, with the glass jars being fixed in place, and will allow for simple replacement of the circuitry- although this may require removing the back tackboard panel for easier rewiring.

Users showed interest in the build so far and enjoyed the interactive experience without too much instruction as to how the instrument would 'play.' This bodes well for the intuitiveness of a final version. It's important to remember that these users have no particular goals in mind when approaching the instrument although they are aware that's it is designed in some capacity for them to "play" or interact with. Some of the users will be musicians, and some will be complete music novices, which made it important to walk the line between open musicality and a kind of "on-rails" interactivity. Given the initial reactions, I would consider it a success in playing upon the technologically-literate expectations of users without needing to give specific instructions for its use.

I consider some competitors of this project to be the 'YouTube hackers' that I have mentioned already- William Osman, Look Mum No Computer, Wintergarten, or even Simone Giertz. However The Mallowtron, once built, could be very quickly repurposed to play anything that requires MIDI functionality so has a broad spectrum of potential. It's something that I would like to finish building, run first as an interactive 'sweet shop' experiment, but then to attempt to use myself as a MIDI controller in writing and performing music. With access to an online audience, and having streamed live gigs from my bedroom, I can see a potential use for this instrument to become a highly novel and entertaining part of my setup.

To refer back to *User-Driven Techniques for the Design and Evaluation of New Musical Interfaces*- "Novel instruments are often created by artists to support their expression of a particular message or idea. As a result, many such instruments end up being used exclusively by their own designers." The flexibility and novelty of the Mallowtron make it a multi-purpose instrument for a wide range of creative future uses- once it is fully complete.

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