Re-hearing the Past in the Age of Digital Re-Production

A Sonification of Media Artefacts

by

Paul Dunham

A thesis
submitted to Victoria University of Wellington
in fulfilment of the requirements for the degree of
Doctor of Philosophy

Victoria University of Wellington
2022

Doctoral Supervisors

Dr. Dugal McKinnon

Dr. Mo H. Zareei

Prof. Dale Carnegie

To hell with making art.
What you do is experiment.
What that experiment leads to is quite inconsequential.
The only thing it leads to is knowledge.

- Theo Schoon

To Maree.
Without your support this would still just be a crazy dream.
Thank you for bringing back the smile.

Abstract

The objective of this research is to reinterpret historic relationships between different forms of obsolete and contemporary media expressed through a series of sound-based art works. The research brings related artefacts, taken from different moments in time, into dialogue with each other by employing approaches and techniques drawn from media archaeology and data sonification. With sound no longer manipulated and rendered solely through digital audio software, each work expresses itself in each historically related artefact's 'voice' through indexical relationships and the re-presentation of data. The primary contribution of this thesis provides a novel approach for methods of inquiry within a media archaeological idiom to the representation of historical media relationships expressed through sound.

Following an investigation and critique of media archaeological approaches, its use in sound-based art and methods of representation, the research's creative output focuses on the expressive materiality of the objects under inquiry. Such a transdisciplinary inquiry provides a new perspective for the re-presentation and representation of information. Each work explores the musicality of numeric sequences in space and time through rhythmic and spatialised patterns created by the absence and presence of data. As sound-basic music, the application of several access tools facilitated by data sonification are used to enhance audience perception and reception of the works. The works show that sonically interesting results can be obtained by creating abstract relationships between source data and the sounding object.

The research establishes a framework in which the method of inquiry realises different outcomes. The framework utilises data sonification to defamiliarise one communication medium, the visual, before refamiliarising it within another medium, sound. Organising sound by using data sonification techniques as a media archaeological method facilitates the creative shaping of an historical narrative. As an approach to sonification within the field of auditory display, the works employ each artefact's 'voice', or elements of it. Thus, the alternative representation of data as a media archaeological method of inquiry is used to achieve different outcomes unique in this research's diversity of inquiry and intent.

Acknowledgements

I do not think I can do justice to the immense support and gratitude to all the people that I have encountered and that have supported me in some way through this crazy journey. What was supposed to be a three year sabbatical when life is thrown into the wind to see what eventuates has culminated with this thesis. A seven year exploration, not only of music, sound and art but of myself and realising that sometimes you just need to take the first step.

First and foremost, I must acknowledge Maree for the support she has provided throughout. Words cannot express my gratitude and appreciation. Thank you for the dedication in reading every part of this thesis and the feedback you have provided. That is only a small but important part of the role you have played in allowing me to achieve this.

I could not have achieved this without the support of my PhD supervisors, Dr. Dugal McKinnon, Dr. Mo Zareei, and Prof. Dale Carnegie. It is thanks to Mo for planting the seed for the direction of this research and the works that form the basis of this thesis. Without your aesthetic eye for detail and questions the works wouldn’t have been as strong as they are. Also, in part, for encouraging me to consider undertaking the PhD.

از استاد راهنمای بزرگوارم جناب اقای دکتر زارعی که با راهنماییهای ارزشمند خود، در تکمیل این پژوهش مرا یاری نمودند و راهگشای مسیر بودند کمال تشکر را دارم

To Dugal, thank you for the knowledge and insights you have provided to focus some of my research and to provide perspectives I would not have otherwise considered. Also, suggesting what I may like to stay away from as much as what I should consider has provided a safer pathway through the research labyrinth. Thank you for the discussions, insights, suggestions and sharing these with me.

It’s fair to say I didn’t know what to expect when Dale agreed to be one of my supervisors. He probably felt the same. However, his dedication, knowledge and perspectives have been a major contribution to completing this research. As well as enhancing the engineering perspective of my thesis, his ability to offer some insights into research direction has ensured it achieved the focus it has. I consider the knowledge and skills I have gained by undertaking this research in conjunction with the School of Engineering and Computer Science (ECS) to be invaluable. Thank you.

I must acknowledge the technical staff at Victoria University that have assisted me during my research. To the ECS technical staff, Tim Exley and Jason Edwards, thank you for providing guidance, comments, and suggestions on what must have seemed some vague ideas. Without your assistance parts of each work would have languished and not been as well developed as they are. I must also acknowledge the early support of Hamish Colenso. To Image

Services, I cannot express what a fantastic documentary resource that they provide. To Kerie McCombe, thank you for making possible the short notice requests for photography and videography. To Gerry Keating, thank you for the images of my works that are included in this thesis. To Ted Whitaker and Nando Azevedo, thank you both for your wonderful videography and for dedicating the time to film and edit in a single session.

I would like to extend my thanks for Dr. Jim Murphy who has been a part of this research from the sidelines. His encouragement, ideas, insights, and perspectives and general chats have been invaluable over the years. He was also another that encouraged me to consider undertaking this PhD. Thank you.

To my lab cohort, thank you for the innumerable chats, discussions, feedback, rants, and support. To Nathan Villicaña-Shaw, for many of the aforementioned. It's not the same over Zoom. To everyone else that has passed through the lab or remains, thank you for your collegial support and in pointing out the obvious when it was needed.

To all the friends who wondered what was going on when I began this research, thanks for sticking by. There's more to come. Finally, to my family for understanding why I needed to do this and being there. To those absent who are not able to share this, I'm sure you'd be smiling too.

Contents

List of Tables

List of Figures

Chapter 1. Introduction

1.1 Overview

In considering Theodore Adorno's treatment of obsolescence in *Minima Moralia: Reflections on a Damaged Life*, Joel Burges observes that "obsolescence has its uses." [1] As consumerism consigns outmoded objects to the technological junkyard, media artists are looking beyond the utilitarian function of these objects, beyond the gaze of nostalgia, seeing ways to creatively appropriate them to produce artworks that use and reference outmoded technologies as an aesthetic and formal element. Mark Goble asserts that the spectacle of obsolete technologies has come to provide contemporary artists with compelling imagery to reflect upon the legacies of modernism's durable network of cultural practices. [2]

The purpose of this thesis is to elaborate a combinatory approach to sound art incorporating media archaeology and data sonification to reinterpret historic relationships between different forms of obsolete and contemporary media. These relationships are expressed through a series of sound-based installations developed as a part of this research. In conjunction with these works, an adaptable and extendable framework is presented to explore the value of a more structured or practical approach as an aesthetic method of media archaeological representation by conceiving, designing and constructing a series of sound-based artefacts as exemplars. The development of this approach is then tested against the resultant sound-based works, which, in turn, informs and refines the approach as a part of this research. To achieve this purpose, a set of research objectives are elaborated on in section 1.4. Utilising objects' specific qualities, this research examines media history and represents this investigation through a series of sound-based installations. In doing so, this thesis investigates methods of inquiry and representation in which obsolescence has its uses. One outcome is that these investigations are 'voiced' by or through the artefacts themselves. As such, this research is devoted to the artistic manipulation and the defamiliarisation of historical relationships between obsolete and contemporary forms of media. These connections are evident in the ideation and production of new multimedia artefacts as this thesis will show. To achieve this, several interdisciplinary approaches, techniques, and representations have been employed to inform the historic representation of media through the resultant creative works.

These representations are realised through an interdisciplinary practice that draws on music, engineering, and computer science, along with elements of philosophy and sociology. These disciplines are manifested in the creative ways sound is organised in combination with the use of mechatronics and microcontroller programming in this research's outputs. Such an amalgam of disciplines draws on "the contingent connection of different elements that, when connected in a particular way, form a specific unity" including "words, concepts, institutions, practices, and effects and material things." [3] As detailed throughout the thesis, this is an effort to invigorate an interdisciplinary rethinking of underlying approaches to reanimating historical acoustemology.[1] This chapter provides a background to the research, its objectives, the approach and concludes with an outline of the thesis structure.

1.2 Ghosts in the Machine

What do computer punch cards, social media, and visual prostheses have in common? They are seeds. Sometimes it takes a 'blue sky moment' to let the mind wander, to get lost in your imagination, to be able to seed an idea. This section is a brief overview of the seeds of this research.

The sonification of data sets from a book of random digits began by wondering whether obsolete computer punch cards could be mechanically sonified using a music box-like apparatus. Somewhere in the archival labyrinth of Herman Hollerith's invention is a set of cards used for the storage and distribution of large random number sets. Due to increasing need, large sets of random numbers were published in print form. In a secondhand bookstore in Aachen, Germany, a copy of a book of random digits sat on a shelf. I bought the book. Its introduction provided insights into how the data sets were generated. It also provided instructions for the use of the tables contained within. Thus, a connection was made between the punch cards as input media for relay-based electromechanical computers, the dawn of

[1] Steven Feld coined the neologism acoustemology, joining acoustics with epistemology to theorise sound as a way of knowing. Acoustemology is grounded in the assumption that life is shared with "numerous sources of action that are variously human, nonhuman, living, nonliving, organic, or technological" and, through these relationships, attends to conscious modes of listening for and resounding to presence. [4]

digital computing and the generation and use of random digit sets. If only the book could 'speak'.

A telegraph key sits on a shelf in a secondhand shop. I picked it up, handling it, observing its mechanics, idly tapping out a rhythm. I came across a copy of Tom Standage's *Writing on the Wall. Social Media – the first 20,000 years*. The seed that social media is more than an engagement with and through 21st century media platforms. How do we communicate through abbreviated forms of language? Signs and symbols. The telegraph. Morse code. Social media. Twitter.

Sometimes you see mention of something that piques your interest. Such was the case for the Optophone. As a prosthesis, the device's conceptual development took two paths. These were in the field of scientific research as an exploring/reading device and as an artistic endeavour for the synergistic presentation of sound and light. From the disruptions of the First World War and Dada expression emerges a seed. If this is an early form of optical sound device, what are its progeny? Contemporary media technologies like light sensing devices, optical readers, scanners? Commodities. How have these subsequent technologies retained and built upon earlier, more primitive structures, whose traces remain as ghosts in the machine? A hack of a dismantled contact image sensor scanner from a printer showing the output of rudimentary light sensing data provided the media.

These different strands of thought are by no means complete. They do not reflect the dead ends, false leads or irrational threads that were encountered or discarded in conceiving the works. This section is intended as a brief overview of the blue sky moments that provided the seeds for the portfolio of works that have been developed and realised in this research. The works, *Click::RAND, Click::TWEET* and *Click::REVU,* are discussed in chapters 3-5.

1.3 Motivation: transforming translations

The motivation for this dissertation is twofold. The first is the exploration of the "potentials of the media archaeological method." [5] What is the intent of this open-ended phrase and what possibilities exist for creating sound-based works by exploring and employing such potentials? This research explores this potential through sociocultural aspects of communication with an understanding of their technical conditions of existence. The second is a desire to explore obsolete media through a tactile engagement with the artefact by considering their sociotechnical properties and relationships, their sound producing capabilities and their relationships to contemporary media. What potentialities exist for artefacts if they were removed from the showcase, the junk bin or the dusty shelf and reanimated in some way to 'tell a story'?

Using these questions as a starting point, this thesis draws upon various media archaeological approaches to connect the social and cultural aspects of obsolete and contemporary forms of media and their various technical conditions of existence. These connections are articulated through a series of sound-based art works utilising several older physical media artefacts from different moments of time. These objects are generally interpreted through our visual and aural senses. This research re-presents them as a series of sound-based artworks. The use of these objects is elaborated on in chapters 3-5 which discuss each of this research's works. By transforming and reconfiguring these obsolete artefacts, this thesis aims to provide concrete examples of the realisation of the ideas established through this research as new artistic forms of media: one that uses a combinatory approach for media archaeology utilising data sonification and material artefacts as the sound producing objects. The choice of these artefacts is further discussed in section 6.1. A core aspect of this thesis is guided by the lens of media archaeology. The next section introduces the key terms and concepts that are employed in the ideation and realisation of this research's creative artefacts.

1.3.1 Media Archaeology

Media archaeology is not a genre but a method of inquiry within the wider field of media studies. To anthropomorphise the term, it is a *bricoleur*, borrowing and re-using available materials as necessary to connect seemingly unrelated forms of media. While criticised for its lack of a common objective, having no one fixed method affords it the opportunity to borrow methods of inquiry from other disciplines. [6] This is evidenced in this thesis which intersects several fields of research and practice.

Two general approaches for media archaeological research excavate socio-cultural and material perspectives of the artefact. For artists, both approaches present new opportunities for re-presenting media in unfamiliar contexts and ways. As a means of reading against the grain of history, novel connections can thus emerge between past and present technologies. In this way, a material approach to media archaeology-informed sound-based art can be a way to critically engage with the historical materialism of obsolescence[2]. While this is elaborated on

[2] Following Walter Benjamin, Joel Burges describes the historical materialist, unlike the historicist, as refusing an image of the past that inculcates the victorious sense that the present inevitably constitutes progress. The historical materialist attends instead to those people and things that have been left behind or defeated. [1] Benjamin's historical materialism implies an ability to connect otherwise separate and distant moments in time through a common theme thereby disrupting the regularity of linear temporality.

in section 2.2.4, the material origins of sound are never without history, theory or culture. [7] Focusing solely on the material artefact ignores Lisa Gitelman's assertion that "culture insinuates itself within technology just as technology insinuates culture." [8] This is evident in some of the works examined as a part of the literature and repertoire review in Chapter 2. as well as the portfolio of works developed within this research. If the artefact is not merely a passive object of human agency, but equally it takes some meaning from human/non-human interactions of connected "networks that engender meaningfulness in their enchained relationships" then its agency derives from those associations. [9]

Although media archaeology is not specifically considered by Leigh Landy in his formulation of a framework for the study of sound-based works, he does acknowledge that "greater knowledge concerning works of organized sound" can be achieved through a holistic interdisciplinary approach. [10] Employing media archaeological approaches to Landy's framework provides perspectives which include the "historical, theoretical, sociocultural, and technological aspects of a given work" that Landy argues "illustrates the connection between intention, discourse and analysis of a work." [10] Such an approach can be used to see and hear the past through the present as the *object-based sound installation*—which works with physical artefacts, rather than sound alone.

1.3.2 Audiovisual Representation

Acknowledging, in part, the influence of Pierre Schaeffer and subsequent composers and researchers on the object-based sound installation, his "acousmatic approach to sound" is as important as his mediated listening experiences as a basis for the "discovery of 'possible musics' in the future." [11] In his compositions, the quantised matrices of melody, harmony and rhythm fall away to reveal a textural and temporal flow of sound as a "post literate sonic experience." [11] However, what Brian Kane terms the epistemological gap, the technically mediated space that dissociates an object's effect from its source, has seen a reaction from sound artists that have sought to expose and foreground the sounding object as a significant part of their works. [12] In a turn away from the dematerialised *objet sonore* of Schaeffer's *musique concrète* the visibly present object can be seen to be a (re)turn to *l'objet concret* (and a turn away from *l'objet sonore*), an essential aesthetic element of the object-based sound installation.

To this end, my research follows Ethan Rose's categorisation of the object-based sound installation as a way to visibly present and foreground the sound-producing object and explicitly connect the sound to the source. [13] Finding similarities with Rose's categorisation, sound-based brutalism is an aesthetic in which the sonic by-products of mechanisms and objects can be expressed. This aesthetic is encapsulated within the wider representation of *audiovisual materialism* – a set of sound-based practices providing a multisensory experience by embracing and utilising the symbiotic audiovisual relationship between the physicality and materiality of objects. [14] These are more fully discussed in section 2.4.

The artefacts used in my research are primarily communicative forms of media with the purpose of conveying information. The works share a common approach of extracting information from one medium and transforming and re-presenting it in another. To facilitate this transformation and organisation of data and to render sound in response to data interactions, sonification techniques have been employed as a method of communicating and transmitting information.

1.3.3 Data Sonification

Caleb Kelly notes a "digital fatigue" emerging in sound-based art due to the prevalence of digital production technologies resulting in artists longing for a "physical connection to the materials of their work." [15] Citing a media archaeological perspective, Kelly argues that such an emergence "coincides with a return to various philosophies of materialism" with "works that, through the sounding of their materials, deliver a series of outcomes that call on us to think about where these materials have come from and where they will end up." [15] As Goddard argues, a key value of media archaeology is "its insistence on the materiality, and material ecologies of media objects, systems and processes, contrary to the still lingering tendency to view informational technologies and processes in disembodied and immaterial terms." [16]

Drawing on data sonification to inform media archaeological approaches constitutes a creative exploration of, and change in, not only the form the data is expressed in, but the sensory comprehension of data. Such an examination and transformation of data is employed to generate new interpretations between seemingly unrelated forms of media. Thus, it draws attention to "the movement and flows of relationships" showing how sonification can articulate "a range of practices that render data for the ear and the ideas and practices articulated to hearing within sonification." [3] A turn to media archaeology in the presentation of sonified data is one way to consider the performance of archival research. Listening to the archive in this way may produce unexpected sonic utterances of the past through new forms of articulation. [17] This approach is a significant part of this research's creative works as a way of making archive material 'say' something new through its recontextualisation.

Bringing related artefacts taken from different moments in time into dialogue with each other, this research utilises data sonification techniques and media archaeological approaches to inform and realise each of the works within this research's portfolio of creative output. Each work expresses itself in its own 'voice' through indexical relationships where an interpretative sign or series of signs are used to refer to a symbol or object. For example, binary 1001 refers to decimal 9, while --- in Morse code refers to the letter O. By reducing the message content through this translation, the messages are listened to at an indexical level rather than for semantic meaning through historically related artefacts drawn from forms of communication media. Doing so offers new combinatory representations of the past through data sonification, its transcoding, transposition, and transference from one medium to another. This approach can be one method of translating data between artefacts that are distant in time and/or place, thus extending our spatio-temporal perception of relationships and recontextualising historical meanings. [18] Using data as an input control for some sound producing mechanism is a way of making aspects of a data set or system perceptible. This allows the examination of and the drawing of inferences from the artefact to gain an insight into the subject of the work.

1.4 Objectives

Errki Huhtamo describes media archaeological research as a form of armchair travel where the phenomenological experience of travelling back in time to another technological era is only limited by one's imagination. Despite this sometimes wild ride through time, he states such a practice cannot be executed in an anarchic fashion. [19] Notwithstanding Huhtamo's view, media archaeology has developed without a codified set of methodological principles or a dedicated institutional framework despite attempts to do so (see, for example, Lovink [20], Ernst [21], Strauven [22], Goddard [16], Monea [23]). This lack of formalisation is reflected in the diversity of approaches that continue to be used by practitioners. Recognising this diversity, Huhtamo states that the practices of artists and researchers differ radically, with artists able to inhabit "a more flexible cultural space without all the restrictions (of method, source criticism, peer pressure) that constrain scholars." [24] He contends that artists have more freedom to:

> dream and fantasize; [enjoying] more liberties to compare, conclude, and leap between times and places—or between real and imaginary things—than researchers. Most importantly, the results of the excavations made by artists are expressed by different means. [24]

To this Wanda Strauven argues that media artists, being free of “academic boundaries, disciplinary conventions, and methodological restrictions”, operate in “direct, physical contact with the medium or, even better, with its materiality.” [22] However, Huhtamo and Strauven’s perspective is considered from the point of view of a meta-language of words or narrative descriptions of the artefact rather than a tactile engagement with and operational enactment of the artefact under scrutiny. A significant amount of artistic research producing wide ranging and diverse bodies of work is undertaken within the academy. The media artist, in this context, combines the flexibility of the artist with the methods and framework of an academic discipline. The artworks not only function as art but also as research by revealing the knowledge developed through the creation of artefacts and the interpretation and contextualisation of the artistic process. As the artefact can be seen as a method of collecting and preserving information, it is the artist as researcher that gives a voice to the embodied knowledge through a process of reflexive and reflective inquiry. [25]

Although Jussi Parikka and Garnet Hertz argue that a stronger articulation of an artistic methodology can be useful, as Gitelman stated in section 1.3.1, the material origins of such work is never without history, theory or culture, that is, a socio-contextual narrative. [26] Thus, an exploration of the potentials of the media archaeological method is not only in how it should be employed, but also how it can be employed. To achieve the purpose of this research stated in section 1.1, the objectives of my research are to:

- evoke concrete relationships between obsolete and current media technologies through a portfolio of sound-based works. These are informed by their historical, theoretical, sociocultural, and technological relationships,
- develop new methods of inquiry into the obsolete object’s engagement and relationship with current media technologies that also investigate alternative perspectives of historical representation.

To achieve these objectives the research seeks to:

- design and develop a series of new sound-based artefacts that reveal the synergistic relationship between technological media from different historical contexts,
- account for the materialities of media through which history is articulated, as a way of producing historical knowledge,

- establish a media archaeological rendering of, and a genealogical connection between, past and contemporary media technologies in the audiovisual domain utilising each artefact's 'voice', or elements of it, within each work.

To explore the relationships between theory and practice and between spatio-temporally separated subject media, this research undertakes the design and development of three sound-based works that employ mechanical and electromechanical objects, electronics and microcontrollers. The sound structures developed for each of the works will be an important element of exploring expressive relationships between subject media. Each work must either utilise the sonic artefacts of the obsolete object under inquiry or become an artificial mouth for a spatio-temporal throwing of the 'voice' as a form of media archaeological ventriloquism. As such, this extends Jamie Baron et al.'s term 'media ventriloquism', beyond the contemporary moment where "audiovisual technologies recombine voice and body in ways that would be impossible without technological intervention", extending the body and voice past their immediate physical and temporal limits. [27]

As the sound producing capability of the artefacts under inquiry are constrained in relation to their melodic and harmonic qualities, a method of organising sound is imperative. This method can be utilised as a technique to increase audience engagement with, and perception of, the works. In creating these works and realising their expressive modalities, this analysis highlights that researchers are capable of dreaming and fantasising, of making leaps between seemingly unrelated media to realise artistic forms of expression. Doing so within a critical context allows the work to be subject to a level of inquiry to educe a body of knowledge that may not be realised by the artwork alone.

1.5 Research Approach

Without engaging in a debate characterising research approaches (i.e., practice-based, practice-led, and practice as, research) to creative arts, this research is practice-based because the production of an artefact is crucial to providing insights from making, reflecting and evaluating which can then be fed back directly into the artefact itself. [28] A fuller understanding of the intention and context of the research is obtained by experiencing the artefact as opposed to using it as an illustration of a critical/theoretical concept. Such an approach shares media archaeology's exploration of the material possibilities of obsolete media through a sensory and tactile engagement with the artefact. This section briefly introduces the practice-based approach employed throughout this research.

Through the process of experimentation, theoretical and practical design iteration and validation, three artistic works have been conceptualised, produced, and refined as a series of object-based sound installations. These are informed by the motivations discussed in section 1.3. In doing so, the overall approach undertaken in preparing this thesis reflects the interactions between practice, research, and evaluation (shown in Figure 1.1). This method is adapted from a model presented by Hazel Smith and Roger Dean. [29] This process-driven approach is used for my practice-based research, one which is aimed towards the emergence of ideas that may initially be conceived as 'sketches'. As such, the method can be seen as non-linear with no fixed starting point but one informed by a number of concepts and processes. Using iterative processes allows the approach to support the cyclic development of a work and to apply learnings to subsequent works. This is particularly evident in *Click::RAND* where, on reflection and through an iterative development process, the work was able to articulate itself through the artefact's own form of 'voice' to more accurately represent the artistic intent. This is described in Chapter 3. The premise for utilising such an approach is aimed towards developing emergent ideas for the creative works that may initially be conceived as 'sketches'. Thus, the overarching research approach provides a number of possible entry points and pathways for the research activities to move between practice, research and evaluation. [28]

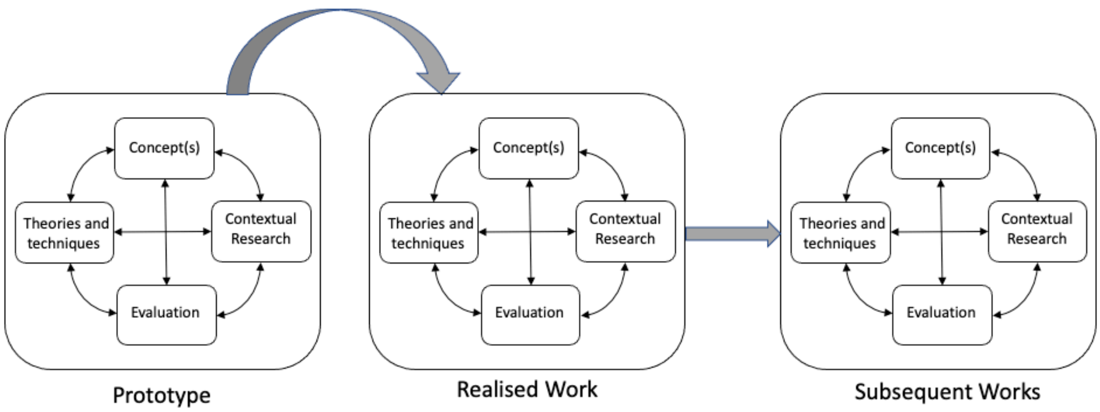


Figure 1.1. Iterative Research Approach

Considering the interdisciplinary nature of the research, a single methodology cannot be used. This research's creative output has utilised different methods of inquiry and different points of entry in their conceptualisation, creation, and realisation. Such methods are embedded in the chapters relating to each work. As much of the work in this thesis traverses disciplinary boundaries, an approach supporting the interdisciplinary nature of the research is required. In this context, the creative process employed by, and the works generated from, this research is the result of alternative perspectives of historical thinking. This is expressed through a convergence of and interplay between distantly related media. However, Barbara Bolt argues the work of art is not the artwork as a fully formed representation of an idea. Instead, she contends that the work of art is the "particular understanding that is realised through our concernful dealings with ideas, tools and materials of production." [30] Rather than simply providing an explanation or a contextualisation for the artworks, this research approach is employed to formulate an understanding of my engagement with those concernful dealings to reveal information about my creative process. This thesis plays a complementary role in revealing the collective knowledge preserved in the artworks produced as a part of this research. By understanding the relationship between the artist as researcher, objects, methods, tools, ideas and material, as is presented in this thesis, the knowledge embodied in the artefact can be articulated.

1.6 Thesis Outline

This section outlines the thesis structure and provides brief descriptions of each of the chapters. An overview of the thesis structure and the chapters is shown in Figure 1.2. Chapter 2 presents and discusses background literature and related works within two broad categories associated with the themes present in my research. These are media archaeology and methods of representation as sound-based art. Each of these categories is examined and discussed as a method of inquiry and mode of representation thus providing the field of media archaeology with insight into a novel representational approach for the ideation and realisation of this research's works. The works themselves constitute a major component of this thesis.

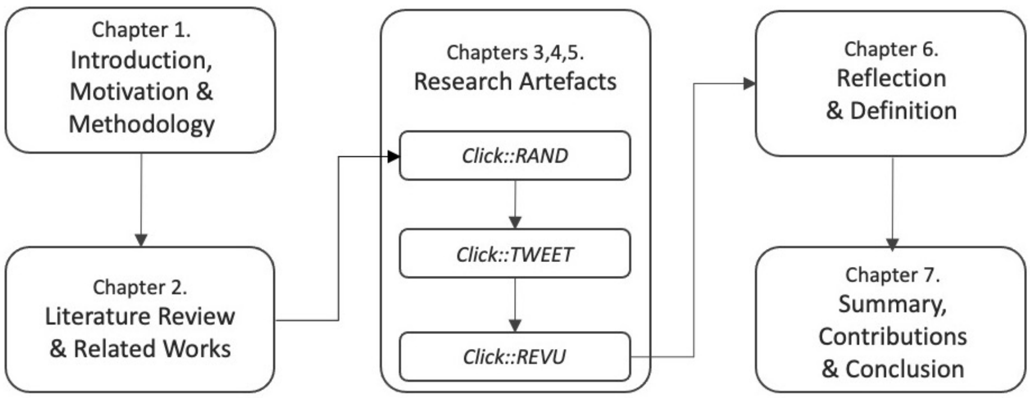


Figure 1.2. Thesis Structure

Chapters 3, 4 and 5 present thorough conceptual, technical and compositional discussions for the ideation and construction of *Click::RAND*, *Click::TWEET* and *Click::REVU*. Whilst all the works utilise consistent methods of inquiry and development, the application of these produce broadly different outcomes in examining and representing relationships between different forms of media. Reflecting on the works previously discussed, Chapter 6 presents data sonification as an interlinking principle of the works. The chapter presents a framework for data sonification as a novel approach to organise sound and as an experimental approach to voicing media archaeological artefacts through their own materiality to shape historical narrative. Chapter 7 summarises the thesis and highlights this research's scholarly and artistic contributions to the field. To this, a total of four peer reviewed papers and eight locally and internationally exhibited artworks have furthered the novel contributions from this research. These contributions are elaborated on in Chapter 7.

He leaves it to others to give themselves to the whore called "Once upon a time" in the bordello of historicism. He remains master of his powers: man enough, to explode the continuum of history.

- Walter Benjamin

Chapter 2. Literature and Repertoire Review

2.1 Introduction

This chapter presents a range of exemplar sound works that are located within a media archaeological idiom. These examples are contextualised as such either by the artist or by exhibiting characteristics of a media archaeological approach in their ideation and realisation. Media archaeology as discourse is treated lightly in this review as the creative works discussed in later chapters embrace a sensory and tactile engagement with the artefact in their conceptualisation and realisation. This approach "excavates the agency of the machine" and is one approach to understanding and rethinking media history through an operative re-enactment and by delving underneath the exterior features and interfaces into the internal workings of media. [31] Therefore a media archaeological method that draws on the materiality of objects is foregrounded in the examples discussed in this review. The first half of this chapter outlines media archaeology as a method of critique into the history of media, and the various approaches used in these inquiries. The section focuses on experimentation through the tactile and sensorial engagement with artefacts as a media archaeological approach for creative practice.

The second half of the chapter presents a number of diverse sound works that exist within, or are characteristic of, a media archaeological idiom. As media archaeology is not considered a genre in itself, methods of representation and expression for media archaeological sound art are also reviewed. [6] Considering the research focus, works that juxtapose obsolete media alongside new technologies are featured.

The chapter concludes with a discussion and summary of the media archaeological concepts that are used to frame this research and aesthetic representations that have informed and influenced the presentation of the resultant creative output.

2.2 Background

In *Theses on the Philosophy of History*, Walter Benjamin distinguished between two opposing approaches to the past: '*historicism'* and '*historical materialism*'.[3] For the former, time is linear, uniform and cumulative. [32] Benjamin describes this additive method as offering a mass of facts in order to fill up an homogenous and empty time. By contrast, his conception of historical materialism is one that rejects the past as a continuum of progress, seen not as a progressive flow of homogeneous, empty time, but as an anachronic constellation of the past and present. [32] The historical materialist attends to those people and things that have been left behind or defeated. [1] Benjamin's historical materialism implies an ability to connect otherwise separate and distant moments in time through a common theme, thereby disrupting the regularity of linear temporality; rubbing against the grain of history.

> If Benjamin said that history had hitherto been written from the standpoint of the victor, and needed to be written from that of the vanquished, we might add that knowledge must indeed present the fatally rectilinear succession of victory and defeat, but should also address itself to those things which were not embraced by this dynamic, which fell by the wayside - what might be called the waste products and blind spots that have escaped the dialectic. [33]
>
> *Bequest, Theodore Adorno*

Theodore Adorno's observations of Benjamin are made within a critique of the modern subject's dread of backwardness, but they equally provide an examination of the possibilities of this backwardness as a refuge from modernity where the past can live on in the present. Joel Burges posits that these refuges can harbour historical possibilities which can be excavated "for alternative itineraries to a present in which capitalism has co-opted modernity." [1] Thus by engaging in counter historical thinking, the "presence of the past can disrupt this temporal form of linear progress by constellating those temporal elements." [1]

[3] The essay was also known as *On the Concept of History*.

One particular perspective as a critique of new media is media archaeology. One stated objective of this critique is to dispute the incessant march of victors over the vanquished and negate a temporal logic, i.e., a linear irreversible time and the progressive view of history that this logic entails. Seeing the possibilities of alternative historical narratives between the past and present through the convergence of obsolete and contemporary media technologies is one purpose of a media archaeological approach to inquiry. However, Philipp Keidl suggests that rather than replacing established narratives with the production of alternative histories, it may be better for media archaeology to describe a defamiliarisation of established historical knowledge. [34] Thomas Elsaesser asserts that while this excavation for alternative itineraries can challenge conventional chronologies, unsettle accepted historical narratives, and question binary categorisations (old/new, analogue/digital, useful/obsolete), an "initial impulse of media archaeology was to make the past strange again rather than all too familiar." [35]

2.2.1 A Media Archaeological Heritage of Sorts

Media archaeology takes inspiration from Michel Foucault's studies in archaeologies of knowledge and power. His concept of an archaeology of knowledge diverges from the 'history of ideas' which is characterised by themes of genesis, continuity and totalisation as a form of historical representation. For Foucault, such an analysis encompasses an abandonment of the search for origins, or questions the already stated. It is, instead, a systematic description of the discourse object. [36] [37]

It seems counterproductive to recapitulate an exhaustive genealogy of media archaeology. This has been undertaken already. Notable examples include Zielinski's *Deep Time of the Media* (2006), Huhtamo & Parikka's *Media Archaeology* (2011), Parikka's *What is Media Archaeology?* (2012), Wolfgang Ernst's *Digital Memory and the Archive* (2013) and *Sonic Time Machines* (2016) and Elsaesser's *Film History as Media Archaeology* (2016). These sources are widely cited and/or expanded upon in other texts (see, as examples, Wanda Strauven's *Media Archaeology: Where Film History, Media Art, and New Media (Can) Meet* (2013), Michael Goddard's *Opening up the black boxes* (2015) and Morten Riis' *Machine Music* (2016)) and generally reference a similar lineage. To summarise, early writers cited as being influential in media archaeological thought include Walter Benjamin, Siegfried Giedion, Ernst Robert Curtius, Dolf Sternberger, Aby Warburg, and Marshall McLuhan. [6][5][38]

2.2.2 Media Archaeology. Old New Beginnings in the Age of New Media

Timothy Druckery contends that an historiographic laissez-faire approach has contributed to an oversimplification and imprecision concerning certain narrative histories of media. He states that history is "not merely the accumulation of fact, but an active revisioning, a necessary corrective discourse, and fundamentally an act of interrogation—not just of the facts, but of the displaced, the forgotten, the disregarded." [38]

Media archaeology emerged during the 1990s as a reaction to the progressive trajectories of historical media technology narrative. As an approach to the critique of contemporary media culture and history, media archaeology encompasses a range of different approaches and attitudes to technology. Ben Roberts notes such approaches and attitudes range "from those that seem to embrace a certain kind of technological determinism to others that use archaeological perspectives to critique the idea of progress and produce nonlinear accounts of technical history." [39] In this way, this broadly based, if loosely defined, research field investigates the meaning of newness in new media through the lens of apparently obsolete, overlooked or poorly understood media practices [5].

Erkki Huhtamo argues that the critique of new media is a response to a 1980s postmodernist discourse that whilst "roaming (to the point of plundering) the storehouse of history" certain historical inscriptions of cultural artefacts have been erased. [19] He states that history belongs to the present as much as the past and, thus, can be perceived as being a mediator and a 'meaning processor' operating between these temporalities. In this sense, rather than see history as a "locus of infallible truth", Huhtamo suggests our conception of the past can be directed by the types of questions we ask. [19] He posits that by approaching media history as a conversational discipline that negotiates with the past, our perspectives of it as a series of rectilinear successions can be expanded to include those traces that have escaped the dialectic. For Huhtamo, media archaeology is the study of "cyclically recurring elements (as topoi) and motives underlying and guiding the development of media culture" by excavating the "ways in which these discursive traditions and formulations are imprinted on specific media machines and systems in different historical contexts." [19]

Siegfried Zielinski's mistrust of historiography is a symptom of what he sees as the neglect of media historians to recycle the pile of debris of the past. To avoid "burying uncovered manifestations of the living underneath strict linear orders" Zielinski suggests that by intervening in the universal narratives of historical discourse we can expose the "potential and possible diversification" of meaning that have been ignored or suppressed by textual histories. [40] In this way, he posited that an archaeology of media would be a "method of foregrounding the resistant local discursivities and the expressions and conceptualizations of technologically based imaginings and worldviews that are at work within our largely linear and chronologically constructed history." [40] To this, his early media archaeological method advocates a two part approach comprising an historical theoretical 'gaze' to expose alternative histories and the development of aesthetic strategies applied for creative expression within contemporary artistic practices.

In the intervening decades since the emergence of the term in Huhtamo and Zielinski's early writings, media archaeology's tendrils have touched an increasingly diverse range of media. Despite this reach and the increasing number of works published under the term media archaeology, answering the question of what is media archaeology remains somewhat elusive. There continues to be disagreement about whether it is an approach, a model, a project, an exercise, a perspective or a discipline and, for some, it has remained an undefinable research approach with inconsistent features. [34][22] Indeed, Michael Goddard contends that these debates, contestations and evasions render any "stable delimitation of the field at the very least problematic." [36]

2.2.3 The Head or the Hand? A Material Media Archaeology

While some see that the "methodological repertoire of media archaeology has been geared to discourse analysis", media archaeology allows for the exploration of the material possibilities of obsolete media through an engagement with the physical artefact. [41] The rather generalist and problematic binary division of socio-culturally oriented Anglo-American studies and the technical approach of a somewhat misleadingly termed German school of thought that splits these two perspectives is seen as a consequence of different readings of Foucault. Although influential in media archaeological thought, the earlier works of notable German socio-cultural thinkers such as Benjamin appear aligned to a non-German perspective. A somewhat mediatic technological determinism of the German school is influenced by Friedrich Kittler. His contention was that "discourse analysis cannot be applied to sound archives or towers of film rolls" and is considered a call to encompass other forms of storage, transmission and retrieval beyond that of written text. [42] This approach is seen to counter Foucault's focus on words and libraries by understanding more media-specific ways of understanding culture.

Discussing different media archaeological methodologies, Wanda Strauven proposes three "branches" of media archaeology: film/media history, media art and new media theory. [22] The remainder of this review focuses on the latter two branches, and specifically the *performative materiality* of objects within these, in relation to the research focus of this thesis. As Paul Rekret reminds us, if we separate the head from the hand, we risk producing an abstracted knowledge that does not connect with the art of working with the material and the knowledge of the craftsman derived through direct contact with the material. [43] Engaging the hand, as a form of research practice, allows the application of alternative historical theoretical thinking to be expressed through experimentation with material media artefacts. Such an approach is crucial in the development of this research.

Matthew Kirschenbaum's material excavation of digital storage media is an example of Strauven's third branch of media archaeology. In *Mechanisms* (2008) he draws on the distinction between forensic and formal materiality as he seeks to "open up the black box" beyond the textual interface of digital media. Kirschenbaum draws on the relationship between the physical objects (as inscribed signs), logical objects (recognised as data and interpreted through software) and conceptual objects (the object we deal with at the interface). For Kirschenbaum, forensic materiality "rests on the principle of individualization, the idea that no two things in the physical world are ever exactly alike", extending his research into the "micron-sized residue of digital inscription" left on the various material surfaces of digital storage media. [44] Formal materiality refers to the codes and structures of human expression. As Johanna Drucker notes, Kirschenbaum's description is "grounded in ontology rather than performance", describing storage media's surface properties and capacities for "*what they are* rather than *what they do*." (Original emphasis) [45] For Drucker, a performative materiality "shifts the emphasis from acknowledgement of, and attention to, material conditions and structures" towards showing how forensic materiality and formal organisation are a part of the production of a work as an interpretative event elicited from those two qualities. [45] Drucker's performative materiality is central to the works produced in this research, engaging with and utilising the materiality of the artefact and the formal structures of the systems associated with these constituent parts. In doing so, each of the works evokes a spatio-temporal relationship between different media through their performance of an event.

2.2.4 Operational Enactment as Media Archaeology as Operative Engagement

A plea for new directions in media archaeological research issued by Andreas Fickers and Annie van den Oever in 2013 specifically called for an experimental approach to media archaeology over discursive enterprises through the historical re-enactment of past media technologies. [41] They called for this approach to offer "new perspectives to a better historical understanding of past media practices" as a way to "produce new historical, ethnographic, and empirical knowledge about past user practices and media experiences." [41] *New Media Archaeologies* (2019) extends Fickers and van den Oever's entreaty through a series of essays by highlighting the contribution that experimentation can make to understanding media archaeology. Again, Fickers and van den Oever argue such an approach can "stimulate our imagination of the past" through the "sensual and experiential potential of technical objects, which … has hardly been broached hitherto in technology or media historiography beyond a purely aesthetic consideration." [46]

Calls for an engagement with media through its re-enactment are not new. Arguably, an engagement with past media has been ever-present in the creation of media archaeological art. Siegfried Zielinski has suggested thinking of media archaeology as a practice, a form of activity with an emphasis on the artistic with its potential for experimentation. Through a series of projects under the heading *Variantology*, Zielinski has sought to develop new ways to perceive the relations between the arts, technologies, and sciences in collaboration with artists, scholars, and scientists from over twenty countries.[4] One purpose of Zielinski's variantology is to foreground the "expressions and conceptualizations of technologically based imaginings." [40] A provisional classification (he suggests he would discard it after its use) for his variantology of imaginary media can be included here. These media are "*untimely media/apparatus/machines"* realised in media either well before or after being invented, "*conceptual media/apparatus/machines"* appearing as concrete ideas but never realised, and "*impossible media/apparatus/machines"* that cannot be built but their significance is such that they have an impact or influence on other forms of media. [48] Zielinski's classification arises in section 5.1.3 whilst discussing Raoul Hausmann's Optophone; a device conceived but never realised.

Undertaking media archaeology research through an operative engagement with the physical media artefact excavates the agency of the machine, a shift from understanding media history through discourse alone. [49][31] Accordingly, one application of Wolfgang Ernst's media archaeology analyses "media-induced phenomena on the level of their actual appearance as physically real traces of past articulation, sonic signals that differ from the indirect, arbitrary evidence symbolically expressed in literature and musical notation." [50] Ernst argues that narrative forms of media archaeology, in their attempts to formulate counter histories to traditional media histories, often fall back into a chronological narrative description of events.

---

[4] Zielinski suggests a variantology of the media to be a body of individual related archaeological studies. [47]

By operatively engaging with the artefact, the historical object is no longer devoid of function but "actively generates a sensual and informational presence" as an expression of itself. [6] Less interested in temporal antecedents, Ernst's form of media archaeology engages with the artefact by a process of technological execution, the operative functioning of that artefact in the present. Functionally engaging with an otherwise inanimate object allows its function and actions to be considered as a "vibrant amalgam of parts" in itself and as a part of a larger assemblage, not only in its original context, but through a genealogy of connections between the past and the present. [51] As a form of non-human embodiment, *sonicity*, Ernst's neologism for the relationship between time, the technical, epistemology and the sonic, expresses the "inaudible events in the vibrational (analog) and rhythmic (digital) fields" that do not "originate from physically resonant bodies but from electro-technical and techno-mathematical processes, made audible by explicit sonification." [17] Through this engagement, Ernst argues that media archaeology adopts the temporal perspective of the artefact itself through the artefact's own processes; a technological re-presencing. He further argues that by returning media to its signal state, the act of 'unfreezing' the media can be a way of hearing a set of rich and variant sonic registers beyond those intended, hearing these sonic articulations as carriers of information. [52][53] As such, Ernst perceives a way of creating a "sonic heritage" not through the reading of symbolic transcription but by listening to the non-musical articulations of inscription media. [50] He contends that from the earliest audio recording technologies to contemporary digitally inscribed archives, the manifest interest is in a "microphysical close reading and close hearing of sound", where the materiality of recording and storage mediums reveal their own traces or residue in the inscription. [50] What he terms the 'media archaeological ear' listens to the materiality of sound as an acoustic articulation of the techno-physical performance of the artefact and its phenomenological experience as a temporal event; a partial trace of a past event enacted in the present.

2.2.5 Discussion

This section has discussed various perspectives of, and approaches to, undertaking media archaeological research. The discussion has highlighted a material or experimental approach, engaging with the media artefact as the subject of research, an approach central to the research's creative work. The following section introduces and discusses a number of sound works that either explicitly use or imply media archaeological approaches or methods in their ideation and realisation.

2.3 Media Archaeological Sound Art

The spectacle of obsolete technologies has come to provide contemporary artists with compelling imagery to reflect upon the legacies of modernism's durable network of cultural practices. [2] Amanda Groom states that:

> early 21st century art has seen a rising concern with re-presenting the past. Many artists are embracing obsolete technologies, abandoned places and outmoded materials; resuscitating unfinished ideas; revisiting documents and testimonies; and restaging downtrodden possibilities. Rather than a winking postmodern pastiche of appropriated styles, or an earnest nostalgic immersion in a fixed, absent past, these new engagements with the remnants of previous times mark a thickening of the present to acknowledge its multiple, interwoven temporalities. [54]
>
> *Introduction, Time*

Noting that media archaeology is being executed in artistic ways, Jussi Parikka attempts to articulate a creative methodology for practicing media archaeology that contextualises artworks within this field. He suggests a number of themes for resurrecting old media in contemporary contexts. Therefore, media archaeological artworks "that visually engage with historical themes" can invoke "alternative histories that offer critical insights into the assumed-natural state of digitality" through the use of obsolete artefacts including the use of media imagined or planned but never constructed. These works may "engage with emerging media cultures" by drawing on concrete archives as a means of "working like an historian" to an artistic end. A sensual engagement with the artefact, whether a past or present form of media, is a way of opening *black boxing* technologies to expose the "buried conditions of our media culture." [5] [5]

Erkki Huhtamo argues that the emergence of artists working in the "archaeological idiom" occurred in the 1990s and cites early practitioners as Paul DeMarinis, Bernie Lubell, Lynn Hershmann and Michael Naimark amongst others that incorporate explicit references to past analogue and mechanical machines in their work. [19] Exploring a media archaeological tradition in art, he argues that such challenging works have been created by artists who have

---

5 With the development of technological objects to a point where they are simply used and not understood as technical objects black boxing, in this context, refers to methods such as circuit bending and hacking techniques as a way of understanding and reutilising such technologies. [55]

done their historical homework. Bernie Lubell's media archaeological explorations of scientific instruments and other pieces of machinery are examples of combining and adapting abstract discursive knowledge to realise concrete forms of media art. [56] Inspired by Etienne Jules Marey, *Etiology of Innocence* (1999), shown in Figure 2.1, contains a hand pumped mechanism based on the heart that powers various "bouncing, breathing, beating" mechanisms. [57]

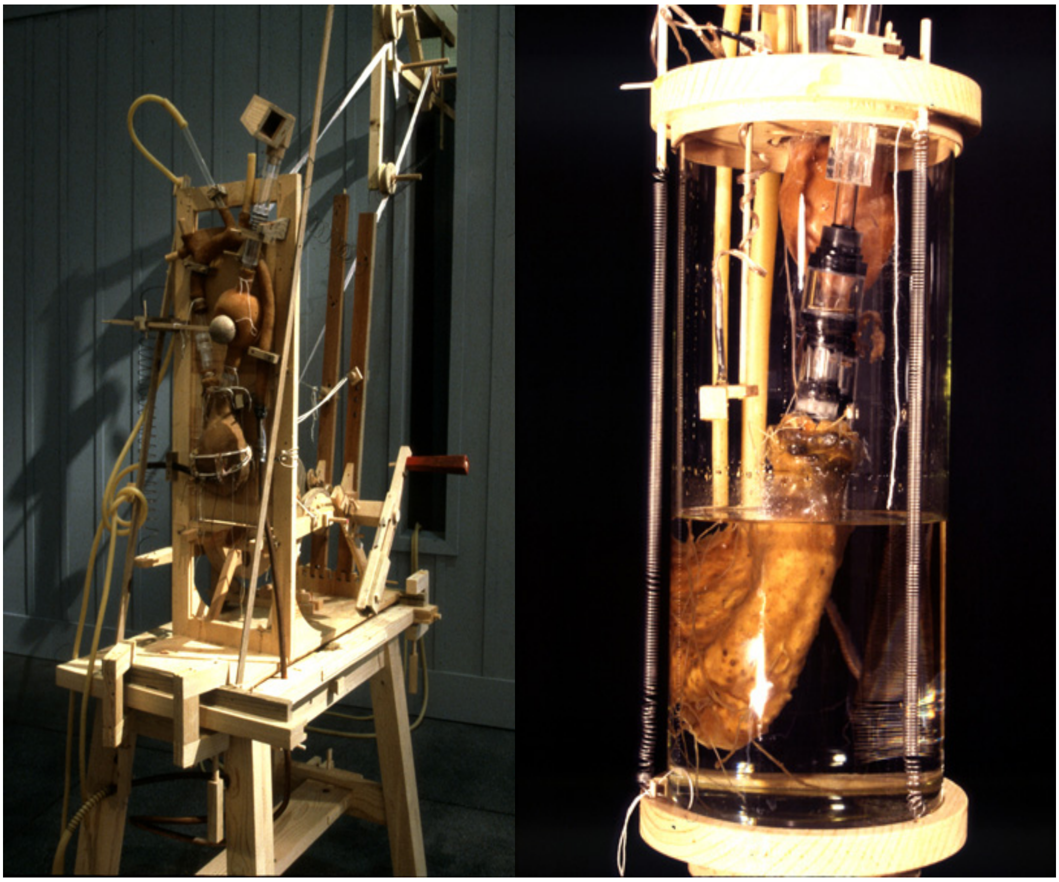


Figure 2.1. Bernie Lubell's *Etiology of Innocence*
(reproduced with permission)

Described as a 'thinkerer', Paul DeMarinis has created a large body of alternative reality works by excavating the past for little known or forgotten media. [24] As a form of *material speculation*, his œuvre draws on the "literary theory of possible worlds." [58] To this, his installations emphasise the "material or mediating experience of specially designed artifacts" by creating *counterfactual artefacts* that "occupy a creative space at the boundary between actual and possible worlds." [58] One example is *Fragments of Jericho* (1991), shown in Figure 2.2, where he creates a playful imagining of early recordings inscribed in clay pots to re-imagine the aural dimension of history. [59] Asking 'what could have happened?', DeMarinis' works embrace an experimental approach in conceptualising what is arguably a realisation pre-dating Zielinski's variantology of imagined media. More comprehensive descriptions of his work have been written (see *Buried in Noise* (2011) and *Art in the Rear-View Mirror* (2016) as examples), however an overview of selected works will suffice. DeMarinis' work ranges from the audification of invisible signals in the ether as fluctuating electrical fields (*The Pygmy Gamelan* (1973)), to the re-presentation (and sometimes remixing) of radio signals (*The Lecture of Comrade Stalin* (1998), *Walls in the Air* (2001), *Rome to Tripoli* (2006), *Four Foxhole Radios* (2000)).

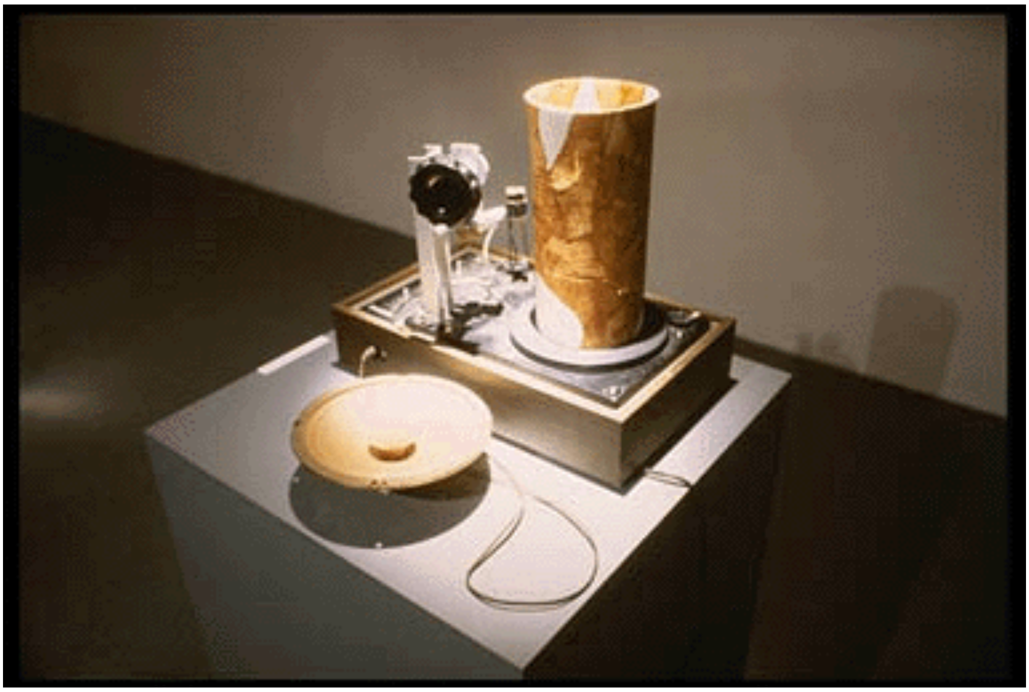


Figure 2.2. *Fragments of Jericho*, one of *The Edison Effect*'s sound sculptures (reproduced with permission)

Through these works, DeMarinis brings early experiments in radio broadcast into the present, as Huhtamo writes, "as recurring themes used as cultural agents to make sense of human encounters with the technological unknown." [24] *The Edison Effect* (1989-1996) is a series of sound sculptures that play a range of obsolete recorded media using laser beams including wax cylinders, 78 rpm records and a clay cylinder. Described as a mediation between music, memory, and time, the works defamiliarise the familiar by "distorting, de-arranging and de-composing the musical material" by merging the raw noise of the medium with the inscribed sounds to create a "havoc of misinterpreted intentions and benign accidents." [60]

The last example described is *The Messenger* (1998/2005), a "continuous enunciation of e-mail messages appearing in the artist's inbox" that are "read out, letter by letter, by three telegraphic systems" (see Figure 2.3). [61] DeMarinis provides an interpretative analysis and meaning to the work as a bridge between three different ages of sound technologies (mechanical, electronic, and digital) by presencing Don Francesc Salvà i Campillo's early telegraph experiments alongside Internet communications. The work creates an historical awareness that many of the Internet's features were anticipated by the cultural formations developed around earlier telecommunication systems. In Chapter 4. *Click:TWEET* contributes a 'fourth age' of *Web 2.0* to DeMarinis' work by presenting social media alongside early electromechanical telegraphic communications thus creating a further historical awareness of anticipated cultural formations.[6]

Figure 2.3. *The Messenger*
(reproduced with permission)

2.3.1 Through the Looking Glass of Black Box Technologies

Garnet Hertz contends that contemporary consumer electronics and information technologies are intentionally designed and concealed to render the mechanism invisible and usable. Hertz and Parikka argue that as an approach to media archaeological art, getting inside the black box of digital media that is increasingly used but not understood, is a way to "depunctualise" the

[6] Web 2.0, is often used to characterise the second generation of the World Wide Web supporting user creativity and collaboration through participatory social media applications.

object to understand the systems within it and between networks of black boxes and their interactions.[7] [55] To this, Hertz ascribes a form of mediatic hacking and reuse "within the earliest frameworks of human tool-building and creative production" and the repurposing of such media within a wider history of the readymade and collage from the early 20th century. [63] As examples, Hertz situates Reed Ghazala's *Incantor* (1978) and Tom Jennings *Story Teller* (1999), shown in Figure 2.4, alongside early examples by Marcel Duchamp, Pablo Picasso and Kurt Schwitters. Parikka states this approach starts to develop both an intensive look inside the machines and at the networks in which machines are being compiled -- and discarded." [64]

Figure 2.4. Ghazala's *Incantor* (L) and Jennings' *Story Teller* (R)
(Images courtesy of the artists, reproduced with permission)

Incantor is a series of circuit-bent Texas Instruments educational toys. Dismantling the toy and adding switches, knobs and sensors to create a new control surface, Ghazala's devices were used to emphasise the inherent instability and unpredictability of the creation, by providing new ways of triggering and modifying the chance-based sounds as a form of 'aleatoric' music. [65]

Using paper tape and an assemblage of obsolete media (including a teletype machine, paper tape reader and a phoneme-speech system), *Story Teller* recites an experimental narrative

[7] Punctualisation refers to the process by which complex actor-networks are black boxed and linked with other networks to create larger actor-networks, the process of punctualisation thus converts an entire network into a single point or node in another network. Opening the black box of technology leads the way to an investigation of the ways in which a variety of social aspects and technical elements are associated and come together as a durable whole, or black box. [62]

about the mathematician/code breaker Alan Turing. In this way, Jennings shifts our perceptions of contemporary computing work through a black box exploration of a tactile and mechanical past where information was "simultaneously digital, tactile and visual" [63]

Rosa Menkman's *The Collapse of PAL* (2010) and *Detektor* (2011) by Shintaro Miyazaki and Martin Howse are contemporary examples of delving inside the black box of media to understand and foreground the analogue and digital systems within them and between their networks and their interactions. *The Collapse of PAL* (2010) is an excavation of technical signals and signal encoding formats for colour television content that deals with obsolescence and the death of media. Signals are modulated through various video forms and fed back into themselves with a soundtrack provided by various obsolete audio devices. With a narrative revolving around Benjamin's interpretation of Paul Klee's Angelus Novus, the tension between the old and new is exemplified by depicting the PAL signal as a loser to successive and superior technologies.

If Kirschenbaum's work, described in section 2.2.3, cultivates a close reading of digital storage media, Shintaro Miyazaki has developed a close listening of signals, rhythms, noises and fluctuations in the transversal transmissions of computing and broadcast technologies. Using Ernst's sonicity as a point of departure, he develops his work within a framework informed by Henri Lefebvre's *rhythmanalysis*, the study of rhythms in all facets of everyday life. He encompasses this framework within the *algorhythm*, a neologism that "denotes the crucial, dynamic, time critical, real-time manipulative processes that happen when digital technology operate in ultra high-speed operation rates." [66] For Miyazaki, the work cultivates a close reading of, and through audification a close listening to, the technical workings of computers and their networks on the level of physical signals. [67] In collaboration with Martin Howse, Miyazaki created *Detektor*, a device that demodulates otherwise inaudible electromagnetic signals and rhythms into audible sound. Through a series of field recordings, Miyazaki's work in sonically and rhythmically exposing the infospheres that surround us is seen as a critical inquiry into the "epistemic situation of contemporary urban life in the age of ubiquitous information networks and devices." [68]

2.3.1.1 Media Archaeology and Rhythmanalysis

Miyazaki's algorhythmic approach follows Lefebvre's call to "[g]o deeper, dig beneath the surface, listen attentively instead of simply looking", to "hear beneath the surfaces of the visible." [69] For Miyazaki, his "[a]lgorhythmics is indeed referencing Lefebvre's rhythmanalysis." [70] However, he understands 'mechanical' and 'organic' rhythms as not opposites but as ends of a continuous spectrum occupied by the notion of rhythm. Whilst Lefebvre does differentiate the mechanical and the organic, he argues there is "[n]o rhythm without repetition in time and in space, without *reprises* … [b]ut there is no identical absolute repetition, indefinitely." [69] Rather than see linear repetition (the mechanical) and cyclic rhythms (the organic) as extremes, Lefebvre contends that these rhythms exist in an antagonistic relationship that interpenetrate in an continuous struggle sometimes giving rise to compromises or disturbances that superimpose themselves upon each other.

Whether as the *algorhythm, rhythmicity* (Ikoniadou, 2014), *rhythmedia* (Carmi, 2020) or *algorhythmic governance* (Coletta and Kitchin, 2016), amongst a number of terms used, Lefebvre's rhythmanalysis provides a conceptual point of departure for the theorisation and conceptualisation of rhythm within media archaeology and new media art of the 'digital revolution'. While media archaeology takes on media specific methodologies to engage with new media technologies (see as examples, Parikka 2012, Ikoniadou, 2014, Berry and Deiter, 2015), rhythmic cartographies predominantly remain within the realm of software, digital communications and algorithmic media cultures. For example, Brian House's media archaeological excavation of the 'machine listening' system *Wavenet*, a deep neural network for generating human-sounding audio in text-to-speech systems, is framed within a rhythmanalytic context. [71]

Lefebvre never directly considered the role of non-humans in the urban milieu. However applying his idea to connect the embodied analogue rhythms of the human and non-human is a point of departure for a rhythmanalytical approach to the ideation and realisation for media archaeologically-informed electromechnaical sound-based art. As practice-based research, a rhythmanalytical approach to the development and production of sound-based artwork is core to the research theme of this thesis. This process is elaborated in the following chapters.

2.3.2 Discussion

This section has introduced creative methodologies for a media archaeological approach to contextualising artworks within this field alongside some specific examples of such works. The section has also introduced media hacking as an artistic form of intervention to delve inside the black boxes of contemporary media technologies, exposing their internal componentry and mechanisms to creative forms of appropriation. This approach has been exemplified by works that have exposed analogue and digital signal systems connecting with themes of obsolescence and materiality of otherwise invisible or immaterial communication media. One such approach to the inquiry of digital media cultures has been informed by Lefebvre's rhythmanalysis.

However, this approach can be extended for the ideation and creation of sound-based media art. The following section builds on the concept of exposing and foregrounding forms of media. As a way of engaging with the material presence of contemporary and obsolete media the themes are considered to be a key aesthetic element utilised in sound-based art.

2.4 The Artefact as Visibly Present Sound Object in Media Art

'Demagnetising' the image from sound as a part of *acousmatic* and *musique concrète* practices has seen reactions from sound artists that have sought to expose and foreground the sounding object as a significant part of their works. [72] The visibly present object is an essential aesthetic element of the object-based sound installation and, as previously discussed in section 1.3.2, could be seen as a (re)turn to *l'objet concrèt*, while at the same time being a turn away from the dematerialised *l'objet sonore* of Schaeffer's musique concrète. It is in this context that the object forms an essential and aesthetic element of this research.

The term *object-based sound installation* was defined by Ethan Rose to categorise the type of installation that "engages an audience by actuating a visibly present object" with the intention for these types of installations to "translate the transformative powers of the sound studio into visibly embodied articulations." [13] He argues that technological developments (both mechanical and electronic) have, in some cases, removed the performer from the performance. This has been most evident in the use of recorded technology and the transformative qualities of the studio that disassociated sound from its source creating an "idealized form of absolute sound." [14] Rose sees the emergence of object-based sound installations as a reaction from sound artists that have sought to expose and foreground the sounding object as a significant part of their works by embodying the physical object as a key component of the sound-based work. An example of Rose's categorisation is his audiovisual installation *Reflection* (2012). Here, the recorded sound of a reversed bell ramps up and at the point the sound ends, an electromechanical bell opposite the speaker is struck (Figure 2.5). Rose states the "temporal manipulation seamlessly shifts the objects' sound between its material presence and its altered reproduction." [73] Through a series of examples as a way of translating studio transformations into visibly present performative objects, Rose connects performance and automated mechanical instruments and installations as the mechanical representation of electronic recording techniques (repeating forms of single sounds, cut/copy, paste, loop etc). Exposing and foregrounding the material object(s) provides a visual emphasis on the sound-producing source highlighting the object in its material form as a key aesthetic element of the work.

Figure 2.5. Ethan Rose's *Reflection*
(reproduced with permission)

Further examples include Dmitry Morozov's *r x2* (2015) use of seismic data to excite acoustic drums, several sound works by Thessia Machado using electromechanical objects and discarded electronics (as examples see *[[[roomtone]]]]]* (2013), *transcient modes & antinodes* (2019) and *pitch & yaw* (2017)). Indeed, Morozov acknowledges a media archaeological approach in some works, including *Metaphase Sound Machine* (2015) which references Nick Herbert's 1970s research into quantum entanglement and computing and *Phantom* (2019) with reference to early research into television and electronic instruments through Nipkow discs and the theremin.

Rose's categorisation is one physical manifestation of a material approach to media archaeology. However, this perspective is not unique. Establishing a frame of reference that includes the iterative use of visibly present sound objects, '*sound-based brutalism'* offers a similar approach with a diverse range of artists presenting the object as the aesthetic focal point of their work.

2.4.1 The Visibly Present Artefact in Sound-based Brutalism

In common with Rose's categorisation, sound-based brutalism considers the visibly present object as an aesthetic element in sound-based works. Revealing the object's materiality represents the material's own inherent qualities and functions and, as such, are "not articulated by a governing musical 'discourse'." [74] Coined by sound artist and researcher Mo Zareei, sound-based brutalism is a shared set of aesthetic principles encompassing a diverse range of audiovisual works connected through common elements: a radically stripped down focus on basic sound-generating mechanisms and material, and their presentation through grid-based structures and repetition. [74] A visibly present object to explicitly connect the sound to the sound source and the iterative use of individual sound types are aesthetic elements used by a number of artists in their creative output. No longer hidden in the background or listened to as sound "divorced from the context of visual meanings", works in this vein are foregrounding the sound-producing object reduced to its raw material form as a key aesthetic element. [13] An explicit realisation of this aesthetic approach is *The Brutalist Noise Ensemble* (Figure 2.6), a series of sound sculptures developed by Zareei. [75] The reductionist, raw, and minimalist features of the sculptures, as well as the harsh, monotonous, repetitive clicks, clacks and whirs of the motors and actuators are reminiscent of Brutalist architecture's non-decorative and 'anti-beauty' approach towards raw material.

Figure 2.6. Mo Zareei's *Brutalist Noise Ensemble*
(reproduced with permission)

Exemplified by Zareei, mechanically produced audiovisual works by Martin Messier, Zimoun and Nicolas Bernier are also examples of Rose's object-based sound installation that foreground the sound producing object, and in the case of Bernier, exhibit media archaeological characteristics in the approach to research for his works.

Zimoun's iterative use of the sound producing object creates layers of sound as evidenced in his many creations using prepared d.c. motors and cardboard boxes and various other sounding objects. [76] Messier's *Sewing Machine Orchestra* (2011) is a striking audiovisual work utilising Singer sewing machines. As an installation piece, the work gives the impression of new life occuring in old technology as the light and early sounds seem like a quickening heartbeat. [77] Similarly, his appropriation of 8mm projectors in *Projectors* (2014) allows him to use the rhythmic sounds of their mechanics, whilst presenting them in skeletal form against a stark backdrop. [78] The projectors do not project as Messier uses their sonic artefacts in a coordinated audiovisual performance. In *Boite* (2008) and *Dans la ventre de la machine* (2011), Bernier's works visibly embody the articulations of recorded sound, creating the link between sight, sound and body that is essential to Rose's conception of the object-based sound installation. Of interest in *Boite* is the exposure of the concealed mechanisms of Russolo's original *Intonarumuri*, a set of acoustic noise making instruments. By exposing the instrument in this way, Bernier's *Boite* connects with Rose's notion of the visibly present object. However, without understanding Bernier's intention for the use of past media and historical texts to inform them, connections with their historical contexts are not explicit in the works.

Two key elements differentiate the object-based sound installation and sound-based brutalism. First, Rose's category appears to exclude genres and characteristics encapsulated within Zareei's sound aesthetic, for example, microsound, solely computer-produced compositions and where there is no explicit physical relationship between the sound and the accompanying visual element. Second, works in Rose's category express the inherent rhythmic qualities of the artefact rather than adhere to a rhythmic grid. To this end, Zareei extends Rose's ideas, under the term "*audiovisual materialism"*, to describe "sound-based practices that integrate some form of physical material, objects or artefacts, and fully embrace their visual qualities to provide multisensory experiences that are rooted in a synergy between the audible and the visible." [14]

2.5 A Representation for Media Archaeological Sound-based Art?

As previously noted, Zareei's brutalist sound aesthetic has some specific aesthetic tendencies that may not be materially representative of a physically present object. However, both Rose's and Zareei's characterisations of the object-based sound installation and an audiovisual materialism support Kelly's contestation of a digital fatigue (previously discussed in section 1.3.3), in which he argues for a hands-on approach to the physical engagement with the materials that produce sounds. [15] The lens through which Zareei proposes viewing certain forms of sound-based art can be one perspective for extending media archaeology's material approach into a variety of sound-based disciplines. [14]

A contemporary sound-based work engaging with the themes of media archaeology outlined by Parikka and Ernst's through an engagement with the artefact and with Zareei's audiovisual materialism is Morten Riis' *Steam Machine Music* (2010). Situating his work within post-digital glitch, Riis gives the machine's material physicality a pivotal role in its performance via an aesthetic of failure as a way to foreground the musical and mechanical errors associated with instability. Taking the role of a mechanic, Riis contends this is a way of getting closer to a "more diverse and complex physical understanding of the machine" as it only "reveals its logic when it breaks down." [79] He contends this to be complementary to the symbolic notion of predetermined functionality of machines concealing their functionality through the lack of an interface. Riis writes "the malfunction of machines is a constantly continuing factor for the use and existence of technology", as evidenced by the "inevitable errors of the machine through the pre-electronic case of mechanical music." [80] He argues that by turning a media archaeological ear to the tempi and tonality of the machine, we hear what Kittler calls the techno-historical event. His work is conceptually interesting with his use of a steam powered DIY instrument made from Meccano and music boxes (Figure 2.7). Using historical discourse to inform his presence, Riis gives human agency to the techno-historical event that from Ernst's perspective should be enacted by the performative presence of past media.

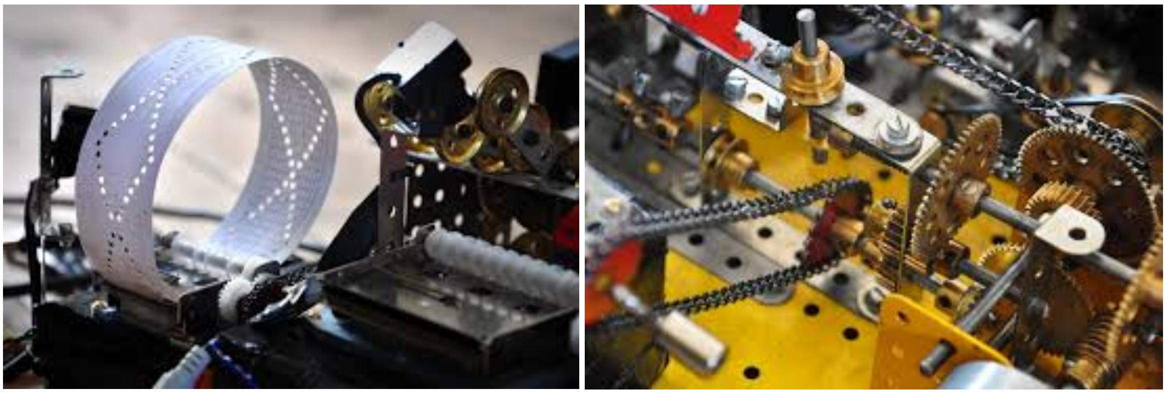


Figure 2.7. *Steam Machine Music* Instrument
(reproduced with permission)

A further example of media archaeological sound-based art foregrounding the visibly present object are installations by Stephen Cornford. His media works utilise consumer electronics to critique the ideologies they embody and the constitutive role they play in our lives. [81] Utilising the audio visual properties of a range of media, *Binatone Galaxy* (2011), *Migrations* (2014) and *Constant Linear Velocity* (2016) consider obsolescence not as an end but an opportunity to reconsider the function potential of abandoned devices and their movement from production to pollution. In his sculpture *Archipelago* (2013), Cornford inverts the normal role of disused CD players turning them into a "network of nervous electronic eavesdroppers" as receptors of sound. [82] Examples of these works are shown in Figure 2.8.

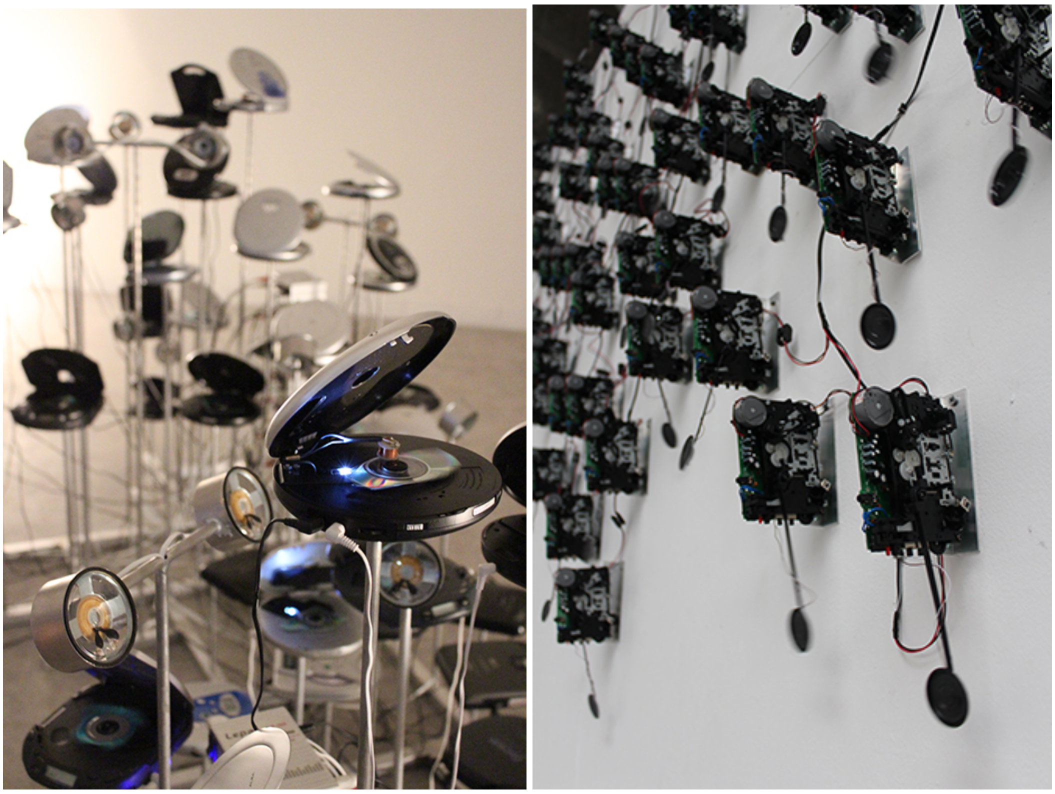


Figure 2.8. *Archipelago* (2013) and *Migration* (2014) by Stephen Cornford
(reproduced with permission)

2.5.1 An Implicit Media Archaeological Practice

Noting that history informs the practices of a number of contemporary audiovisual artists, Nicolas Bernier writes that, from antiquity, humans have sought to establish relations between sound and vision that sit somewhere between art and science, citing as examples Castel's Ocular Harpiscord and Wilfred's Clavilux. [83] Bernier's works exhibit some parallels with media archaeological approaches to research by, as Parikka notes, visually engaging with historical themes and drawing on concrete archives as a means of working like an historian to an artistic end. Whilst not specifically referencing a media archaeological method, Bernier's approach has led him to imagine past and future stories embodied in the object and draw inspiration for his sound-based art from historical ideas and objects. [84][85] Reflecting on his creative relationship with sound and light in his series of works *frequencies* (2011-2017), Bernier draws inspiration from science, historical archives and figures (e.g., Lissajous, Hermlotz) and science fiction. Two examples from the series are shown in Figure 2.9. Referencing *frequencies(a)* (2012) and *frequencies (a/continuum)* (2016), he notes the physical layout of "tuning forks … arranged in a serial and linear fashion on a light table" (and the controller in the latter) appears as an oversised keyboard allowing streams of light to burst in synchronicity with the struck forks, evoking a relationship with Castel's harpiscord. [86][87]

Figure 2.9. Nicolas Bernier's *frequencies(a)* and *frequencies (a/continuum)*
(Images courtesy of the artist, reproduced with permission)

2.5.2 Discussion

This section has discussed characterisations for sound-based works that engage an audience by actuating a visibly present object and embracing their visual qualities as a part of a multisensory experience. Alongside examples of such works, a media archaeological perspective has been introduced as one method for their representation. By way of contrast, a series of installations by Nicholas Bernier have been exemplified that, in the artist's approach to research and materials, are implicitly media archaeological. In these installations Bernier foregrounds and emphasises the sound-producing objects and their tightly coupled relationship with light utilisation in his examination of the relationship between "music, sound, old and "new" technology" as a further example of audiovisual materialism. [88]

Connecting with Kelly's call for a physical engagement with materials, Drucker's performative materiality of the physically present artefact as a form of media archaeological re-enactment, can call on us to think about the entangled history of where it has come from and where it ends up. Shifting the focus from sound-based brutalism to the wider lens of audiovisual materialism as a set of sound-based practices provides media archaeology with a method of representation for media archaeology-informed sound-based art; one not constrained by specific aesthetic tendencies associated with a sound-based aesthetic.

The next section discusses the differing perspectives of data sonification within the auditory display community and is presented as context for the sometimes-contentious relationship between its use in scientific and artistic forms of exploration and expression. Following that, the use of data sonification is presented as a specific tool for creativity and expressivity in media archaeologically informed sound-based art.

2.6 Data Sonification: Listening for Meaning

Data sonification has been defined, and variously described, as a way of communicating information by translating data relationships into sound. By exploiting the human auditory system, sonification can provide a way of exploring, analysing, and/or interpreting the sonic potential of listening to multivariate or time series information. As some information may be difficult to understand in visual forms, sonification can be an alternative method of representing data, models, and processes. [89][90][91][92] Successive attempts have been made to define sonification since the initial working definitions were proposed in the early 1990s. The following definition was provided in the 1999 National Science Foundation Sonification Report. [93]

> Sonification is defined as the use of non-speech audio to convey information. More specifically, sonification is the transformation of data relations into perceived relations in an acoustic signal for the purposes of facilitating communication or interpretation.

Although this remains one of the most cited definitions for sonification, Thomas Hermann finds this definition problematic. [94][95] He suggests that the definition limits sonification only to the mappings between data and sound, and is also challenged when used in the arts and music. He contends that important differences between sonification and music are not manifest in this definition. Drawing an analogy with visualisation, Hermann suggests that while music can be listened to for different layers of interpretation, sonification is expected to have a precise connection to the underlying data. His proposed definition sought to narrow the field. [96] His single phrase definition states:

> Sonification is the data-dependent generation of sound, if the transformation is systematic, objective and reproducible, so that it can be used as scientific method. [8] [98]

Alexandra Supper argues that limiting the field to a scientific method reduces subjective intervention to a "mechanistic objectivity" and effectively denies the existence of "artistic sonification." [94] However, Carla Scaletti counters this, arguing that whilst they share technologies and techniques, a distinction between data sonification and "data-based music, data-based sound art or simply music" is the difference in intent. [99] She describes the purpose of data sonification as the discovery of something new about the original phenomenon that produced the data, whilst using the terms data-based music, data-based sound art or simply music to describe the "use of data as a component of artistic expression." [99] However, Scalleti's use of *music* to differentiate data sonification from other forms of data-driven works appears reductive of the types of works that share this distinction. Instead the term *sound-based music* opens up the "boundaries of music to all forms of sound organisation." [100]

Proposed by Leigh Landy, the term sound-based music applies to works in which sound is the basic unit where "the majority of the content is not based on the traditional note-based paradigm." [100] He highlights a broad range of categories and genres related to the term. Works that use data in the generation of sound can be included in this categorisation. He also notes that in making the works accessible to an audience, a number of techniques can be utilised to give an audience "something to hold onto", in other words, to enhance accessibility. [10] Some of these techniques include the application of a limited number of sound parameters and textures and with a homogeneity of sound. Examples of the use of these techniques are evident in this research's works to assist in making them accessible to an audience and conveying artistic intent. Noting the different approaches that arise from such an interdisciplinary research field, the tensions that exist between science and art, and discussions of developing and using a common language to integrate the field, divergent ways of thinking can open up new creative potential and ideas. [95]

2.6.1 The Musification of Data

Marcel Cobussen notes the result of sonification processes may not necessarily be "attractive to listen to". This supports Paul Vickers argument for incorporating musical elements to engage

[8]For a full definition and discussion, please refer to [97]

and hold audience attention. [101] Such an approach has been described as the *musification* of data, defined as the representation of data through the musical interpretation of source processes or a course of events in the data. [102] Further to this, Grond and Berger speak of musification as the use of sonification for artistic output. [103] Cobussen notes that the tension between what amount of the musical aesthetic to include in relation to the information transfer and signification goals of sonification remains unresolved.

If the data source is made explicit, can the source phenomenon be better understood, and can the listener comprehend the composer's intention? Aligning the data source and sonic experience to audience perception using a sonic metaphor can provide a context for understanding and interpreting a sonification-based work. This approach, as Landy argues, can increase accessibility to the work's intent by giving the audience "something to hold on to". Offering an experiential link between sound and source can be one way of doing so and increase an appreciation of the work. Dynamics, pitch, and rhythm as single parameters of sound, timbral or textural homogeneity, or a visual element in relationship to the sound are just some such access tools for increasing this engagement. [10] However, Scot Gresham-Lancaster argues that a perceptual connection does not need to be apparent as the most musically satisfying results are rarely so obvious. [104] He contends that the "real interest is manifest in the discovery of unpredictable and emergent sound qualities" resulting from sonically interesting and abstract interrelationships between the source data and the sonic output of a given process or set of processes. Grond and Hermann note that sometimes it is not the sound itself that catches our attention, but the technological apparatus that produces or projects it giving an audience something to hold on to in Landy's terms. [96] They further state that the apparatus producing or projecting the sound is an attractive point of access to the work and creates a strong context that influences how we perceive the sound.

2.6.2 Balancing Musification with Meaning

The adaptation of data sets as series of patterns to capitalise on the ear's ability to detect anomalies that might 'pop out' of a continuous stream of data is an aesthetic strategy for the musification of data. This approach incorporates features that represent more traditional elements of music such as melody, harmony, and rhythm. [105] An argument for this musification is to make the underlying data more palatable and more familiar within cultural contexts. As such, music, its systems for the organisation of sound, and its aesthetic values have influenced sonification designers. [106] Gresham-Lancaster argues that, as music is an important part of everyday life for a large number of people, framing data sonification within musically stylistic forms can be one method of highlighting/framing familiarity and difference in data patterns. [104] Barass notes that musification "has narrative qualities that can convey … affective musical dimensions of valence and arousal" as a basis for affective sonification. [91] To this point, the use of melodic and harmonic material to create continuous or chromatic scales which represent data points may produce harmonically consonant or dissonant sequences. Similar concepts apply to rhythmic alignment, symmetries in phrases, or timbral balance. Tsuchiya et al. state, "[w]ith daily exposure to music, it is difficult to assume that the listener's ears are free from such musical perceptions." [107]

However, attempting to achieve a stronger (and more familiar) mode of musical expression can have the negative impact of masking the communication of essential information. If data is *over-musified*, its essence may be displaced by music and by doing so the significance of sounds are reduced. In this process, the goal of communicating information is subverted by the pursuit of aesthetic interest. Just as listening to the unvarnished output of a data set can be intrusive and tiresome for some people, the overuse of musical information also risks presenting a sound that is beyond the perceptual abilities and immediate grasp of a non-musical audience, because the sound and data source cannot be connected. [104] To this end, it has been suggested that, whilst embracing elements of aesthetic representation, giving an audience a 'sense' of the underlying data which is less about hard facts and "more how it might serve as a stimulant for curiosity" may be an appropriate compromise. [108] One way to negate the over-musification of data is to reduce the elements used, as suggested by Landy, when representing data. His use of single parameters of sound or timbral homogeneity as a reductive process, is an aesthetic strategy that can be applied to data sources in a number of artistic works including this research.

If a section of the auditory display community disagrees on aesthetic principles and the musification of sound for expressing data relationships, perhaps it is time to step outside that community to consider another perspective, which is to interrogate data utilising the material and physical elements of sound. Media archaeology, as a form of spatio-temporal conversation, can create an understanding of physical media that carries the past into the present. [55] Introducing sonification techniques as a method of interrogation within media archaeology provides additional insights to historical relationships through sound. Paraphrasing Gresham-Lancaster, these relationships between the past and present may lead to the discovery of non-linear engagements between obsolete and current technologies expressed by this kind of sonic relationship and certainly this is the aim of my research. As discussed in the next section, from a material media archaeological perspective, data sonification can be utilised as a technique for transforming and aiding the organisation of sound. This discussion is provided as context before elaborating on my approach to the representation of data in the portfolio of sound-based works developed in this thesis.

2.7 Towards a Data Sonicity for Physically Present Media

Ethan Rose critiques the use of technology's transformative qualities, arguing that they can disassociate sound from its source. In common with this, a culture of expression using technology has been developed in data sonification for manipulating and presenting data. Such an expressive use of technology through the development of systems, processes and tools manipulates data flows and synthesises sounds to create an "impressionistic wash of sound" as a tangible experience of the sonification of data. [104] However, abstracting the sound from the source in this way can bias our understanding, especially when we consider the context in which the sounds originate, the place in which we hear them, and how our experiences are mediated by technology. [109] Concerned with the "disingenuous arbitrariness of sounds" assigned to data, Norie Neumark questions sonification's disregard for the voice of the underlying data source. [110] She argues that sonification's over-aestheticisation of sound, in a move to make data "sensible and meaningful", is a 'denaturing' of sound and is one outcome of the many ways that data can be translated. [111] To this, Neumark suggests an approach that, by bringing back the voice of the "machinic and technology, … we can listen to machines voicing themselves." [110]

Some sonification strategies involve representing something that lacks a natural reference point. In parallel, explicitly representing data through a physically present artefact is a strategy that acknowledges the representation of sound as more than just itself. This approach can be used to specifically connect sound and source through historic cultural and technical relationships. In the absence of a strong melodic and harmonic material that may occur through the physical use of an artefact's sonic byproducts (in other words, in the absence of musical pitch), a sensitivity to, as well as changes in, repetition and rhythm can be exploited to indicate changes in the state or value of sonified data. [112] As an aesthetic strategy in sonification, rhythm as repetition allows us to establish patterns of similarity and difference. Elizabeth Margulis argues that musical repetition can be "*involving* - like a call and response", inviting listeners "to participate in the phenomena" by tracing out a musical path and then representing it for the listener to follow. [113] The rhythmic form and familiarity of events through repetition produces a pleasure in the listening experience as an audience becomes cognitively aware of new elements or patterns as they emerge. If, from a musical perspective, repetition exposes temporal interrelationships then such repetition and familiarity of rhythmic events can give a sense of form and structure of the listening experience to sonified data voiced by the visibly present object itself.

Representing familiar things in unfamiliar ways through artistic methods may impart a sensation of things as they are perceived and not as they are known. [114] In part, data sonification is a process of making data unfamiliar by translating it, transcoding it and remediating it so that we hear elements of the data that our familiarity with visual modes of expression may blind us to. [115] Changing the way data is perceived can establish new forms of expression outside its normal utility as a stimulus for curiosity. However, if, in the process of this deformance, the resultant sound palette is unfamiliar to the listener, the subtlety of the work will be lost. Likewise, if the connection between the sonified output and the data source is not clear then the value of sonification as an artistic tool may be lost. Hence, the value of the visibly present object to represence the data. One approach to making the data familiar again is to perceptibly connect the sound and source. As an art practice, the object-based sound installation – which works with physical artefacts, rather than sound alone – can be one way of making the unfamiliar familiar again through by the presence of the object within the work.

2.7.1 Discussion

This section has discussed the tensions between sonification as a scientific method for understanding underlying data and as tool used for artistic expression. As a creative tool the use of musical elements have been utilised to make the sonification of data more palatable to listen to. However, in doing so, some proponents argue that the over- musification of data can render the connection between the data source and the sounds used to represent it less meaningful. One way of overcoming this is, as Neumark states, to allow the machines to voice themselves.

A deformance through a media archaeological convergence of obsolete and current media technologies and the re-presentation of data from one medium to another, both physically and sensually, is an approach used throughout this research's works to defamiliarise common historical narrative. [34] Supported by the sonic rendering of data, the presence of traces, residues, or resonances of the past can be established through connections between existing means of expression and/or material. Scaletti's own reflection on her previous statement (see section 2.6) is that if the sound is data-driven, it is "not sufficient justification for calling it sonification; it must also have been done with the intent of understanding or communicating something about the original domain." [116]

2.8 Summary

It is not the intent of this review to exhaustively cover the range of possibilities for media archaeological sound art. Even whilst focusing on activities of tactile engagement with media artefacts as an approach to the creation of sound art, the field is increasingly diverse and, at times, it is difficult to distinguish between what is explicitly intended as media archaeology and those works that exhibit characteristics of these approaches. As such, this review brushes lightly over 'do-it-yourself' approaches, circuit bending and hacking as potential archaeological approaches. Bruce Sterling's *Dead Media Project,* which Garnet Hertz attributes as an influence in his work and research, is not noted as many citations in this review provide better references to this work. This review has not noted the many media labs and examples of the range of works that are produced in them. These include Lori Emerson's *Media Archaeology Lab* in Colorado, *PAMAL* in France, Garnet Hertz's *Concept Lab*, Hainburg's *Institut für Medienarchäologie* and the *Medienarchäologischer Fundus* at Humboldt University to which Wolfgang Ernst is attached, and the vast number of researchers and artists attached to various media and cultural academic departments practicing media archaeology. Areas unrelated to the research thesis, for example, visual media, have not been a focus for this review. Whilst intentional, it is not to write them out of any historical media contexts. As noted in section 2.2.2, the lack of any stable delimitation of the field sees its tendrils touching on an increasingly diverse range of media, one to which justice cannot be done in the constrained context of this chapter.

The chapter has provided an overview of media archaeology as a method of inquiry into, and use of, historical artefacts. With reference to Kittler and Rekret cited in section 2.2.3, this chapter has focused on material approaches to exploring and understanding media through an operative, tactile and sensory engagement with artefacts. A range of sound works that are explicit in, or exhibit characteristics of, a media archaeological idiom have been provided as illustrative examples. Some of these highlight the diversity of representation and use of obsolete media, not as some retro-maniacal form of nostalgia, but as a constant reminder of the perpetual presence of the past in the here and now. Others have exposed the materiality of seemingly immaterial forms of contemporary digital technologies through analysis and audification of signal processes. Such methods of inquiry and engagement with obsolete artefacts have provided key insights into approaches that have contributed to informing this research.

Media archaeology is not a genre. As already stated, it is a *bricoleur*, borrowing and re-using available materials as necessary to solve new problems. To this, the review has presented Ethan Rose's object-based sound installation as a way to visibly present and foreground the sound-producing object that explicitly connects the sound to the source. Finding similarities with Rose's categorisation, sound-based brutalism is an aesthetic in which the sonic by-products of such media can be expressed. However, this aesthetic is encapsulated within the wider representation of audiovisual materialism. Although utilising different media, a large number of the examples discussed in this review share common characteristics. The sound object is presented as a part of the works. It is this approach that forms the basis for the works developed as a part of this thesis. The research develops this further by explicitly utilising the artefact to, in some way, provide a voice for the works. The sound-based installations developed in this research are the result of the convergence of sonification and media archaeology as a method of inquiry to facilitate an understanding of relationships and connections through the socio-cultural and technical exploration of media. What is significant about this combinatory approach is its potential to affect a listener by producing unexpected relations between events, locations, or artefacts through the transduction of raw data into sonic events. Building upon this as an aesthetic element, the works foreground the historic materiality of an expressive past in the present through the lens of audiovisual materialism. This approach, as Landy argues, is one technique for enhancing accessibility to, and creating an appreciation of, this research's work. In this way, each work uncovers unpredictable and emergent sound qualities from the abstract interrelationships between the source data and the sonic output through a reductive musicality based on series of rhythmic patterns generated from its sound producing artefacts.

This provides media archaeology with a representational approach in the ideation and realisation of sound-based art and a context for the conceptualisation and realisation of the three sound-based works developed as a part of this research and discussed in the following three chapters. The next chapter discusses the first of this research's portfolio of works, *Click::RAND*, which utilises chance and computation history as the basis for its ideation.

Un Coup De Des Jamais N'abolira Le Hasard
(One Toss of the Dice Will Never Abolish Chance)
- Stéphane Mallarmé

Chapter 3. *Click::RAND*

3.1 Introduction

Expressing his scepticism of quantum theory, that nature is inherently probabilistic, Einstein stated, "God doesn't play dice with the world." [117] Someone did not tell our ancestors. Some believed an outcome determined by the use of randomisers to be an expression of God's will. [118][119] Randomisers included the roll of the dice, the casting of coins, the drawing of straws or lots or other aleatoric methods. Uncomfortable with the idea of randomness and the belief that things happen for a reason, early sentiments were that these events were God's way to explain the unexpected. [117]

Randomness, as an inherent part of the world we live in, is a phenomenon we strive to understand and control. Even the best efforts in the 20th century to capture randomness mathematically or algorithmically have yielded "no single 'true' notion of randomness." [120] Instead, a number of equivalent definitions have been proposed that contextualise randomness relative to prior notions. These include, but are not limited to, the mathematical definitions of Richard von Mises in the 1920s to Kolmogorov and Chaitin in the 1960s, Thomas Malaby's framework for understanding indeterminacy and definitions in statistics, philosophy, physics and based on social phenomena. [118][121][122][123][124]

Sebastiaan Terwijn encapsulates the milieu of random definitions in stating,

> A random object is defined as an object that is random with respect to a given type of definition, or class of sets. As the class may vary, this yields a scale of notions of randomness, which may be adapted to the specific context in which the notion is to be applied. [120]

The objective of this chapter is not to argue an exact definition for, or to provide a definitive history of, randomness or methods of random sequence generation. Rather, the research objective is to apply Terwijn's notions of randomness to the specific context of sound-based art. As media archaeology, this research approach forms a relationship between two interrelated and intertwined forms of media, the electromechanical relay and a book of random number tables. This relationship informs a conceptual and aesthetic approach for the appropriation of these media to create a sound-based installation titled *Click::RAND*. This chapter presents how the ideation and creation of *Click::RAND* have been informed by the relationship between the mechanical production and publication of large random number sets and the development of electromechanical relay-based computers in the early to mid-20th century. As will be discussed, these objects are utilised as input and output artefacts to create a sound installation as a representation of a moment in computational history where these objects' paths intertwined.

The remainder of this section introduces three themes that inform the ideation and creation of *Click::RAND*. This includes brief introductions to the use of published random number tables for probabilistic analysis, relay-based computing machines around the mid-20th century and the use of non-deterministic approaches in the arts.

3.1.1 Electromechanical Computing Takes Command

As the need grew to perform more complex scientific and engineering calculations, electromechanical calculating machines were developed based on reconfigurable systems of relays. Early examples of these include Zuse's Z2, Z3 and Z4, Aiken's Automatic Sequence Controlled Calculator MARK I-II, Stibitz's Complex Number Calculator, Bell Labs' Arithmetic Units and Condon's Nimatron. The advantages of these new calculating machines were twofold. First was the ability to perform more complex calculations than merely addition and subtraction. Second was the ability to flexibly reconfigure a circuit according to what one wanted the circuit to do i.e., to perform arithmetic, control functions or number storage. [125] As the relay, an artefact of electric telegraphy, is essentially a two-position lever, the development of notation (AND, OR, NAND, NOR, etc.[9]) to express the logical relationships of decimal numbers in binary format facilitated arithmetic and control functions for these early machines. [127] This relationship includes the capability of performing arithmetic operations on both binary and decimal numbers and both systems can represent integer and fractional numbers. For the relays performing these binary forms of arithmetic, it was a matter of activating or deactivating the relay as a series of off (0) or on (1) sequences through a series of programmatically controlled logical operations. However, the performance of these early machines was bounded by the electromechanical technology used in them. [128] This in turn limited the complexity and quantity of computations. Another issue was that the relay had been adapted from less precise communication systems such as the telex, the telegraph, and the telephone. Paul Ceruzzi notes that relays' intermittent failure, generally caused by dust, dirt or insect matter between their contacts could result in incorrect calculations that may, at times, go unnoticed. [129] Without inbuilt checking systems, calculations would periodically be re-run as an integrity check. This intermittent failure, heard as irregular rhythms, is creatively interpreted and used as a compositional element in both iterations of *Click::RAND* (see sections 3.3.4 and 3.8.2.3).

Constrained by computational performance and precision, other non-computational methods continued to be used to generate large random number data sets for use in calculations and modelling studies.

3.1.2 Large Random Number Sets in the Age of Mechanical Production

Randomness not occurring from natural sources has been characterised as taking three general forms. These are 'roll-your-own-devices' including coins, cards, dice and various mechanical devices, 'tailor-made' random numbers assembled on punch cards or in books, or 'pseudo-random' or 'pasteurised' number sets constructed in a recursively related sequence. [129] In describing these forms, John Tukey does acknowledge overlaps between them, especially between the use of roll-your-own (which I will call mechanical as opposed to computational) approaches and the production of large data sets for publication. Even before the use of electromechanical and electronic devices to perform more complex scientific and engineering calculations, demand for larger and high quality true random number sets was increasing. These number sets took the form of published tables as text and/or as series of Hollerith punch cards as input sources for calculating machines.

[9] A form of algebraic notation, operating only on 0 and 1, that defines a set of rules for logical operations on binary numbers. Described as Boolean algebra, it is the basis of all computer operations. [126]

The construction and publication of large tables of random sampling numbers was driven by a need in probabilistic experiments where the one-time generation of sufficient numbers in each case was considered slow, laborious and not without bias towards certain numbers or number sequences. In 1927, L.H.C. Tippett's *Random Sampling Numbers* became the first large random set of numbers to be published. [130] The set consisted of 41,600 numbers generated from a 1925 census report. In 1938, Kendall and Babington-Smith defined a series of tests for randomness of number sets and produced a 'randomising machine' to generate 100,000 digits published as 25,400 random four digit numbers. [124][131] In the ensuing two decades, large number sets were published to overcome the perceived "patchiness" of previous sets (a bias towards certain numbers in a sequence), the need for additional and larger random number sets (to overcome reuse of number sets), or to provide large normal deviate number sets for testing and validating random number sets. These sets varied between 1,000 and 105,000 numbers or normal deviates. Data sources included logarithm tables, survey results, lottery numbers and variations of previously published number sets. [129][119][132][133] In some cases, numbers sets were committed to punch cards for use in calculating machines and electromechanical computers.

A variety of applications for probabilistic modelling studies increased demand for larger, truly random number sets of which the quality would not be questioned and which would overcome the reuse of data sets in a model. [134] Motivated by this need in its own experimental research, RAND Corporation constructed an electronic mechanism to generate random numbers and store them onto punch cards. [128] A punch card of the type in use at RAND when the digits were generated in shown in Figure 3.1.

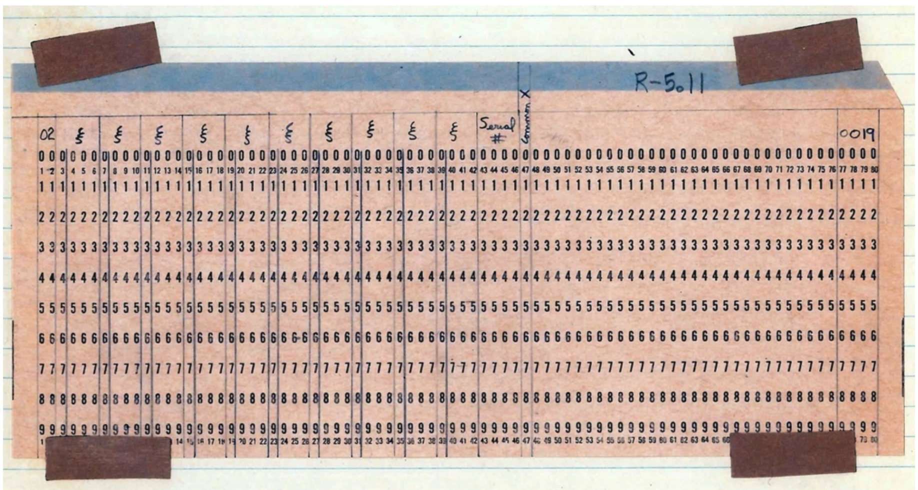
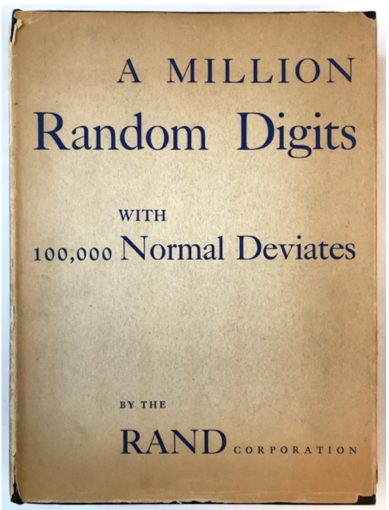


Figure 3.1. Punch card of the type used for creating deviate number tables, 1949
(Image courtesy of RAND Corporation Archives, reproduced with permission)

After testing to identify and remove certain biases, the work was completed in 1947. The random data set consisted of 20,000 punch cards each containing 50 numbers. RAND Corporation published the work as a book in 1955. Named *A Million Random Digits and 100,000 Normal Deviates*, (see Figure 3.2) the volume consisted of two large tables containing the random digits and normal deviates. [11]

Subsequently, RAND Corporation has noted the tables have become "a standard reference in engineering and econometrics textbooks and have been widely used in gaming and simulations that employ Monte Carlo trials[10]" and were "routinely used by statisticians, physicists, polltakers, market analysts, lottery administrators, and quality control engineers." [128] This book is the source stimulus for the ideation of a non-deterministic sound installation. The random number and normal deviation data sets are now publicly available from RAND Corporation's website.[11] Could this data be transformed and utilised to create a connection between the book and the electromechanical computer? This question is the basis of the *Click::RAND* research project which uses indeterminacy as an artistic construct. Before proceeding to describe and discuss the project as the creative response to this fundamental question, the next section provides a brief survey of related works of the use of elements of chance or indeterminacy in art.



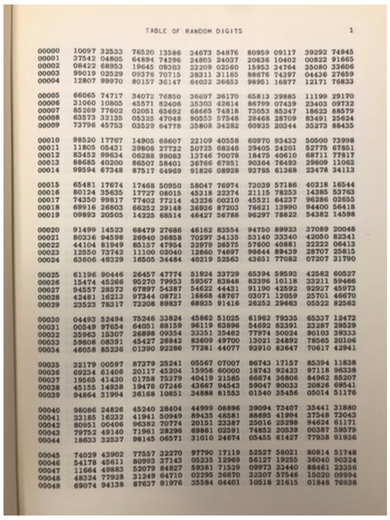


TABLE OF RANDOM DIGITS 1

Figure 3.2. Cover and first page from original 1955 printing, RAND Corporation, 1955
(Images courtesy of RAND Corporation Archives, reproduced with permission)

10 A Monte Carlo trial is a statistical method of understanding complex physical or mathematical systems by using randomly generated numbers as input into those systems to generate a range of solutions. By using larger and larger numbers of trials and larger non-repeating random number sets, the likelihood of the solutions can be determined more and more accurately. [135]

11 https://www.rand.org/pubs/monograph_reports/MR1418.html

3.1.3 The Art of Chance.

Even before Marcel Duchamp used chance methods "as a way of going against logical reality", randomness, as a creative ideal, had a centuries long history in literature and the arts. [136] Duchamp's use of chance in works including *3 Standard Stoppages* (1913-14), *Large Glass* (generally known as *The Bride Stripped Bare by her Bachelors, Even*) (1915-23) and his musical experiments entitled *Musical Erratum* (1913) allowed him to creatively conceive things in different ways. Working outside what he perceived to be a social convention of what is aesthetic or what is artistic, Duchamp considered this way of working outside those conventions as an "aesthetic of the possible". [136] The art movement Dada included chance operations in their ridicule and negation of the perceived norms of art in the early 20th century. Tristan Tzara's and other Dada (anti)poetic utterings were conceived by pulling words out of hats to create unpredictable, provocative, and occasionally nonsensical works. Tzara describes this technique in *To Make a Dadaist Poem* (1920). William Burroughs similarly described an unpredictable method of composition when he proposed his 'cut-up' technique, an approach of rearranging cut up pieces of text or words. From the mid-1950s Jackson Mac Low devised and used systematic methods including chance operations to compose poetic, musical and performance works as a way for freeing these works from his individual influences. [137] These chance operations utilised playing cards, die and the RAND Corporation's *A Million Random Digits and 100,000 Normal Deviates* to inform works such as *Sade Suit* (1959) and *Light Poems Chart* (1962). In 1952, Christopher Strachey developed his *Love Letter Generator* as a conceptual writing program for the computer. Rather than an attempt at conceptual writing in a new medium, Strachey's work was an attempt to highlight his contention that simple rules could "generate diverse and unexpected results." [138] Strachey's program randomly selected nouns, adjectives, verbs and adverbs from lists to populate a predetermined sentence template to generate his parodical love letters.

The use of stochastic methods of composing or performing music also has a long history. Some of the descriptions for these techniques include, but are not limited to, aleatoric, non-deterministic or chance music. More recent precedents for the use of these forms include John Cage's use of indeterminacy across a range of works including *Music of Changes* (1951), a work based on his study of the I Ching. In pushing the limit of indeterminacy, Cage's goal for the works was to abandon all sense of control by the composer or performer. For *4'33"* the performance was left to the unpredictability of environmental sounds. Pierre Boulez's experimentation with 'controlled chance' in works such as *Troisième Sonate- Format III: Constellation-miroir* (1957) and *Improvisations sur Mallarme* (1957) differed from the indeterminacy of Cage by only allowing a choice from a set of possibilities for the performer. Described as a loading of the dice, Boulez's saw that the unstructured, imprecise use of chance could "conceal a fundamental weakness in compositional technique" and instead sought to use controlled chance and risk within a strict structure, with limited outcomes. [139][140] Randomness also played a role in the artistic practice of Iannis Xenakis, providing new ways of composing through the use of probability distributions and stochastic techniques. He saw the use of probability functions in music as a technique for creating and articulating sound inspired by natural events and saw it as an opportunity to incorporate scientific concepts into modern music. [141] Examples include *Pithoprakta* (1954) and *GENDY3* (1991) along with his development of computer systems such as the ST Program (1962) to generate indeterminate compositions and multi-media works (for example, *Polytope de Cluny*, 1972).

The use of an indeterministic approach in electromechanical sound art allows an artist to explore the agency and behaviour of materials and objects in their works. Jon Pigott describes this as a process-driven sensibility that exhibits unpredictable sounding, non-linear and unpredictable *material* behaviours. He argues that, as a creative method, the use of the indeterminacy in electromechanical sound art adds to a sense that the artist has relinquished an element of control in the creative outcome. By letting the natural unfolding of events play a part in the creative process, "the work is free to voice the unexpected behaviours of the electromechanical." [142] In this way, the work is indeterminate with respect to its performance, differing from the use of chance operations as a form of "random procedure in the act of composition." [143][144]

Examples of the use of unpredictability in the resultant sound work include Stephen Cornford's *Migration* (2014). This installation piece uses a number of obsolete Dictaphones whose resultant sound is left to small rhythmic variations of each device's mechanism. Darsha Hewitt's *Electrostatic Bell Choir* (2012-2013) utilises the static electricity emitted from discarded cathode ray tube television monitors tuned to various channels of white noise. The oscillating polarity of static charges from the TVs energise and agitate hanging pith balls that lightly strike sets of bells. A number of Sergey Filatov's sound sculptures introduce elements of randomness generated through algorithmic processes. Examples include *Long Wave: 150-400* (2018) and *Random Tala* (2017). Zimoun's immersive sound installations include the use of everyday objects and materials along with mechanical elements such as d.c. motors. He describes his works as generating or evolving by elements of chance but does not use chance "to discover unexpected results, but to elevate the works to a higher level of vitality." [145]

3.1.4 Discussion

This section has presented a relational context between early relay-based electromechanical computers and the generation and use of large random number sets for probabilistic analysis. It has also introduced the use of chance operations in artistic contexts to show that the use of chance is not limited to scientific research. This chapter will now discuss an object-based sound installation that, through a media archaeological approach, connects the electro-mechanical relay[12] and *A Million Random Digits and 100,000 Normal Deviates* as historically related media artefacts. Titled *Click::RAND*, the work foregrounds the relay as the sound-producing object and uses the sonic by-products of a series of relays to create a sound installation. Thus, the work is an audiovisual representation of distinct, but genealogically related, forms of media. The chapter discusses various conceptual and technical components and processes that have been developed for the realisation of *Click::RAND*.

The next section briefly introduces *Click::RAND*. The first iteration of the work is described in section 3.3. Following a brief reflection of the first iteration, section 3.4 presents and describes the reconceptualisation and redevelopment of *Click::RAND*. Following this, the current iteration of the work is described. This latter section describes the technical, aesthetic and compositional elements of the work. Following this is a discussion of *Click::RAND*'s audiovisual connection between published random number sets and electrotechnical calculating machines as a part of the continuum of computational development. The chapter concludes with a brief summary.

3.2 Click::RAND

Click::RAND has been conceptualised as a sonic articulation of RAND Corporation's book, *A Million Random Digits with 100,000 Normal Deviates*. As an object-based installation, the work repurposes and foregrounds a series of relays as the primary artistic materials. An example relay used in the work is shown in Figure 3.3.

[12] A relay is an electro-mechanical switch that controls one circuit by opening and closing another.

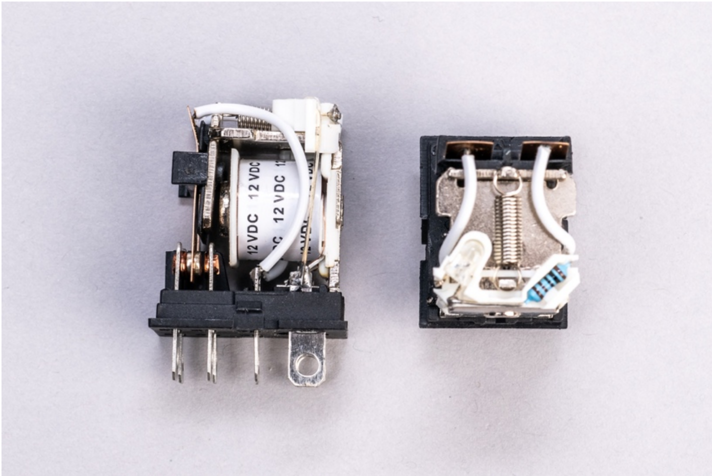


Figure 3.3. Single Relay with LED

Click::RAND uses the sonic by-products of the relay as the raw material to create an object-based sound installation utilising the random digit and normal deviate sequences contained in two file-based data sets. The primary sound is heard as a double click when the relays' contact points engage and disengage. This reductionist approach, previously described in section 2.4.1, highlights the relay's sonic characteristics and, as such, the compositional palette is very limited. The work has been developed through an iterative process of conceptualisation and development, culminating in the sound installation described in section 3.5.

3.3 *Click::RAND*, the first iteration

*Click::RAND'*s use of ten relays as an expansion of the single relay is a way of expanding the sonic palette and exposing the slight nuances of each relay. This form is shown in Figure 3.4. The series of ten relays represent digits from 0 to 9 (left to right) which, in turn, represent each random digit used in the book, *A Million Random Digits with 100,000 Normal Deviates.* As a sound installation, each selected random digit engages the representative relay, it clicks and an embedded LED flashes. The LED reinforces the sonic experience by providing a visual connection to the sound source and reinforcing perception of the delicate timbres of the relay. The visual cue of the LED assists the audience in connecting the sonic nuances to a specific sound object.

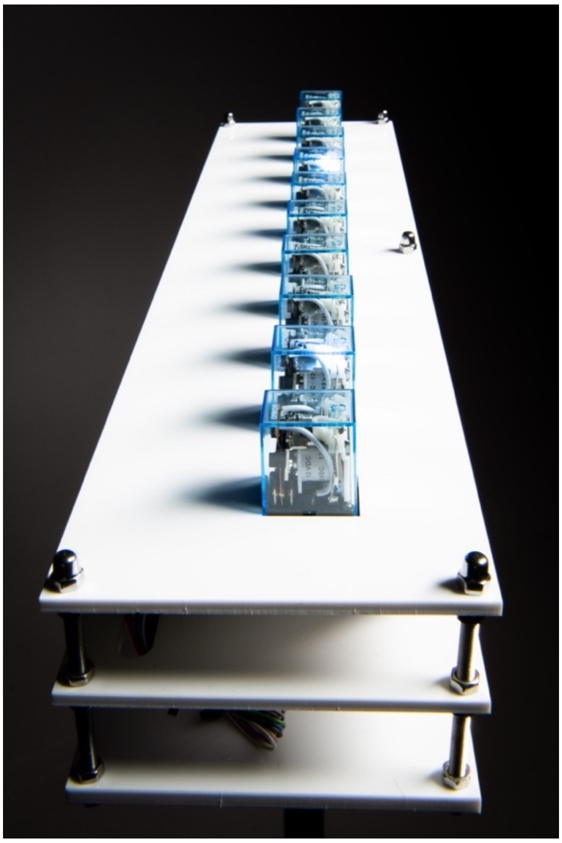


Figure 3.4. *Click::RAND* row of relays

3.3.1 Technical Implementation

As an object-based installation, *Click::RAND* foregrounds the ten relays as the sound making objects by shrouding the other components under a white acrylic plate (seen in Figure 3.4.) These additional components include ten generic, low-cost commodity MOSFET driver boards used to drive each relay, a Teensy 3.5 microcontroller and cabling between the various components. A diagram of the system is shown in Figure 3.5.

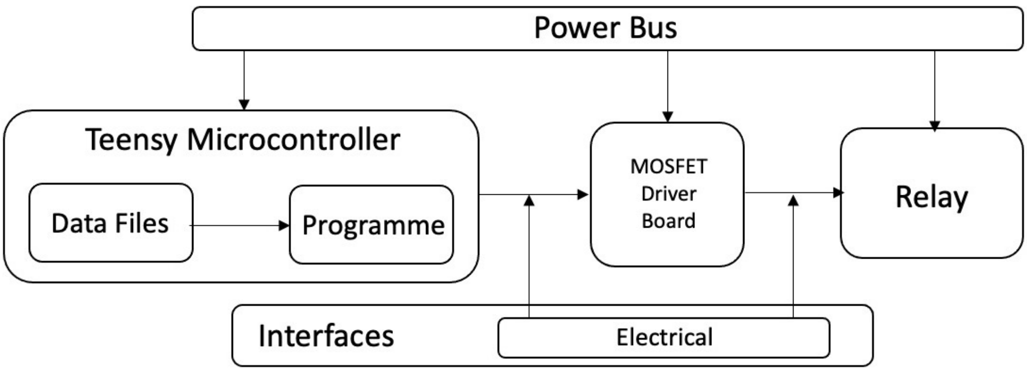


Figure 3.5. *Click::RAND* system overview

The Teensy microcontroller programmatically controls each relay through the MOSFET driver boards. It hosts a custom-developed software program (*sketch*) used to control the work and process the random digit and normal deviate text files. These files are contained on an onboard memory card. Due to a combined file size of approximately 1.5MB for both digit and deviate files and a Teensy memory size of 256KB the data sets are split into 20 random digit and ten normal deviate text files to allow selected files to be loaded into memory. A random software function selects the digit and normal deviate files to be loaded into separate data arrays. A number is randomly selected from each array. The random digit corresponds to an output pin on the Teensy which sends a pulse to the input gate of the associated MOSFET board which, in turn, engages the relay. The normal deviate is used as a temporal element for the time a relay is engaged and the space between relay actuations. This is elaborated on in section 3.3.4.

The physical structure of *Click::RAND* comprises three tiers of acrylic plates. The top tier is used to foreground the relays as the sound-making objects by having them protrude through a series of holes in the plate. The middle tier provides a platform to mount the relays' base connectors and the MOSFET driver boards. The bottom tier provides a platform to mount the Teensy and mounting options for using a stand or wall mounting the work. The acrylic plates are connected by a series of M4 threaded rods (see Figure 3.6).

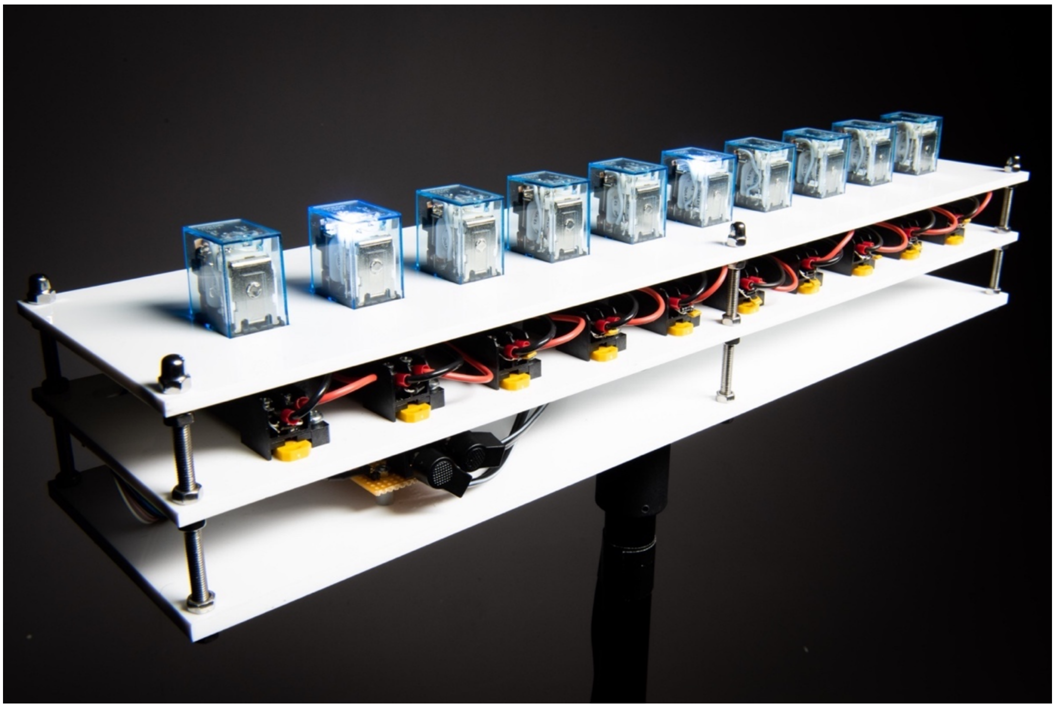


Figure 3.6. *Click::RAND* Physical structure

3.3.1.1 System Circuitry

Each relay is connected to an individual MOSFET driver board. The driver board's original IRF520N MOSFET has been replaced with an IRL540N MOSFET. The IRL540N has been chosen for its lower gate trigger level to enable low powered microcontrollers such as the Teensy to be able to actuate the ten relays simultaneously if necessary. Figure 3.7 shows the MOSFET circuit and its interfaces for power, signal input from the Teensy and output to each relay. With reference to Figure 3.7, the circuit comprises a current limiting resistor (R2) with an LED for a visual indication of the signal input being ON. A pull-down resistor (R1) ensures the MOSFET gate (1 on the IRL540N) closes when a gate voltage is removed.

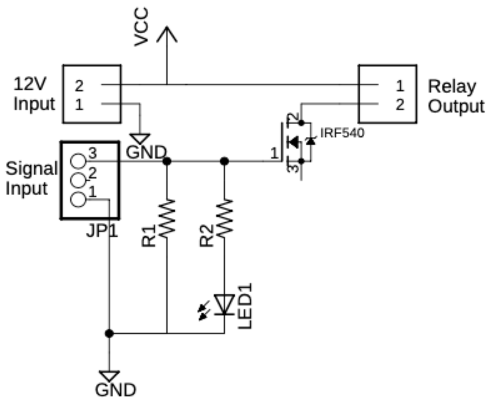


Figure 3.7. *Click::RAND* driver circuit

The Teensy's output pins are attached to each driver board via a header connection. The selected random number is assigned to an output pin that, through the software, generates a pulse to open the corresponding MOSFET gate to actuate the respective relay. The MOSFET board is shown in Figure 3.8. Each board is connected to the 12V power supply. Following the first installation of the work, a number of LEDs did not work. This was due to a voltage spike occurring when the relay's inductive load was switched off. The issue was resolved by placing a flyback diode across the relay output connector on the board.

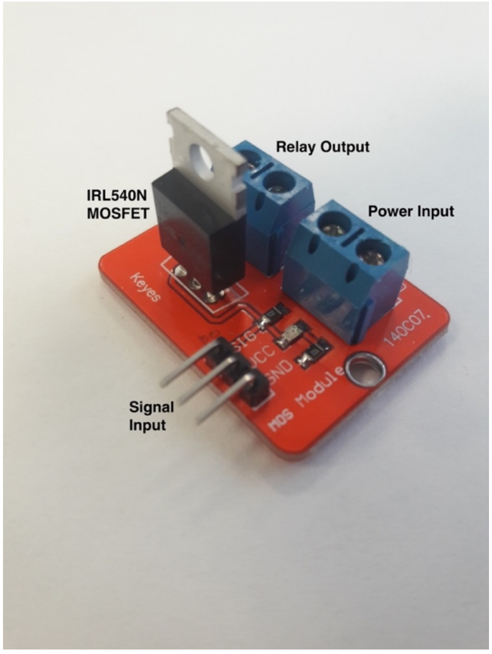


Figure 3.8. MOSFET driver board

Each relay is actuated by a short pulse signal and draws approximately 30-50mA. As each relay is individually actuated, a 12V 2A power pack is used to power the work. A separate 5V power supply is used to provide power to the Teensy.

3.3.2 Software Implementation

A custom program has been developed to enable the selection of random digits used to actuate the relays and normal deviates as temporal elements for the work. A signal flow diagram is shown in Figure 3.9.

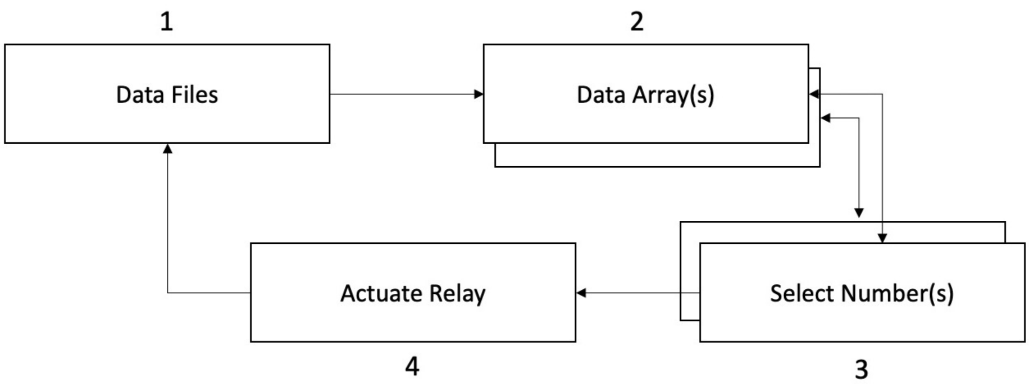


Figure 3.9. *Click::RAND* program flow

The program begins by constructing a filename to select both a random digit file and a normal deviates file. This random selection process and filename construction for selecting a digit file is effected in lines 3-5 in the code fragment of Figure 3.10. With reference to Figure 3.9, these files are loaded into separate data arrays (1, 2). The process to populate the array with digits is implemented by lines 7-25 in Figure 3.10. The process is identical for the deviates file. Next, two random deviate numbers are selected from the array and are used to specify the time a relay is actuated and the space between each relay actuation. Following this, a random digit is selected from its array (3 in Figure 3.9). The selected digit is sent out the corresponding Teensy output pin as a digital pulse. This pulse charges the MOSFET gate allowing the corresponding relay to be actuated (4 in Figure 3.9). The process is then repeated. The full program is contained in the Appendix.

```
1.   void digits() {
2.    // open the file for reading:
3.    int digitRandNum = random(1, 21);
4.    char digitFilename[11] = {'\0'}; //11 characters in the filename
5.    sprintf(digitFilename, "digits%d.txt", digitRandNum);
6.    Serial.println(digitFilename);
7.    digitFile = SD.open(digitFilename);
8.    if (digitFile) {
9.     while (digitFile.available()) { // read from the file until there's nothing else in it
10.     switch ((char)digitFile.peek()) {
11.      case ',':
12.       digitFile.read();
13.       break;
14.      case '\r':
15.       digitFile.read();
16.       break;
17.      default:
18.       int digitValue = digitFile.parseInt();
19.       digitArray[digitArrayCount] = digitValue;
20.       Serial.println(digitArray[digitArrayCount]);
```

Figure 3.10. File open and data load process

3.3.3 *Aesthetic Considerations*

Click::RAND is based on the sonic artefacts of a single model of relay. The relay is the Omron LY2N-J, a general purpose double pole relay used because of its ready availability in larger quantities and its low cost.

3.3.3.1 *The Relay as a Sound Object*

The relay's structural frame is constructed from metal and plastic. The frame provides support for the primary Silver Cadmium Oxide faced contacts and lever mechanism, the copper coil, the pivot point and spring tensioner for the contacts and mounting for the LED indication and associated resistor. [146] A set of metal pins is supported in a plastic socket and is the 'switched' input and output contacts of the relay. Visually identical and manufactured to the same specification, there should be no discernible differences in the sound of the relays.

By isolating the relay to a single sounding object (see Figure 3.11), its individual sonic materiality can be foregrounded. *Click::RAND*'s sonic material is provided by relay contacts, each heard as a click when they engage and disengage.

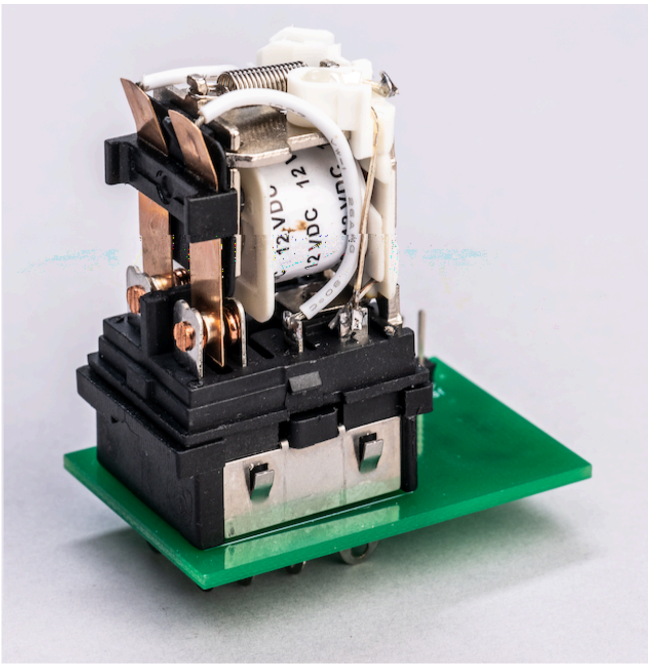


Figure 3.11. The relay as sound object

Heard as a series of clicks, the work's sonic palette appears to be limited. However, differences can be heard in the sound of the contacts of some relays when they are actuated. Some are muted, some have a resonant ring to them, some are simply a metallic click. For some relays, other elements of their material construction can be heard as higher frequency micro-tones. A timbral variation is manifest as a higher pitch resonance that is heard when a relay is being regularly pulsed. This sound is a result of the spring's tension and release and has the effect of creating a higher frequency drone across a series of relays. These sounds are a part of the inherent material characteristics of the relay. As such, these acoustic micro-tones become a part of the work and are integrated into its overall sonic palette.

3.3.3.2 An Audiovisual Aesthetic

Click::RAND is presented with the published data source, the book, as an explicit part of the work (see Figure 3.12). This first iteration of the work was influenced by the characteristics of a book and size of the random digit tables. The decision to present the work as a line of relays was analogous to a line in a book and representative of the decimal numbers 0-9 in the book. The intent of placing the book alongside the work was to identify the presence of the physical artefact as a tangible connection between the artefact as the data's source and the work. In doing so, the realisation of the work was to present an interpretation of the book's content in the audiovisual domain as a new perspective for interpreting and using the data sets.

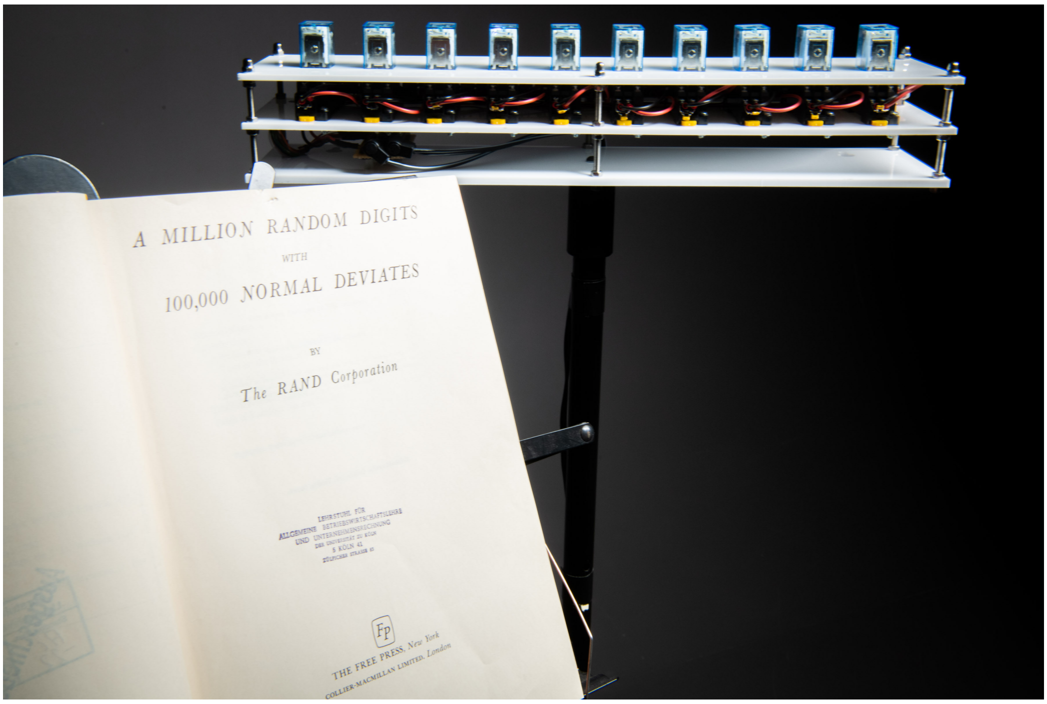


Figure 3.12. The presence of the book *A Million Random Digits*

3.3.4 Compositional Strategy

The book's instructions for use of the tables (see below) has been the primary source for informing the compositional strategy for *Click::RAND*.

> In any use of the table, one should first find a random starting position. A common procedure for doing this is to open the book to an unselected page of the digit table and blindly choose a five-digit number. [147]

This instruction has been literally interpreted and incorporated into the software that controls the work (described in section 3.3.2). In this case, a single digit is selected. The act of random selection for the actuation of relays can be perceived as selecting a new starting point each time by opening the book to an unselected page and choosing a number.

As a way of discovering unpredictable and emergent sound qualities resulting from the abstract interrelationships between the source data and the sonic output, *Click::RAND* eschews the use of musical elements such as a regular tempo or rhythm [104]. Instead, by using the normal deviate data set as a temporal element for the time a relay is actuated and the time between actuations, it is left to random processes for patterns to briefly emerge and ebb. This mode of interpreting and utilising the data sets affords perceptual access to particular rhythmic qualities not heard with an imposed fixed tempo on the source material. This creates a qualitative relationship between the data and its sonic articulation as a way of hearing the rich and variant musicality of the source data. This form of musicality is elaborated on in section 3.6. This approach allows a listener's focus to shift between two levels. At the macro-level are the emergent and ebbing patterns as a part of the work as a whole. At a micro-level, the randomness that disrupts those patterns draws attention to the individual sounds. In this way, a listener's attention is always in flux as it shifts between these levels; this may not be the case if the use of a regular tempo or rhythm was employed. Finally, by using the normal deviate numbers, those irregular time intervals between relay actuations are analogous to the disrupted patterns and rhythms heard in the (mal)functioning of the original electromechanical computers (as discussed in section 3.8.2.1).

3.4 Reflective Discussion

The form of *Click::RAND* described in section 3.3 has a small physical and sonic presence that encourages an intimate engagement with the work. The work was best received in more intimate spaces as the subtle sounds, and timbral and kinetic nuances of the relays' actions, were able to be heard and seen in this type of environment. In a competing or larger space, the physical presence of the work and the ability to experience it in this detail was diminished. As such, the early iteration is limited to these more intimate spaces and not suitable for noisier competing or larger spaces.

The idea of giving a 'voice' to *A Million Random Digits with 100,000 Normal Deviates* through the operative presence of the relay, heard as a click, is problematic in the early iteration of *Click::RAND*. If one were to vocalise the content of the book, such utterances would be "surrounded by a shimmer of homophonic variants" rendered through speech. [148] However, a rendering of the book's text in this case is reduced to a single relay's click for each symbol, a relationship that is ambiguous. Creating a relationship between a number and a relay's position as a numeric representation attempts to 'activate' the book's presence. As a "surrogate body", the relay's presence, again, is ambiguous with the relay unable to represent the text in decimal format and to voice the prosodic form of text as read. [148] *Re-presenting* the text as a form of data allows the transference from one symbolic form to another. In this way, representing the decimal characters of the book as their binary equivalent is a way of allowing the relay to 'speak' with its own voice. Paraphrasing Katherine Hayles, the relay's voice echoes the book albeit in a way that breaks it apart and represents it in a new way; one that reproduces it through a different medium and with a new temporality, leaving traces of the past through this technologically produced voice. [148]

Each digit, 0-9, can be represented as binary-coded decimal by four relays. The physical structure of *the early iteration*, based on a decimal form of representation, does not accurately portray this new binary representation. Reconceptualising the physical structure of *Click::RAND* based on the structural layout of the book's digits presents a way of enabling the interpretation of data as binary sequences. The digits in the book are presented in a series of blocks. Each block consists of five rows of five digits in a grid-based pattern. An example is shown in Figure 3.13. By adopting this pattern as a structural and aesthetic element for the second iteration of the project, each individual digit can be represented on a single row of relays. Selecting digits based on their row/column as a form of coordinated grid, and as the basis for a redesigned physical layout, allows a block of numbers to be represented by five rows of four relays each.

09188	20097	32825	39527	04220	86304
90045	85497	51981	50654	94938	81997
73189	50207	47677	26269	62290	64464
75768	76490	20971	87749	90429	12272
54016	44056	66281	31003	00682	27398
08358	69910	78542	42785	13661	58873
28306	03264	81333	10591	40510	07893
53840	86233	81594	13628	51215	90290
91757	53741	61613	62269	50263	90212
89415	92694	00397	58391	12607	17646

Figure 3.13. Example of the 1,000,000 digits grid-like pattern

Using the grid-like patterning in this way allows a discrete 'sound block' to be created as an iteration of the basic sound unit (the relay) with each sound block comprising 20 relays. Following different interpretations of the book's structural layout, *Click::RAND* can be installed in a number of configurations as a reference to the presence of the book in the work. These can include being installed as a series of sound blocks or a linear sequence of sound blocks and spatialised on a number of walls. The need for the book to be physically present as a part of the work is diminished through this referential interpretation.

Rather than being limited to a more intimate experience of the work as was the earlier iteration, redeveloping *Click::RAND* is one strategy to enable it to be adapted to a range of spaces to expand and extend its physical and sonic presence. Adapting the work in this way can be an aesthetic approach for exploring the different acoustic qualities of space as an active participant in the work. In this way, different installation spaces may create different sonic interpretations of the work. Combining this physical approach with different interpretations of the data as compositional elements may create new spatialised sound patterns such as synchronous, syncopated or discordant rhythms. The early iteration did not creatively utilise the rich and extensive data set to it's full extent. One way to do so is to utilise the data sets in different compositional forms to explore and expose the rhythmic qualities inherent in the binary interpretation of them. By iterating the sound blocks, *Click::RAND* can be extended to create a multi-dimensional and adaptable series of works to explore both the interwoven rhythmic patterns in the data and the acoustic nuances of the space it inhabits. This approach may result in a more complex sensory exploration that is representative of the complexity of *A Million Random Digits with 100,000 Normal Deviates*. This complexity can be experienced by interweaving a series of discontinuous non-linear rhythms (the 'digital') into more continuous or analogue rhythmic patterns through iteration and the spatial distributing of the sound blocks.

3.4.1 *Summary*

This section has described a number of approaches for developing *Click::RAND* as a more expressive artistic work. By translating the text of the book, as decimal symbols to binary form, it is digitised. Utilising the relay as an expressive medium gives a voice to the text. *Click::RAND*'s presence is further expanded by using a series of sound blocks to adapt the work in different spaces. In this way, space becomes an active participant in engaging with the work through different acoustic qualities and spatial layout of the work. The next section describes the current iteration of *Click::RAND*. The section provides a description of the technical, aesthetic and compositional elements of the work.

3.5 *Click::RAND* realised

Click::RAND expands the presence of the relay as an aesthetic element and sound unit by extending from the 10 used in the earlier iteration to 20 relays. The linear presentation of the relays is now configured in a 4×5 grid on a single printed circuit board. This structural layout, as the sound block, is shown in Figure 3.14 and elaborated on in section 3.5.3.

Figure 3.14. *Click::RAND* sound block

Each row of four relays is used to represent binary-coded decimal digits 0 to 9 (i.e. 0000 to 1001). Converting the decimal character to its binary equivalent, the sound block represents each random digit in its respective row within a block of digits in the book's text. As with the previous work, an embedded LED flashes as a visual indication of a sound's source.

Rather than utilising separate circuit boards for each relay as in the earlier iteration, all electronic componentry is now contained on a single printed circuit board. Locating all componentry on a single board makes each board self-contained in terms of its operation. These components include the driver circuitry to actuate the relays, a Teensy 3.5 microcontroller and voltage regulation. This is elaborated on in section 3.5.2. A diagram of the system is shown in Figure 3.15.

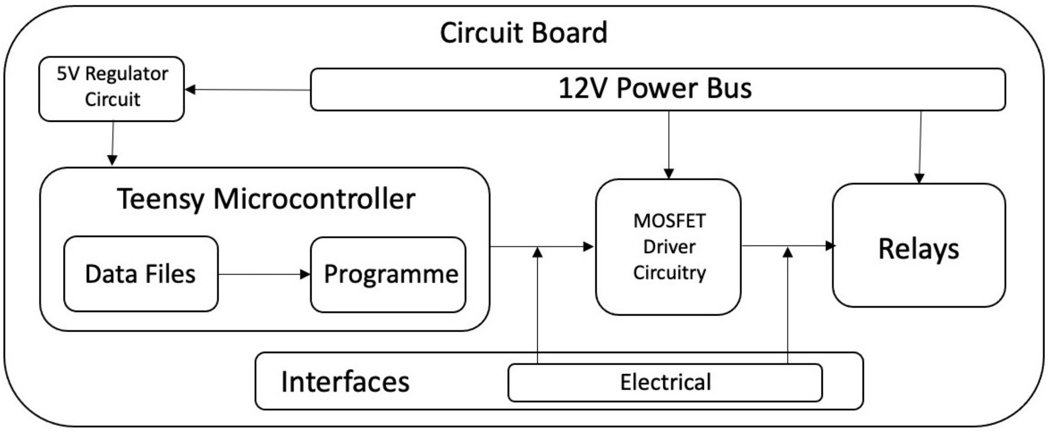


Figure 3.15. *Click::RAND* system overview

The Teensy microcontroller programmatically controls each relay through MOSFET driver circuitry. The Teensy hosts a software program (*sketch)* developed as a part of the work. This sketch is used to control the work and the random digit and normal deviate text files. These files are contained on an onboard memory card. Unlike the previous work, each data set is contained within one file each. The rationale for this and further details of the software implementation are discussed in section 3.5.2.2. A digit is randomly selected from each file. This digit corresponds to an output pin on the Teensy which sends a pulse to the input gate of the associated MOSFET which, in turn, engages the relay. Three compositional modes have been developed for the work. These are elaborated on in section 3.8.

3.5.1 Technical Implementation

The physical structure of *Click::RAND*'s sound block is provided by the printed circuit board. All electronic components are mounted on the reverse side of the circuit board using surface mount components. Surface mount technology has been used primarily for aesthetic reasons which are detailed in section 3.5.2. The reverse side of the circuit board with componentry is shown in Figure 3.16.

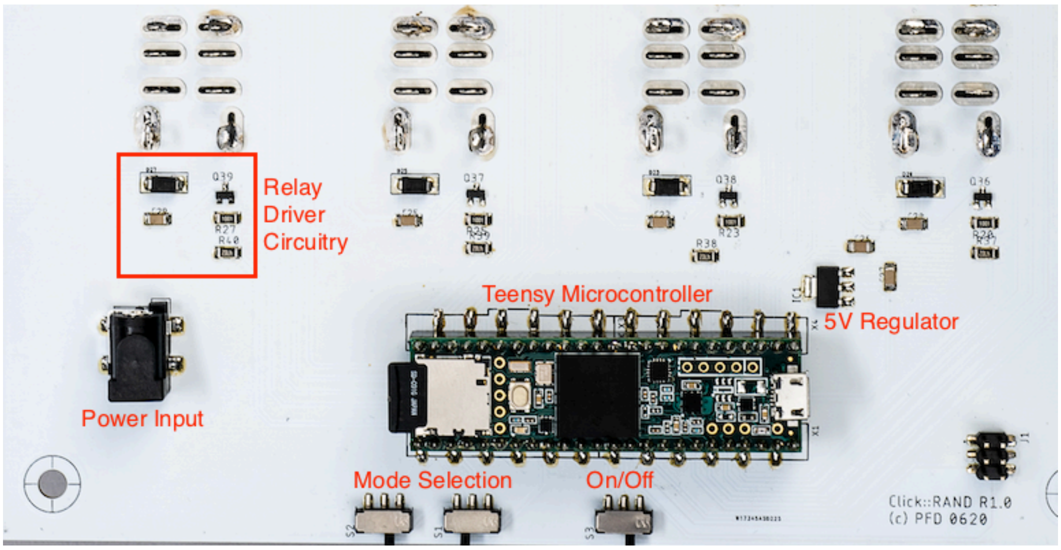


Figure 3.16. Example of *Click::RAND*'s componentry

The basic MOSFET circuitry used in the previous work has been modified with additional features. The MOSFET circuit used is shown in Figure 3.17.

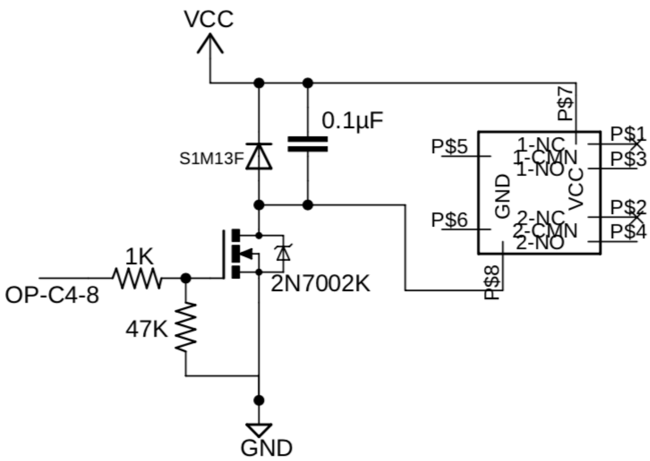


Figure 3.17. MOSFET driver circuit

With reference to Figure 3.17, the following modifications have been made to the circuit used in the previous work. A flyback diode and capacitor (SA1M13F and 0.1µF) have been added across the output to the relay to prevent inductance spikes when power is removed from the relay. A 1kΩ resistor has been added to the MOSFET input to place an impedance between the trigger circuit and the gate of the MOSFET to limit inrush current. This circuit is replicated 20 times on each board. A small 5V regulated circuit provides stepped down power from 12V to power the Teensy. As in the previous iteration of *Click::RAND*, the Teensy's output pins connect to each MOSFET driver circuit. The binary sequence of a selected random digit generates a pulse from the associated output pin group thus opening the corresponding MOSFET gates to actuate the respective relays. Each relay is actuated by a short pulse signal and draws approximately 30-50 mA. Testing has shown an average current draw for a board ranging between 150-300 mA whilst noting that not all relays will typically be active at the same time. Further testing with four boards using a single power supply has shown an average current draw ranging between 800-1200 mA using a 12V 2A power pack.

Three switches have been included in the circuit. One is a power switch; the other two switches are used to select the board's compositional mode. Each switch is attached to two pins on the Teensy to read their state (on/off). Based on the binary setting read from the switches, the software selects the different compositional mode. The two switches allow up to four different modes to be selected. This is discussed further in section 3.5.2.

3.5.2 Software Implementation

As with the previous iteration of *Click::RAND*, a custom program has been developed to enable the selection of random digits used to actuate the relays and, depending on the selected compositional mode, normal deviates as temporal elements for the work. The software extends the use of functions to 'modularise' the code; two significant additions are in this version.[13] The first is the use of a thread library to allow parallel processes to run independently.[14] This is particularly relevant as the Teensy is considered a single thread microcontroller capable of only running a single process. This software library facilitates the actuation of multiple rows of relays in tandem. An example of the thread code is shown in Figure 3.18.

[13] A function is a way of standardising code fragments that may be reused or when the same action is performed multiple times in a program.
[14] https://github.com/ftrias/TeensyThreads

```
if (sensorValue1 == 0 && sensorValue2 == 0) {
 id2 = threads.addThread(randompage, Entropy.random(0, 5));
} else if (sensorValue1 == 1 && sensorValue2 == 0) {
 id1 = threads.addThread(readbook, 0);
 id2 = threads.addThread(readbook, 1);
 id3 = threads.addThread(readbook, 2);
 id4 = threads.addThread(readbook, 3);
 id5 = threads.addThread(readbook, 4);
```

Figure 3.18. File open and thread processes

Second, is the use of an entropy library to improve the function of randomness in the Teensy.[15] In general, the *random()* function, as a pseudo-random number generator (PRNG), is predictable as it uses a deterministic process to generate sequences of numbers. [122] Adding a *randomSeed()* function does not return an adequate level of randomness. This has been evidenced during multiple restarts of a sound block which started with the same sequence of numbers. The *Entropy* library is used in place of the *randomSeed()* function and uses the jitter of the microcontroller's clock to produce a stream of, arguably, true random numbers that are used as seeds. Limited testing with one sound block, and using the same mode on four sound blocks, has shown different starting sequences on all boards. As such, this library supports the use of RAND Corporation's true random number sets and maintains a higher degree of random selection.

3.5.2.1 Click::RAND's use of the Data Sets

As with the early version of *Click::RAND*, the book's instructions for use of the tables (see below) has informed a method of selecting random digits and normal deviates for *Click::RAND*. However, adding to the earlier interpretation of the instruction in section 3.3.2, the method of selecting a digit makes further use of the instructions.

> In any use of the table, one should first find a random starting position. A common procedure for doing this is to open the book to an unselected page of the digit table and blindly choose a five-digit number; this number with the first digit reduced modulo 2 determines the starting line; the two digits to the right of the initially selected five-digit number are reduced modulo 50 to determine the starting column in the starting line. [147]
>
> \- *A Million Random Digits with 100,000 Normal Deviates*

[15] https://sites.google.com/site/astudyofentropy/project-definition/timer-jitter-entropy-sources/entropy-library

Within the software, a randomly selected number for the row and column are selected to determine the selected digit. The instructions further describe a method for selecting a starting position in the deviate table. Again, this instruction has been interpreted in the same way as selecting a random digit.

> The digit table is also used to find a random starting position in the deviate table: Select a five-digit number as before; the first four digits give the starting line (the lines being numbered from 0000 to 9999) and the fifth digit gives the starting position in the line. [147]

The following code snippet in Figure 14 shows the implementation of this instruction. The row and column selections are performed in lines 2 and 3. These starting points are added together (line 4) to determine a starting point to select a five-digit number. Lines 5-9 read the selected five-digit number and lines 10-14 read the two digits used to select the column. The process is identical when selecting a normal deviate. Modulo 50 (line 15) and modulo 2 (line 17) are applied as per the instruction. The returned numbers are added (line 23) to return a data position to select a single random digit (line 24).

```
1.   lCount = Entropy.random(0, 5);
2.   volatile int dataRowStart = ((lCount + (lCount * 50)) + ((255 Entropy.random(4001))));
3.   int dataColStart = 5 * (Entropy.random(10));
4.   int data = (dataRowStart + dataColStart);

5.   for (int x = 0; x < 5; x++) {
6.    dataFile.seek(data + x);
7.    rowRead = dataFile.read();
8.    rowNumber += rowRead;
9.   }
10.  for (int y = 0; y < 2; y++) {
11.   dataFile.seek(data + 5);
12.   colRead = dataFile.read();
13.   colNumber += colRead;
14.  }
15.  colNumber = colNumber % 50;
16.
17.  int z = rowNumber.charAt(0) % 2;
18.  char modNumber;
19.  if (z == 0) {
20.   modNumber = '0';
21.  } else modNumber = '1';
22.  rowNumber.setCharAt(0, modNumber);
23.  dataPos = (rowNumber.toInt() + colNumber);
```

Figure 3.19. File open and thread processes

This selection method can be perceived as choosing a new starting point each time by opening the book to a different page and choosing a number.

3.5.2.2 Program Flow

To overcome the need to use smaller individual data files imposed by storing them arrays in memory, a new method of accessing the data has been implemented. With reference to Figure 3.20 below, instead of loading the selected data file into an array, each file is opened for reading (1). This negates the need to store multiple files (and randomly select one) and makes the full data sets available for use. In this way, each file remains open for reading and memory use is minimised. The Teensy reads the status of the mode switches to determine the software function to run (2). Three modes are currently available. These modes are presented as compositional strategies in section 3.8. Within the selected function, a digit is chosen at random from the necessary file. Modes 00 and 10 use the digits file while mode 01 uses both the digits and deviates files with the deviate number being used as a tempo element within the work (3a, 3b). The selected digit is converted from a decimal character to a binary string (4). This string is split into individual 'bits' and used to actuate the corresponding relays in a row (5).

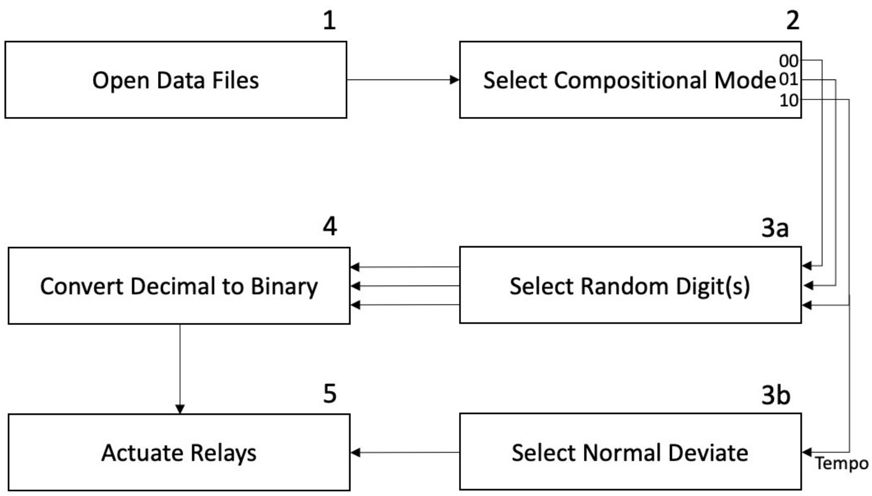


Figure 3.20. *Click::RAND* program flow

The full program code is contained in the Appendix.

3.5.3 Aesthetic Considerations

Click::RAND uses the same relay as the earlier version. In this iteration the use of a single relay is extended to 20 relays on a single sound block to highlight the relays' sonic nuances through repetition of their sound and to expand the visual and sonic elements of the work. The significance of the 20 relays has been discussed previously in sections 3.4 and 3.5.

This iteration of *Click::RAND* works with the same constrained sonic palette described in section 3.3.3.1. This sound can be heard as a double click as the relays' contacts close and open when a single binary digit is represented (e.g., a decimal 1, 2, 4 or 8). However, when a digit comprises 3, 5, 6, 7 or 9, the timing of the on/off sequences used in this iteration is such that relays disengage and engage in unison. Whilst separate gestures, these are heard as single clicks with the click of a relay's contacts disengagement merging with the sound of another relay's contacting engaging. This gestural timing is discussed in section 3.5.3.2.

The individual sonic nuances of the relays, when heard through a series of regular pulses produce moments of difference out of repetition. Along with the absence of sound within the binary sequences, these differences are a way of creating new rhythmic patterns. This is in contrast to the implementation of digit representation in the earlier iteration where the rhythms were irregular or 'arrhythmic'. Without a way of disrupting this measured pulse, a slightly robotic presence is maintained. Using binary sequences as a series of 'moments' introduces differences into what could be considered a continuous or linear form of repetition analogous to a metronome. Difference, as a way of introducing something new or unforeseen, is a potential strategy to create interest with such a limited sonic palette. [149] This sound patterning as moments of difference is a compositional strategy that is outlined in section 3.8.

3.5.3.1 An Audiovisual Aesthetic

As an *object-based* installation, *Click::RAND* foregrounds the 20 relays as the sound-making objects by presenting them against the 'blank' white 'canvas' of a printed circuit board. All electronic components are mounted on the reverse side of the circuit board. In this way, the relays' placement against the white printed circuit board focuses attention on the audiovisual elements of the work. The one external connection provides power for the work. The use of a white circuit board is also an abstract reference to the page in *A Million Random Digits with 100,000 Normal Deviates*. This is shown in Figure 3.21. Containing all componentry on a single circuit board also overcomes the need in the earlier version for three separate layers to support the various components and structural elements of the work.

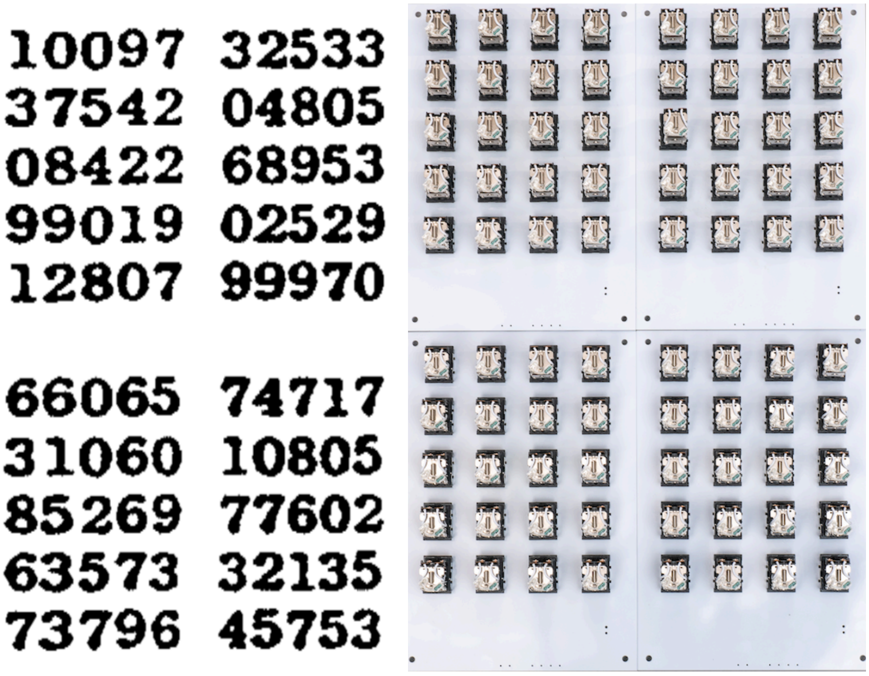


Figure 3.21. *Click::RAND*, physical abstraction of the book's layout

Each relay has an indicator LED that turns on when the contacts are engaged. The original green LED and 5.5kΩ resistor have been replaced with a white LED and a 1kΩ resistor to complement the aesthetic of the board and to increase the LED's brightness. As with the earlier iteration, the LED reinforces the sonic experience by providing a visual connection to the sound source. The LED, as an aesthetic element, assists the audience in connecting the sonic nuances to a specific sound object. Each relay's protective blue cover has been removed. The purpose of this is twofold. First, the cover partially attenuated the sound of each relay. Without the cover, each relay's sound and sonic nuances are clearer. Second, the sequenced rhythmic gestures of the relays are enhanced and contribute, in part, to the visual aesthetic through their kinetic movement.

3.5.3.2 Binary as Click::RAND's Expressive Logic

Binary, symbolically represented as a series of 0s and 1s, can be represented when an object is turned on and off or a circuit is closed and opened. These latter forms of representation occur in *Click::RAND* when the relays' coils are energised and the sets of contacts close and open. Occurring in unison, an LED in each relay turns on and off as a visual representation of the binary sequences. Used as a form of digital signalling, a stream of 0s and 1s is determined by how long they remain in each state, usually against some form of clock signal. That is, there is no 'null state' gap between each state. The number of consecutive 0s or 1s in a stream is determined by the length of time the signal remains in that state. This is illustrated in Figure 3.22.

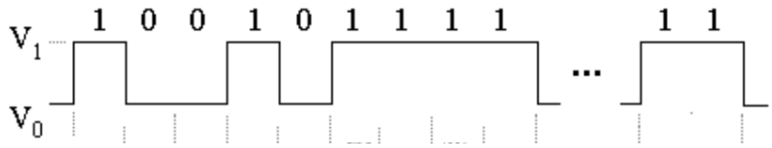


Figure 3.22. Example of a continuous bitstream

This approach is used in *Click::RAND* with no delay introduced between each bit. As a result, *Click::RAND* presents a continuous stream of binary-coded decimal moments. As each bit is represented on a separate relay, the perception of a null state gap between bits is amplified by the representation of 0s as absences of sound. This perceived delay creates moments of anticipation that are utilised as compositional strategies in section 3.8.

3.6 Material Sound as a Creative Media Archaeology

Having detailed the technical and aesthetic aspects of the work, this section discusses the various approaches to the ideation of a compositional approach for *Click::RAND*. First, the section develops a media archaeological method as a creative expansion of Wolfgang Ernst's 'media archaeological ear', a mode of listening to a "technically mediated sonic processuality", an alternative to the cultural emphasis on listening to musical semantics. The discussion considers Ernst's perspective of the agency of the machine, that, through its functional operation, is a container of knowledge, and the use of such a perspective in an artistic context. Next, it introduces Henri Lefebvre's concept of *rhythmanalysis* as an approach used to develop a series of compositional forms for *Click::RAND*.

Wolfgang Ernst's particular media archaeological method displaces human subjectivity and focuses on the agency of the machine and how it records the passing of time. Using the term *media archaeography*, Ernst describes "modes of writing that are not human products but rather expressions of the machines themselves, functions of their very mediatic logic." [50] As described in section 2.2.4, Ernst argues that apparatus only reveal their essence through a process of technological execution; an operative engagement with an artefact that can reveal a sonic heritage. Listening to the extraneous sonic articulations of media reveals the artefact's rich and variant sonic registers beyond that capable of being expressed symbolically in literature and musical notation. Initially focusing on early inscription (recording) media, these media recorded not only the performance but an "informative surplus: the non-musical articulations, noise in the background." [50] Through this microphysical close reading of sound, Ernst calls for the media archaeologist to "suppress the passion to hallucinate life" when listening. [50] Extending his media excavations into digital signal processing, Ernst contends that:

> technological media that operate on the symbolic level (i.e., computing) differ from traditional symbolic tools of cultural engineering (like writing in the alphabet) by registering and processing not just semiotic signs but physically real signals [50],

and that:

> inside the computers themselves everything becomes a number: quantity without [...] sound, or voice, it is only by coupling the binary world of the symbolic machine with physical impulses and time-discrete clocking that mathematics becomes rhythmically operative. [17]

As a form of non-human embodiment, *sonicity*, Ernst's neologism for the relationship between time, the technical, epistemology and the sonic, expresses the "inaudible events in the vibrational (analog) and rhythmic (digital) fields" that do not "originate from physically resonant bodies but from electro-technical and techno-mathematical processes, made audible by explicit sonification." [17] This allows one to hear the 'musicality' taking place within, and emerging from, these media. It is this musicality that is at the core of *Click::RAND*. The realisation of the work explores and exposes the digital (rhythmic) in the analogue (vibrational) through the use of binary sequenced patterns expressed through a series of electromechanical relays.

3.6.1 Hearing? Listening?

Ernst argues throughout his media archaeological approach for a time based analysis of media. As a method for analysing the dynamic nature of media technologies, Ernst examines the relationship between rhythmics, sound and the wider sonic sphere as an operative exploration of media, less interested in a semantic interpretation by or indexical relationship to the human body. This form of analysis is introduced in analogue inscription media and is then extended into the pulses and rhythms of digital signal processing in computing and Internet time. He describes these various chrono-techniques as the freezing, fixing, replaying, decelerating, and accelerating of media and data signals as a time axis manipulation of the way they store, process, and transmit signals. [150] In positing this approach, Ernst argues for the specific decoupling of acoustic "tempor(e)alities" (another of his neologisms) with the digital practices of algorithmic manipulation. [50][17] He contends "the analogue world as acoustic space has been replaced with the discontinuous rhythms, beats rather than waves, of a non-linear discrete temporality of an Internet time", the "calculated, 'clocked', mathematical time" of an Internet culture. [17] However, rather than advocate a media archaeological method based on bare physical acoustics, Ernst suggests an interlaced approach to the analysis and interpretation of these sonic underworlds, one that focuses on the "epistemological dimension that is embedded in sonic articulation", By doing so, he argues, "the study of the signal event can refrain from an immediate cultural contextualisation without being reduced to mere physical acoustics". [17][151]

3.7 Rhythmanalysis. Rhythm and Repetition

One method of rhythmic analysis that incorporates subjects that do not produce any obvious sound to the listening experience is Henri Lefebvre's rhythmanalysis. For Lefebvre "everywhere where there is interaction between a place, a time and an expenditure of energy, there is **rhythm** [emphasis Lefebvre's]." [149] His rhythmanalysis does not "isolate an object, or a subject, or a relation" but "seeks to grasp a moving but determinate complexity." [149] Lefebvre notes a rhythmanalyst must be capable of deeper observations, unafraid of disturbing the surface to "grasp every being [*chaque être*], every entity [*étant*] and every body, both living and non-living, 'symphonically' or 'polyrhythmically."

In his treatise *Elements of Rhythmanalysis*, a study of embodied rhythms in everyday life, Henri Lefebvre notes that the triadic concept of melody-harmony-rhythm is at the centre of musical life and cannot be separated. However, he notes an antagonism can exist if one of these elements tends to dominate the others. Arguing that modern music finds itself "back in the body" with rhythms supplanting melody and harmony without suppressing them, Lefebvre sees these changing antagonistic relations creating interest within the triad. [149] Further, Lefebvre notes,

> for there to be rhythm, there must be repetition in a movement, but not just any repetition. For there to be rhythm, strong times and weak times, which return in accordance with a rule or law – long and short times, recurring in a recognisable

way, stops, silences, blanks, resumptions and intervals in accordance with regularity, must appear in a movement. Rhythm therefore brings with it a differentiated time, a qualified duration. [149]

Lefebvre's *Rhythmanalysis* is comprised of a variety of rhythms that coexist and clash. He categorises these as eurhythmia, polyrhythmia and arrhythmia. Eurhythmia is considered to be the smooth combination of rhythms in equilibrium. Polyrhythmia is composed of diverse rhythms that, at times, interact to maintain a symbiosis but at times clash as relational forces of contradictions and resistance to maintain a harmonious relationship. Arrhythmia is the state of discordant rhythms, rhythms that break apart in a divergence of time and space. [66] Accordingly, Lefebvre's rhythm is a repetition in time and space which is never absolute and produces differences.

Lefebvre contends that rhythm embraces both cyclic and linear forms of repetition, as "rhythmed times and brutal repetition" in tension and opposition to each other. [149] Alongside a linear rhythm, the recursive loops of cyclical rhythms creates an emergent interaction of repetition, rupture, and resumption. [152] Lefebvre situates cyclic repetition within nature as repetition and difference with each return a restart, something new. Conversely, linear time is a quantised time imposed by industry and technology, a monotony of actions and movement of a standardised and mechanised society. These transverse rhythms, as layers that may compete against or complement each other, weave complex forms among times, spaces, and energies that move between the human and non-human. Paraphrasing Gaston Bachelard, at the modal intersection of Ernst's internet time and the acoustic time of the lived is a temporal disorder; an anarchy of vibrations and rhythms. [153] In musical terms, Lefebvre evokes these differences as melody and harmony (the cyclic) and measure and beat (linear time). In this sense, Lefebvre's combination of cyclic and linear time, as a way of producing differences out of repetition, is one the rhythmanalyst can utilise to discover new opportunities for creating rhythm. [153] The combination of cyclic and linear time evokes Ernst's approach to the study of sound (in this case rhythms). In this context, Ernst's time axis manipulation of digital data signals is a way of introducing difference into an otherwise linear conception of a calculated, mathematical computing or Internet time.

Lefebvre contends the act of rhythmanalysis draws together diverse things into a "dramatic becoming" whilst concerning itself with different rhythmic temporalities and perceiving them in relation within the whole. Paraphrasing Lefebvre, the rhythmanalyst listens to the world and above all what is disdainfully called noises … and finally he will listen to silence. [149] In the context of *Click::RAND*, a rhythmanalysis elicits Ernst's media archaeological inaudible events that do not originate from physically resonant bodies, to be expressed through the object (the relay), allowing those events, as rhythm, to enter the body where the work is experienced moving through space and time. As such, Ernst's operative exploration of media in combination with Lefebvre's study of embodied rhythms provides an interlaced approach to the conceptualisation and realisation of *Click::RAND*.

3.8 Compositional Strategies

This section describes *Click::RAND*'s various compositional forms as expressive rhythmic patterns. Following a brief introduction detailing how a temporal and structural logic has been used as a form of meter for digit replay, Lefebvre's rhythmanalysis is introduced as a way to contextualise and describe the various compositional forms used in *Click::RAND*. This is followed by descriptions of each of these compositional forms.

3.8.1 'Voicing' the Artefact

A media archaeological "unpassioned listening" (Ernst) as a non-hermeneutic analysis of the event suggests the machine is the sole arbiter of representation and denies the relationship between transmitter and receiver, in this case the artefact and the audience. [50] The limitation of using such a material media archaeological approach is exposed when it comes to its creative application as an artistic method. For Ernst, of importance is the confluence of the artefact's materialities in operation. For the audience it is the material entanglement of sound leaving one body and entering another that determines how it is experienced. As Jonathan Sterne notes, the perceptual quality of sound, as an explicit sonification of the vibrational or rhythmic event, is a "product of the human senses and not a thing in the world apart from humans. Sound is a little piece of the vibrating world" and "somewhat human-centred." [154]

Elaborating on the idea of the relay as a 'surrogate body' (refer to section 3.4), and following Hayles, what happens when the text of *A Million Random Digits with 100,000 Normal Deviates* is 'read' by an electro-mechanical object? [148] The transference of materiality from the printed page to a digital medium is *Click::RAND*'s explicit sonification of both a silent reading of the book's text and of Ernst's vibrational or rhythmic events without sound or voice. The algorithmic processes used in *Click::RAND* allow the possibility of "embodying the 0s and 1s, the notation of presence and absence" as a method to expose the discrete time signalling and patterns of state transitions of a binary sequence in the real as a series of rhythmic clicks. [155]

3.8.2 Rhythmanalysis as Context and Concept

Lefebvre's concept of rhythm is based on repetition as a quantified measure of time and the continual interference of cyclic and linear time. Each rhythm's reprise or return introduces something new and unforeseen as moments of difference. [149] Modelled on an abstract quantitative time, *Click::RAND*'s meter is the measure of time for its transmission of binary coded decimal sequences. *Click::RAND*'s meter is based on a computational time of 104ms for the compositions *Eurhythmia* and *Polyrhythmia* (see sections 3.8.2.1 and 3.8.2.2).[16] This timing is used as the delay period for representing binary 0s and 1s. Imposing a fixed temporality to the reading of the data recalls the calculated, mathematical time (the digital signal clock time) imposed in the informational processing of the early electromechanical computers. In these compositional modes, only the binary sequences are used to articulate a temporality through the presence or absence of sound in these sequences. Lefebvre's rhythmic measure consists of both quantitative aspects, that of marking time and moments, and qualitative aspects, that link them together, as a form of harmony. In this context, harmony "exists in eurhythmia or polyrhythmia (on which of these forms, Lefebvre appears to contradict himself), composed of diverse rhythms, in a metastable equilibrium as an alliance between different rhythms." [149] *Click::RAND* weaves together the different rhythms of binary sequences as quantified moments. The work draws on Ernst's media archaeological approach as a method of engagement with the materiality of the artefact and making audible the medium of print. Alongside this, *Click::RAND* uses Lefebvre's *Rhythmanalysis* as an approach for each composition with three expressive forms of message replay conceived for the work. Again, these three forms are characterised by eurhythmia (rhythms of equality), polyrhythmia (rhythms of diversity), and arrhythmia (rhythms of disturbance). These are discussed on further in the next three sections. Examples of these expressive forms have been presented in the video documentation for the work.

Click::RAND's video documentation shows the creative and rhythmic forms of expression within the context of Lefebvre's characterisation of *Rhythmanalysis*.[17] Each of *Click::RAND*'s rhythmic forms are titled after these characterisations. *Eurhythmia* shows the smoother rhythmic but machine-like patterns of interwoven binary sequences across multiple rows of relays. *Polyrhythmia* introduces the element of space into the compositional form, both

[16] The choice of timing is simply continuation of using 144bpm as a tempo in a number of works. As 1/16th notes, this equates to 104ms.
[17] Video documentation can be found at https://www.dunham.co.nz/works/rand

physically by the placement of sound blocks and into the work by each boards individual selection and replay of numbers represented through the presence and absence of sound. *Arrhythmia* disturbs the work's spatio-temporal element through the presence and absence of sound as nonsynchronous binary sequences. The relays' clicks are the concrete abstraction of the inherent rhythmic pattern within binary sequences. The repetition of a linear time, and moments of rupture and antagonism, manifest as a difference, are explored and experienced through the rhythmic pulses of the relays. However, each of these characteristic rhythmic forms derive from Ernst's sonicity. These rhythms, through sonification, are the physical vibrational event of an implicit sonicity; those techno-mathematical and electro-technical processes transformed from stored digits to binary encoded form and then into electrical pulses in *Click::RAND*.

3.8.2.1 Eurhythmia

As discussed, eurhythmia, as a state of rhythmic resonance, is a state characterised by the synchronisation of different rhythms into a cohesive whole. It involves a form of rhythmic coordination as a distinct way to express how the experience of space and time may interact. [149]

Stanley Blue (in Lyon) argues that eurhythmia contains elements of arrhythmia in the form of irregular "pauses, breaks and off-beats." [152] *Eurhythmia* is a composition for one sound block. The composition is a linear 'reading' of the book from the first to the last digit (1-1,000,000). Rather than read each digit individually, the book is read sequentially in rows of five. Therefore, each row of relays re-presents a binary coded decimal digit simultaneously. In this form, the binary sequences sway between moments of synchronised and syncopated rhythms that are briefly disrupted by moments of disturbance. These arrhythmic disturbances are the result of a eurhythmia signified by an absence of sound - eurhythmic as synchronised patterns of 0s, arrhythmic as a perceived break in the rhythm. Heard as an irregular pause or off-beat, the arrhythmic moment is the result of the synchronisation of two consecutive 0s in the binary sequences occurring simultaneously across all five rows. An example of this pattern is shown in Figure 3.23 with the arrhythmic pause highlighted. Compositionally, these minor ruptures are audiovisual representations of Lefebvre's description of eurhythmia where the discordant rhythm clashes before coordinating once again. *Eurhythmia*'s concentration of sound and the sustained playing of binary sequences creates machine-like rhythms that evoke a connection to the rhythmic clattering of electromechanical relay computers.[18] The linearity of quantised time is evident in the fixed tempo used in this compositional form. As a reading of the book, *Eurhythmia* is a long form composition lasting approximately 46 hours. Once the final set of digits is read, the work is silent.

Figure 3.23. Notated example of arrhythmia in *Eurhythmia*

3.8.2.2 Polyrhythmia

Michel Alhadeff-Jones considers Lefebvre's polyrhythmia to be an environment where heterogeneous rhythms co-exist simultaneously without coordinating with each other. [156] In the absence of synchronisation, one has to focus on each of them separately, and eventually successively, in order to grasp their specific rhythms.

Polyrhythmia is a composition for multiple sound blocks. This use allows varying spatial installations. Partly dependent on the installation location, the work's physical layout can be installed as a line of sound blocks or as a grid. Example installations are shown in Figure 3.24.

[18] This rhythmic clattering can be heard in a 1958 Facom 128B electromechanical computer in operation. A brief video is available at https://www.youtube.com/watch?v=24LZzvZhLIk&t=22s

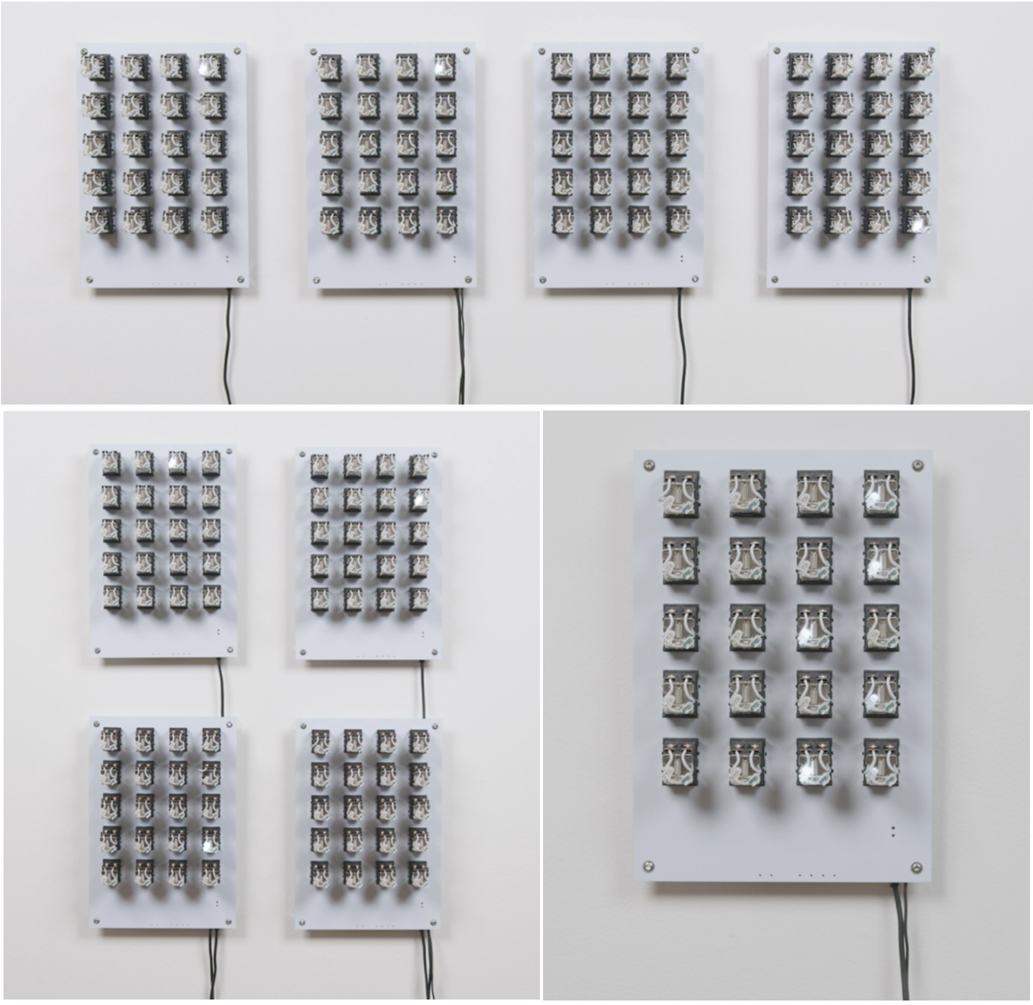


Figure 3.24. Installations of (clockwise) *Polyrhythmia, Eurhythmia* and *Arrhythmia*

The number of boards can be varied with up to 16 sound blocks being used in a single installation. This may consist of single or multiple sound blocks installed on multiple walls or a varying number of sound blocks installed on a single wall. This compositional form makes use of both a location's physical space and through the presence and absence of sound – the click – the spatiotemporal nature of binary sequences. Unlike *Eurhythmia*, where the sound is tightly confined and therefore experienced as a totality of rhythms, *Polyrhythmia*'s use of space allows a listener's focus to shift between two levels. At a micro-level, the individual sounds and sequential moments of each binary pattern draws a listener's attention to the individual sounds and sound patterns. At a macro-level, the interweaving rhythmic patterns can be experienced as the totality of the work. By creating both compositional and physical space in the work, the nuances of individual relays and binary patterned sequences become apparent whilst the physical spatialisation of sound blocks can create different experiences of the work as an audience moves arouns the space to engage with the work.

Polyrhythmia selects a random single digit and plays the binary encoded sequence on the grid row it is found on in the book. Like *Eurhythmia*, *Polyrhythmia* uses a fixed tempo. Whilst not synchronised to a single clock source, each board uses the same tempo parameter of 104ms. A notated example of this compositional form is shown in Figure 3.25. Each stave represents a sound block with each line representing a line of relays.

Figure 3.25. Notated example of *Polyrhythmia.*

3.8.2.3 Arrhythmia

Arrhythmia is characterised by the provisional or permanent lack of synchronisation between rhythms. [156] It can, subjectively, be perceived as a form of dissonance. Dawn Lyon notes that a rhythmanalyst is interested in this discordant form for "its potential to generate creative differences". [152] With examples of unanticipated natural events, a snowstorm and an earthquake, she notes the disruption of patterns, as 'off-beats', from unanticipated natural events: a snowstorm and an earthquake to specific everyday routines and the creative ways of reasserting familiar rhythms during these disruptions. Although Lefebvre considers arrhythmia as existing in other forms of rhythm, e.g. in eurhythmia, (see section 3.8.2.1), this potential exists in two contexts in *Click::RAND*. Conceptually arrhythmia provides the opportunity of disrupting the mechanical regularity of the imposed tempos of *Eurhythmia* and *Polyrhythmia*. Perceptually, this creative difference, utilised in the earlier iteration of *Click::RAND* (see section 3.3.4) exposes particular rhythmic qualities not heard with an imposed fixed tempo on the source material.

Like *Polyrhythmia, Arrhythmia* is a composition for multiple sound blocks, as described in the previous section. Similarly to *Polyrhythmia*, a random single digit is selected, binary encoded and played on the grid row it is found on in the book. However, any great variations in the timing of a digital signal (as a binary coded decimal digit) will introduce a discordance between the rhythms as a form of arrhythmia.

Arrhythmia, as a form of pattern disruption, uses the normal deviate table as the compositional form's temporal element in a similar way to that used in the earlier iteration of *Click::RAND* (discussed in section 3.3.4). As a form of pattern disruption, the normal deviates were used to test for bias (or lack of) in the distribution of the random digits. As an intrinsic part of the overall set of data, its purpose is a form of arrhythmia to the distribution of the digits. To recapitulate, this mode of interpreting and utilising the data sets affords perceptual access to particular rhythmic qualities not heard with an imposed fixed tempo on the source material, creating a qualitative relationship between the data and its sonic articulation as a way of hearing the rich and variant musicality of the source data. Instead of each interval conforming to a single time unit, as it would if it were based on the clock time of a digital signalling process, Arrhythmia disrupts the rhythmic linearity by randomly changing the timing of each binary sequence. In this way, the sequences' indexical relationship is blurred as the temporal logic is disrupted. Lefebvre notes in listening to the city that "noise, chaotic, has no rhythm" and that the attentive ear begins to separate out, to distinguish the sources, to bring them back together to perceive interactions." [149] The use of a disruptive temporal element as a form of chaos allows an audience to engage with the work on two levels. At the macro-level, the random processes of digit selection and temporal representation appear without rhythm as fleeting moments of sound or long silences of anticipation. At the micro-level, the listeners' attention focuses the individual sounds of the relays before returning to the macro-level to hear the emergence and ebb of moments of rhythm. A notated example of an arrhythmic pattern for one sound block is shown in Figure 3.26. As with the earlier iteration of *Click::RAND*, using the normal deviate numbers as irregular time intervals between relay actuations allows an audience to listen to the disrupted patterns and rhythms as the imprecise functioning and intermittent failure of the original electromechanical computers.

Figure 3.26. Notated example of *Arrhythmia*

3.9 Discussion

Through a transference of materialities, from the book to digitally inscribed data files to electrical pulses and finally the materiality of the relay's metal contacts, *Click::RAND* is the sonic articulation of a large set of true random numbers produced by The RAND Corporation. Originally printed on Hollerith punch cards, the digit sets were then published in human readable book form before being published in digital format as data files. These data files have been creatively appropriated for compositional use in *Click::RAND*. From the machine rhythms of the punch card reader and the electromechanical computer to the prosodic rhythms of vocalising the book of digits to the micro-temporal acts of repetition and regeneration in the storage and transmission of digital files, *Click::RAND* re-presents the random digits as a series of compositions exploring the inherent rhythms present in binary encoded format. Using the relay as the sound producing object, the rhythmic patterning as a presence and absence of sound is manifested by the metallic clicking of the relays' contacts. Not only do we listen to an articulation of the media in the present, but the work evokes a temporal connection with the past articulations of the data sets in their various material forms.

This work does not to seek to establish a media archaeological connection between present and past media constellations. Instead the work forms an audiovisual relationship between two artefactual forms of media, electromechanical computers via the relay and the RAND Corporation's book of random digits, expressed through a series of binary sequences. By doing so, *Click::RAND* bridges two distinct temporalities. The first temporality is the immediate present. The appropriation of a set of random digits, reduced to a primal level as 0s and 1s, are expressed by operatively engaging a series of relays as an expression of themselves and of the inherent rhythms of binary sequences. The second temporality is an evocation of the past as an expression of the sounds of mid-20th century electro-mechanical relay-based computers when those machines used sets of random digits to perform analytical and probabilistic calculations. As a form of media archaeological anamnesis, the rhythmic chattering of the relays seeks to establish a point of connection and recollection of this past media moment.[19]

Drawing on Ernst's operative media archaeology of a microphysical close reading and hearing of sound, *Click::RAND*'s aurality is based on a close listening to the sonic artifacts of a single relay. The media archaeological ear focuses on the object's sonicity rather than a semantic listening as a musical object. [50] By creatively utilising this as an objective form of hearing, the cycling units of storage and transmission of digital media can be acoustically revealed as a series of binary patterned rhythmic sequences experienced as an embodied response to listening.

Coupling the binary world of a symbolic digital machine language and physical electrical impulses to actuate a series of relays. *Click::RAND* is a bridge between the implicit orality of *A Million Random Digits with 100,000 Normal Deviates* and the aurality of the production of the digits and an electrotechnical 'reading' of the data. By transforming the modality of the original iteration of *Click::RAND* from the book to the relay, the artefact allows the relay a form of vocalisation of itself that was not present in the earlier work.

The reduction of semantic meaning of the number, recognisable by humans, to a series of impulses, reinterprets the prosody of printed text in a way that explores and exposes the inherent rhythms in this reduced language. *Click::RAND* makes use of the temporality in a series of short binary coded decimal sequences that, experienced in their totality, are expressed in compositional form as *Eurhythmia*, *Polyrhythmia* and *Arrhythmia*. Utilising the relay to enact a form of aural inscription, *Click::RAND*, as an object-based sound installation, creates moments that harmonise, clash, disturb and co-exist as the rhythms interpenetrate one another. [158] The next chapter discusses a socio-historical perspective on social media that has informed the ideation and subsequent development and realisation of *Click::TWEET*, that connects the telegraph and Twitter as socially mediated forms of communication.

[19] Anamnesis can be loosely defined as recalling the past as a recollection or reminiscence. It has also been described as the rediscovery or recollection of knowledge that can occur during inquiry and learning. [157]

Chapter 4. Click::TWEET

4.1 Introduction

A quick look at Wikipedia's *Timeline of social media* page shows that today's social media has its origin in the early 1970s. [159] However, the same website's *Social Media* page states, "Social media may have roots in the 1840's introduction of the telegraph." [160] These brief examples highlight some of the debate surrounding the history of, and what is, social media. Social media, as it is manifest today, is considered a part of the second media age. In its concept and application in the 21st century, the birth of social media is generally considered to have its origins in the emergence of Web 2.0 technologies. The term, Web 2.0, is often used to characterise the second generation of the World Wide Web supporting "user creativity and collaboration through participatory social media applications." [161][162] In this context, social media are considered to be a set of web-based and mobile platforms that allow an audience to interact and share content, or to participate in social networking. Social networking is the use of those platforms where audiences gather and interact in communities of shared interest. Facilitated by the development of online social networks, user-generated or self-published content allows individuals and groups to communicate and collaborate through a series of virtual communities. [163] However, today's increasingly naturalised expression of sociality through technologies may be seen as nothing more than a "way of realising what has existed in human nature for millennia." [164]

If social media is considered more than a collection of technologically-mediated platforms that are used to communicate and collaborate, what alternative perspectives exist? Zizi Papacharissi argues that all media are social by definition and that "socially based communication has always utilised platforms, digital or non-digital, which were somehow networked." [165] Tom Standish defines social media as "an environment in which information was passed from one person to another along social connections to create a distributed discussion or community". [166] Grant Bollmer posits that rather than social media being a "shorthand phrase for a specific articulation of technology", it should be used to identify a "specific manifestation of a massively complex social formation." [164] Silvia Ruzanka has applied this perspective creatively in her audiovisual installation, *Sounder and Relay.* The work, based on Ella Cheever Thayer's 1879 book *Wired Love: A Romance of Dots and Dashes,* replays excerpts of the book in Morse code to present a social world that prefigures the Internet, avatars and online dating. [167] These various perspectives question the assertions that social media is a uniquely 21st century phenomenon. By defining the "social in media" only through particular contemporary media technologies such as Facebook, Twitter, Instagram, or LinkedIn implies some older media were not social at all. This lack of acknowledgement for otherwise separate but distant related moments in time as a part of their historical development overlooks earlier socially-based forms of communication. [165] Previous forms of media exhibit characteristics that suggest them to be precursors to contemporary social media through a series of genealogies and prehistories that have made contemporary social media possible. These include early networked forms of communication like early mail systems, the telegraph and the telephone.

From early electromechanical innovations such as the electric telegraph to contemporary social media technologies, communication media continue to exert an influence that have transformed relationships, facilitated new cultural networks, and mediated and unsettled people's everyday experiences, in ways that have signified progress to some and doom to others. For instance, in contextualising Twitter within a general history of communication media, Dhiraj Murthy reveals similarities with, and departures from, the electric telegraph. [168][169] He argues that both mediums bought an immediacy and brevity to communication, compressed space and time, and brought the private into the public. An Xiao Mina provides a creative example of this perspective in her work, *Morse Code Tweets*, The installation bridges the past and present through the presence of early electric telegraph communication alongside Internet communications. She presents the work as an examination of the evolution of instant communication as an expansion of time, space and our sense of identity. [170] In this way, the telegraph provided a significant advancement in the global reach and immediacy of communication, one that is further amplified with social media platforms such as Twitter.

4.1.1 Socially Mediated Language

The interplay between writing and communication technologies have provided a sense of what it is to read and write in a world defined by machine interactions, where socio-economic (e.g., the per character pricing of a telegram) and technological constraints (e.g., the character limit of each Tweet) have had significant impacts on the written word. Seen in the abbreviated forms of language used in telegraphic writing such as shortened words and phrases, these forms of lexical compression continue today in the use of Internet acronyms and emojis in social media. In a similar manner to criticism of the telegraph, that its linguistic compression would bring the downfall of traditional forms of communication, Twitter has been criticised for potentially threatening established concepts of communication. Yet, despite this criticism, both the telegraph and Twitter can be implicated in a rise of expressive forms of writing. One area this is evident is in poetry. Adopting the modalities of a telegraphic language, 19th century poets like Emily Dickinson have used the "linguistic compression and typography of telegrams" in their poetic discourse. [171] Similarly, Modernist poetry, informed by the new advances in technology, considered a way of expressing the speed and intensity of the modern world through a fractured mode of speech. Indeed, these linguistic forms of destruction were evidenced in a loosening of grammatical rules and a lack of punctuation reducing works to a series of essential words. [169] Just as modernist writers sought to reduce writing to a series of essential words, Twitter has been able to foster a creativity evidenced in various forms of micro-poetry. Utilising Twitter's need for brevity and conciseness of communication, these poetic expressions have been likened to modern day forms of Haiku. [172] As such, both the telegraph and Twitter's economies of resource have been utilised as both economic and creative aesthetics.

This section has presented opposing perspectives as a way of contextualising what is the social in, or what is a social, media. This suggests that media has always been social and that contemporary social media is a continuation of that. This chapter presents *Click::TWEET* (see Figure 4.1), an object-based sound installation that, through the performative presence of the telegraph key acting as an historic relay, replays tweets as variations of Morse encoded messages[20]. Appropriating obsolete telegraph keys and foregrounding their sound making qualities, *Click::TWEET* is an audiovisual representation of a genealogy of connections between an earlier media technology and contemporary social media. Using a media archaeological approach to the work's conceptualisation and realisation, *Click::TWEET* connects the telegraph and Twitter as historically related forms within a broader history of social media.

[20] *Click::TWEET* was originally titled *TWTTRGRAPH.* The name change reflects alignment with the other works in this portfolio.

Figure 4.1. *Click::TWEET*

The objective of this chapter is not to argue an origin or exact definition for social media nor is it not to negate the technological reality of progress. Rather the research objective here is to use these divergent perspectives of social media to explore traces of past media within contemporary social media, in order to create an interpretative relationship between two forms of media whose origins are approximately 160 years apart. The relationships from within the wider frame of reference of interrelated and intertwined forms of technological development are used to inform a conceptual and aesthetic approach for the appropriation of obsolete media to create sound-based art. The ideation and realisation of *Click::TWEET* has been informed by characteristic similarities between Twitter, the telegraph and Morse code. Their different material and lexical features have been utilised in creating a sound installation that re-presents the interwoven temporalities between these historical and contemporary media technologies. By perceiving the social in media in this way, lines can be drawn between past social practices and technological invention and today's social media platforms.

To realise the work, a number of conceptual and technical components and processes have been integrated into *Click::TWEET*. The following section describes the physical implementation of the work. Following that, the chapter describes the conceptual approach informing the ideation and realisation of *Click::TWEET* and the compositional strategy for the work's expressive forms of message replay. The chapter then presents the various compositional strategies employed in three modes of realisation for the artwork. Following this is a discussion of *Click::TWEET* as an audiovisual temporal bridge between the telegraph and Twitter as social media. The chapter concludes with a brief summary.

4.2 Click::TWEET

As a sound installation, *Click::TWEET* is the re-presentation of Twitter messages (tweets) replayed as a series of Morse encoded telegraphic messages. As an *object-based* installation, *Click::TWEET* foregrounds a line of six obsolete telegraph keys as the primary sound objects in the work. These can be seen in Figure 4.1. All other components of the work are housed inside the plinth. As discussed further in section 4.2.1, these include a Raspberry Pi computer, a MOSFET driver board, an audio amplifier and speakers, solenoids and cabling between these components and to external interfaces.

Central to the work is a Raspberry Pi computer that provides an interface between, and connectivity to, the various peripheral components and external systems. The Raspberry Pi also hosts Processing software, a Java based programming language used primarily within the context of the electronic arts. Through the use of custom developed sketches (Processing programs), the software connects to Twitter and extracts and transforms Twitter messages. Connecting to Twitter via the Internet, messages are retrieved and transformed from alphanumeric and punctuation symbols to Morse elements. Each Morse element is then translated to digital pulses that actuate the solenoids operating the telegraph keys. A diagram of the system is shown in Figure 4.2.

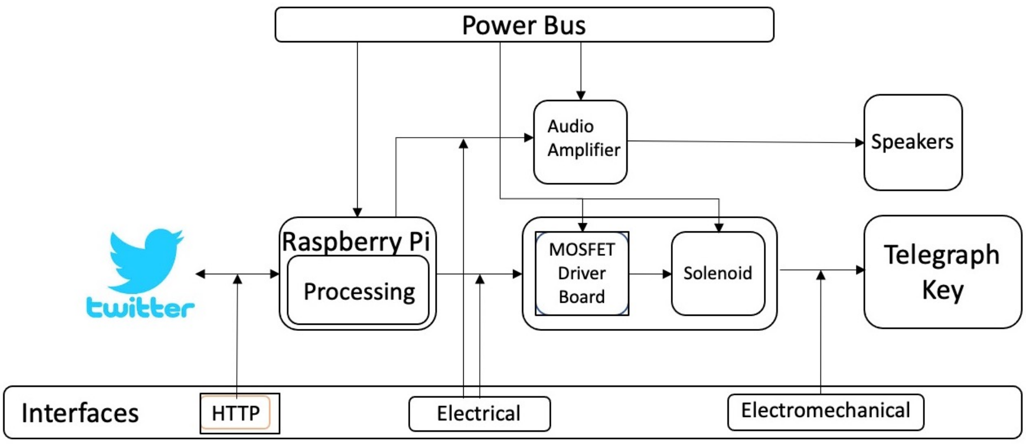


Figure 4.2. *Click::TWEET* system overview

4.2.1 Technical Implementation

Acting as a form of bridge between historic and contemporary media, *Click::TWEET* suggests the telegraph, as a system of networks, to be an historical extension of today's internetworked systems. This system is housed in a translucent white acrylic plinth. Six telegraph keys are connected to individual solenoids as mechanical 'fingers' that provide the keying function of the operator. The rationale for this is discussed in section 4.2.3.3.

A rigid connection could not be used as a connecting mechanism between the telegraph key's rocker arm and the solenoid. The curvature of the key's rocker arm movement prevented the solenoid from fully engaging it and, at times, the solenoid jammed. To ensure smooth travel of the rocker arm and problem free actuation of the telegraph key, a flexible connection mechanism had to be used. A swivel connection has been attached between the key and the solenoid (see Figure 4.3). This simple mechanism provides the necessary flexibility, freedom of movement and strength to fully engage the key over a sustained period of use.

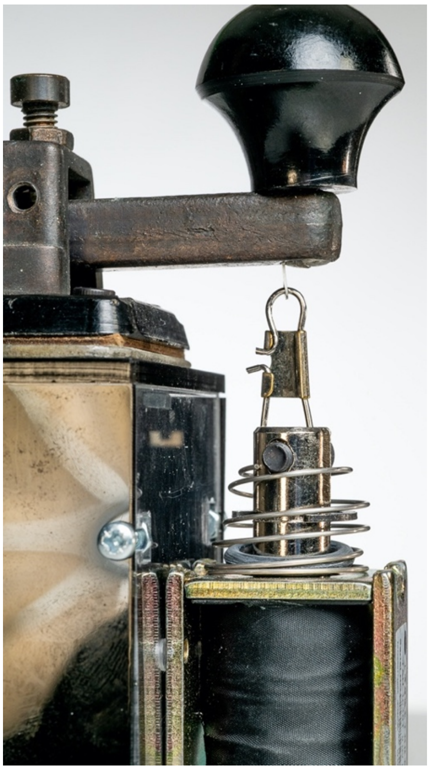


Figure 4.3. Swivel connector between telegraph key and solenoid

4.2.1.1 MOSFET Driver Board

Each solenoid is connected to and controlled and powered by a custom made MOSFET driver printed circuit board (PCB). The PCB uses an external 12V power supply that provides power to the main MOSFET circuitry while an onboard LM7805 5V, 1.5A regulator provides power for the Teensy microcontroller. The current required to fully engage each solenoid used for *Click::TWEET* is up to 0.5A at 12V. The multifunction PCB can power and control up to ten devices with an appropriately sized power supply. The PCB has been designed to be able to be used in a range of projects that require circuitry to actuate electromechanical devices. The PCB is designed to host a Teensy 3.5/3.6/4.1 microcontroller directly on the board or to interface with other microcontrollers by using a small custom designed adapter board that fits into the Teensy header socket. *Click::TWEET* uses an interface adapter to connect the MOSFET driver board to a Raspberry Pi 4's general purpose input/output (GPIO) ports. These are shown together in Figure 4.4.

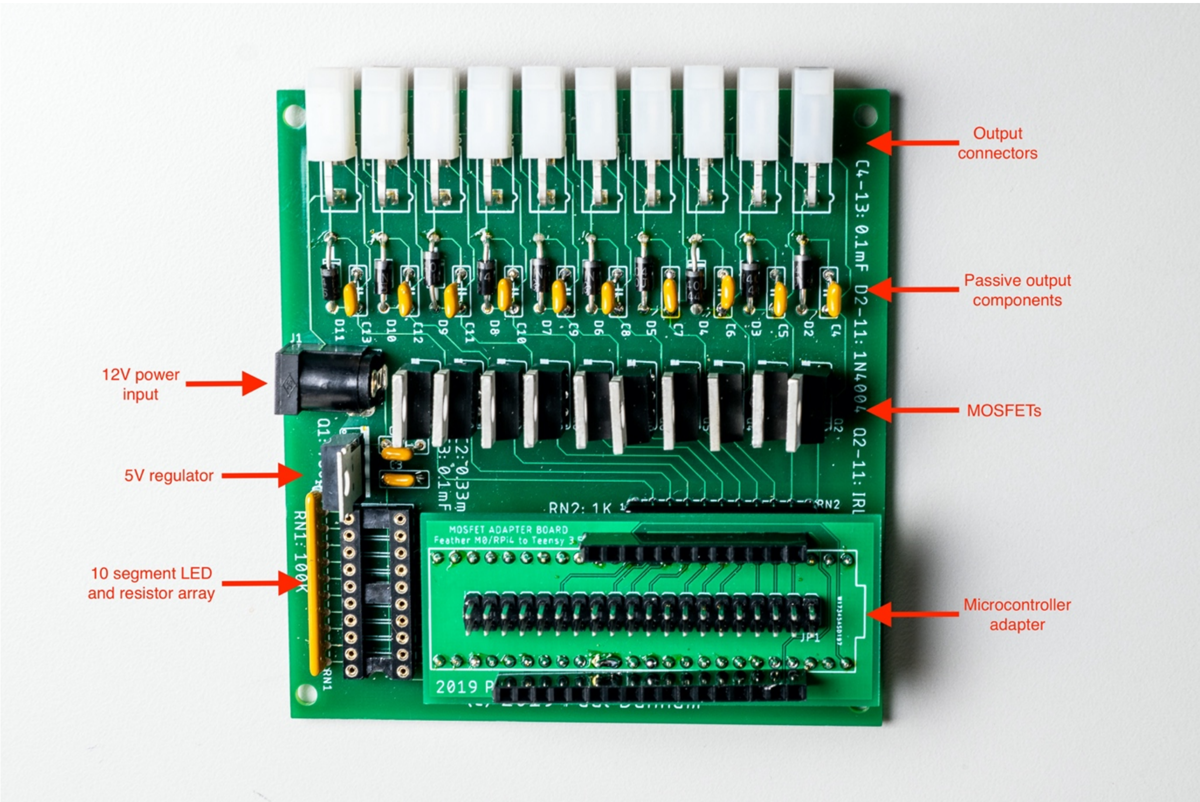


Figure 4.4. Custom MOSFET circuit board with adapter

The PCB uses IRF540N MOSFETs with a maximum Drain-to-Source voltage of 100V whilst supporting a continuous maximum drain current of 33A. The IRF540N has been chosen for its lower gate trigger level but the higher voltage and current specifications allows it to be used in higher load environments if necessary. The lower trigger level allows a low power microcontroller such as the Teensy to actuate 10 outputs simultaneously. A three-pin header strip is used to mount the MOSFETs and 5V regulator, as this facilitates the easy and quick replacement of a failed component without removing and replacing the entire PCB. A 10 segment LED, powered by the Teensy GPIO ports, is used on the PCB as a visual indicator of channel actuation and as a troubleshooting aid. The LEDs have been current limited using a 10 pin resistor network array to ensure no light is visible through the acrylic. A similar array is used in the circuit's output stage. These have been used because of their smaller form factor over standard resistors. The circuit showing the input stage from the Teensy and one of the output stages is shown in Figure 4.5.

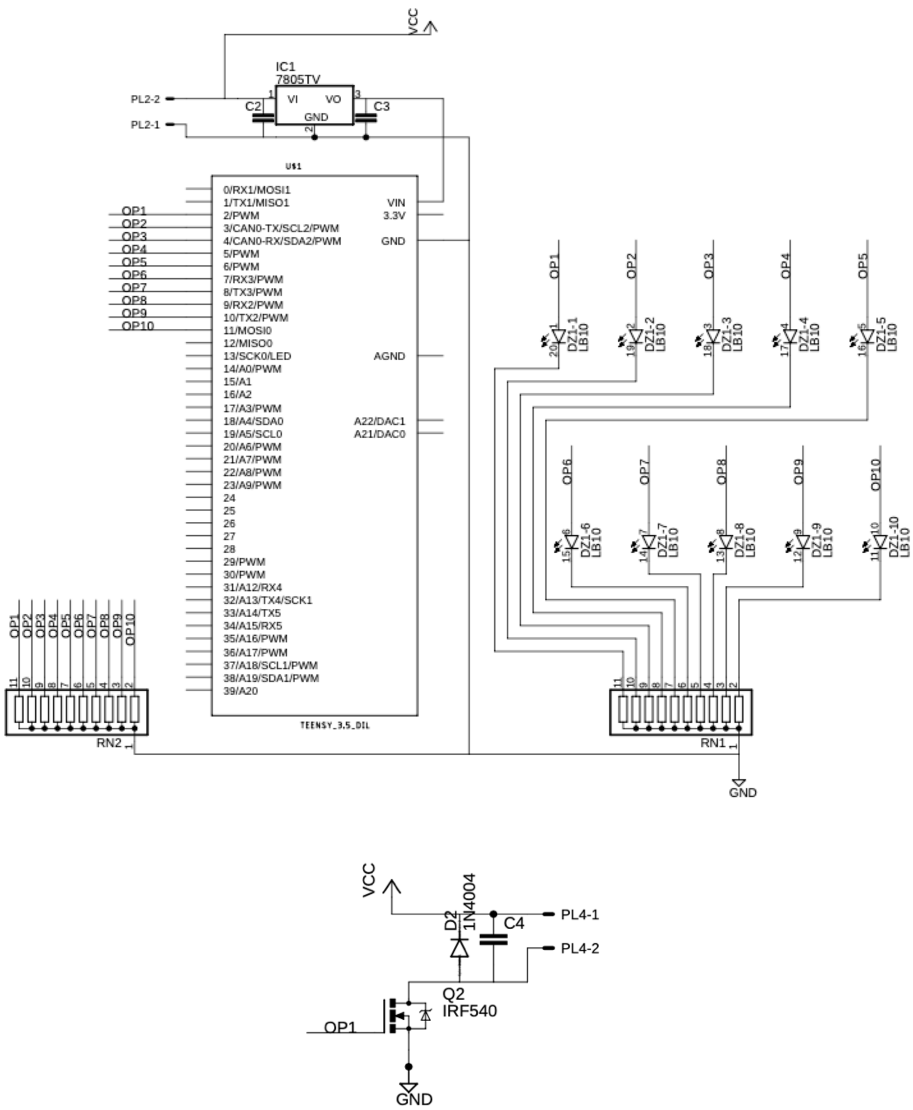


Figure 4.5. MOSFET circuit input and output stages

The Raspberry Pi's GPIO interface is connected via an adapter board to the PCB with a 40 way ribbon cable. When messages are being replayed, the Morse code elements are sent out a designated GPIO pin as an electrical pulse. This pulse opens the MOSFET gate to pass 12V to engage the respective solenoid.

4.2.1.2 Audio Amplifier.

Click::TWEET uses a Dayton 15W amplifier to provide audio output for a sine tone used in some forms of message replay. The purpose of the sine tone is further elaborated in section 4.2.3. The amplifier, housed inside the enclosure, is connected to the audio output of the Raspberry Pi. Speakers connected to the amplifier are mounted internally on the enclosure's end plates that, combined with the internal cavity, act to resonate their sound. Figure 4.6 shows one of the internally mounted speakers.

Figure 4.6. *Click::TWEET*'s internally mounted speaker

4.2.2 Software Implementation

Custom software has been developed in Processing for Raspberry Pi. The decision to use Processing on a Raspberry Pi was made to overcome the need for a laptop to be physically connected as a part of the installation. This decision is for aesthetic reasons and can be considered a way to maintain the audience focus on the visibly present sound objects. Further, the Raspberry Pi provides all the necessary connectivity options required for the various components of the work. These include a method of connecting to the Internet via a Wi-Fi or Ethernet connection, HDMI for video output, connectivity to the MOSFET controller and an audio output.

Twitter4j, a programming library utilised by Processing, is used to connect to Twitter's application programming interface (API). [173] Twitter4j provides the ability to listen for and process live tweets or to extract tweets from Twitter's message archive. A live streaming service continuously listens to a live stream of messages. Keywords or phrases can be defined that enables the listening process to only 'hear' messages that contain the keyword/phrase. A query mode allows messages to be extracted from Twitter's message archive and stored in a data table. If no keyword is specified, a random selection of messages are returned. Signal flow diagrams for both modes of operation are shown in Figure 4.7 (Live) and Figure 4.8 (Archive). Each of these replay modes are discussed below.

4.2.2.1 Live Mode.

Live mode begins by initialising and instantiating several operational parameters (1). Next, a connection to Twitter is established by utilising the Twitter4j API and an authentication process is undertaken. Once authenticated, a listener process is instantiated that listens to live tweets for keywords or a keyword phrase (2). When a message is detected (3), the listening processing parses the message to extract the text from the content of the message. The text is passed to a function that transforms the text to Morse code elements (4). These Morse code elements are then split into individual symbols to apply the correct temporal structure for replaying the message (5).

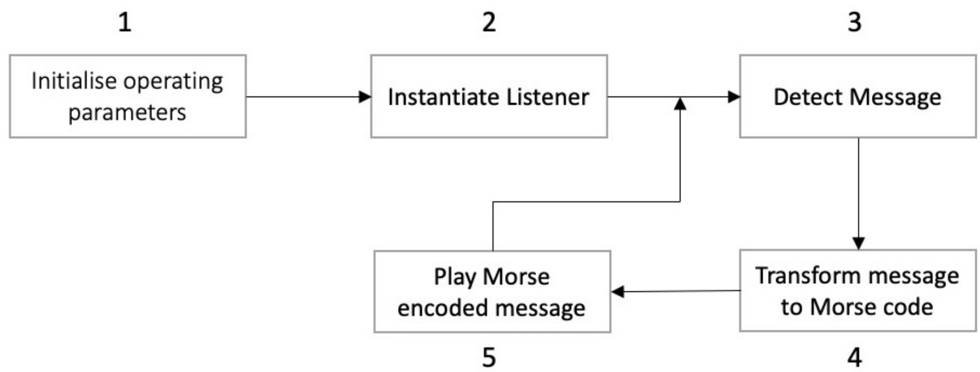


Figure 4.7. Live Mode program flow

As this replay mode uses a single message, the compositional form plays each character's Morse elements sequentially across the keys. This form is discussed fully in section 4.4.4.1. Once the message has been replayed, the program returns to the listening process.

4.2.2.2 Archive Mode.

Archive mode uses some of the same processes as Live mode. After initialising and instantiating the operational parameters (1), a connection to Twitter is established with the use of the Twitter4j API and an authentication process is undertaken. Once authenticated, a query process searches Twitter's message store for tweets containing defined keywords or a keyword phrase (2). As messages are returned from the query, the program parses the message to extract the text from the tweet's content and the message text is stored in an array. Once the query is complete, the program selects a message at random from the array (3). The text is passed to a function that transforms the text to Morse code elements (4). These Morse code elements are then split into individual symbols to apply the correct temporal structure for replaying the message (5). The message can be replayed in one of three different compositional forms. Where the compositional form plays a different message on each key, each message is spawned to a separate thread. Using separate threads allows the replay of each message to operate independently without affecting the timing of the other messages. These forms are discussed fully in section 4.4.4. Once the message has been replayed, a timer is initialised for a defined period before the process is repeated (6). During this pause, a sine tone can be heard. The purpose of the sine tone is discussed in section 4.2.3.2.

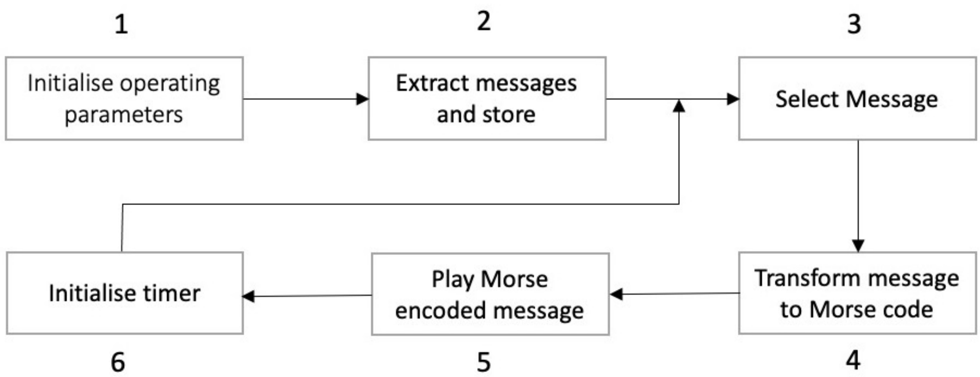


Figure 4.8. Archive Mode program flow

These software artefacts are contained in the Appendix.

4.2.3 Aesthetic Considerations

In its minimal prototypical state, *Click::TWEET* is based on the sonic artefacts of a single model of telegraph key, the ubiquitous Key W.T. 8 AMP No. 2. (shown in Figure 4.9). The raw building block of a single telegraph key is extended to six keys as an iteration of the single unit to expose the nuances of each key, introducing the variations in the inherent sound making qualities of each key to expand the compositional palette. Again, the significance of six keys is elaborated in sections 4.2.3.3 and 4.4.4.1.

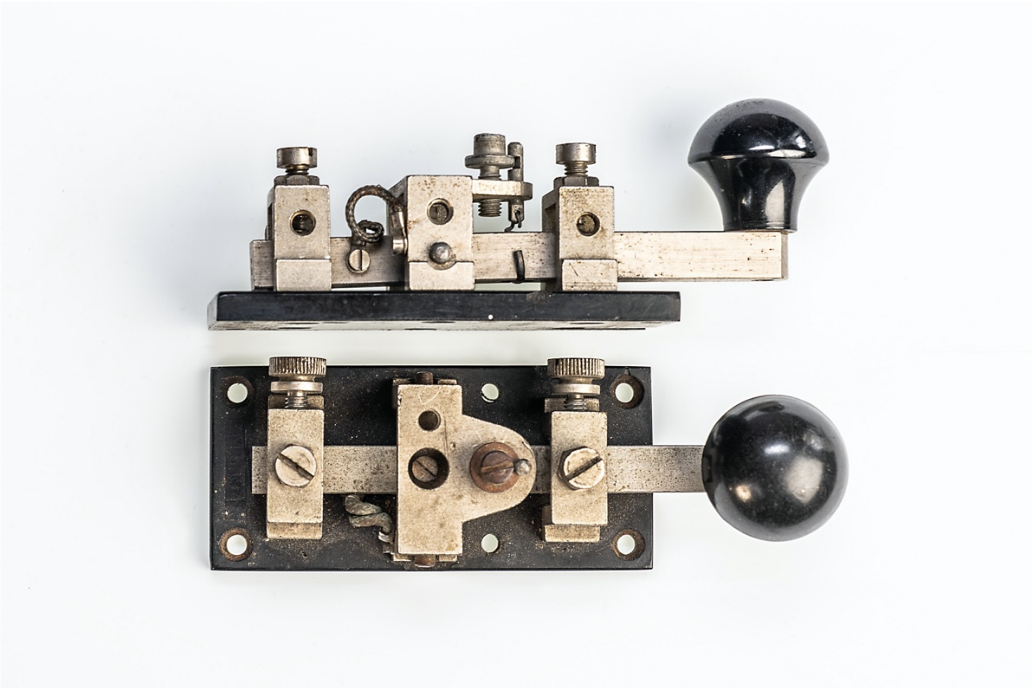


Figure 4.9. Key W.T. 8 AMP No. 2 Telegraph Key

4.2.3.1 The Telegraph Key as a Sound Object

Reduced to a basic sounding object, the telegraph key is a means to foreground an individual key's sonic materiality (see Figure 4.10). This materiality is heard as a double click when the key's contacts engage and disengage. As such, the sonic palette is limited, which also places constraints on the compositional outcome of deploying this palette.

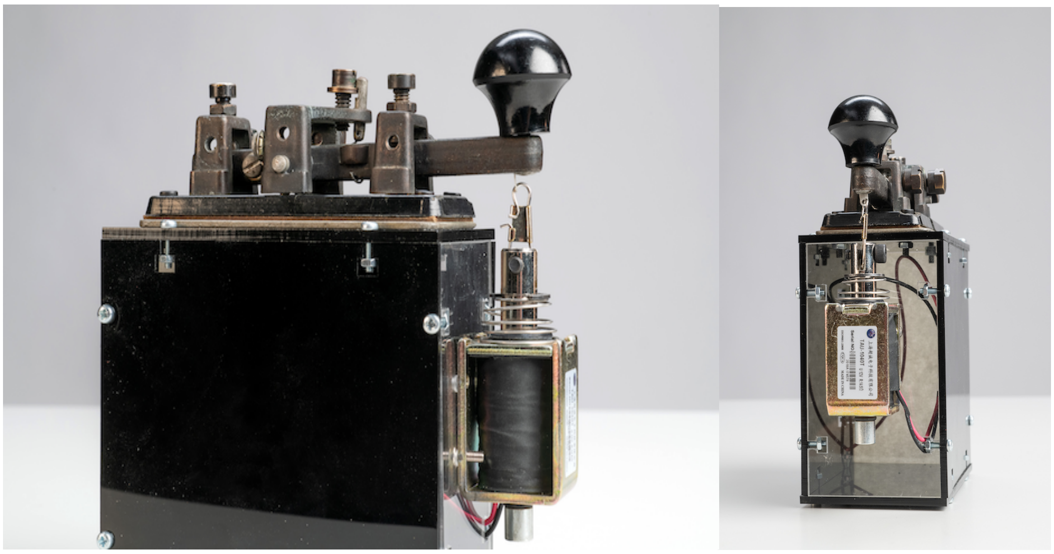


Figure 4.10. *Click::TWEET* single key prototype

The primary material components of the key used in *Click::TWEET* are the brass square rocker arm and three stirrup-shaped brackets, the spring tensioner and spring, the black ebonite base and knob and the tungsten-faced steel contacts. [174] Each of the telegraph keys used for *Click::TWEET* may be perceived to be the same. However, although manufactured to the same specifications, differences in the construction or manufacture, and in the wear, of each key's materials ensure an individuality to them. [44] While mechanically designed the same, small material and manufacturing differences result in subtle variations in their physical operation, and subtlely, in their sound-producing qualities. These are manifest in the variations of each spring's tension, the erosion of each key's contacts and the travel of each rocker arm, thus ensuring a unique set of nuances in each telegraph key's individual material characteristics. It is in this individualisation that the unique sound of each key is heard. These barely perceptible material differences add elements of interest to what appears to be a somewhat robotic approach to the work. Allowing each telegraph key to voice these unexpected behaviours in their own way introduces a small element of unpredictability to the work.

4.2.3.2 An Audiovisual Aesthetic

The telegraph keys' position atop a white plinth draws attention to the primary audiovisual elements of the work. Other electromechanical and computational processing components are contained inside the plinth to reinforce the presence of, and maintain focus on, the telegraph key as a sound making object as shown in Figure 4.11. The use of external components to support the installation (e.g. a laptop, external speakers) has also been minimised to foreground the physical presence of the telegraph key and to maintain a perceptual invisibility to the digital information as it is stored and transmitted.

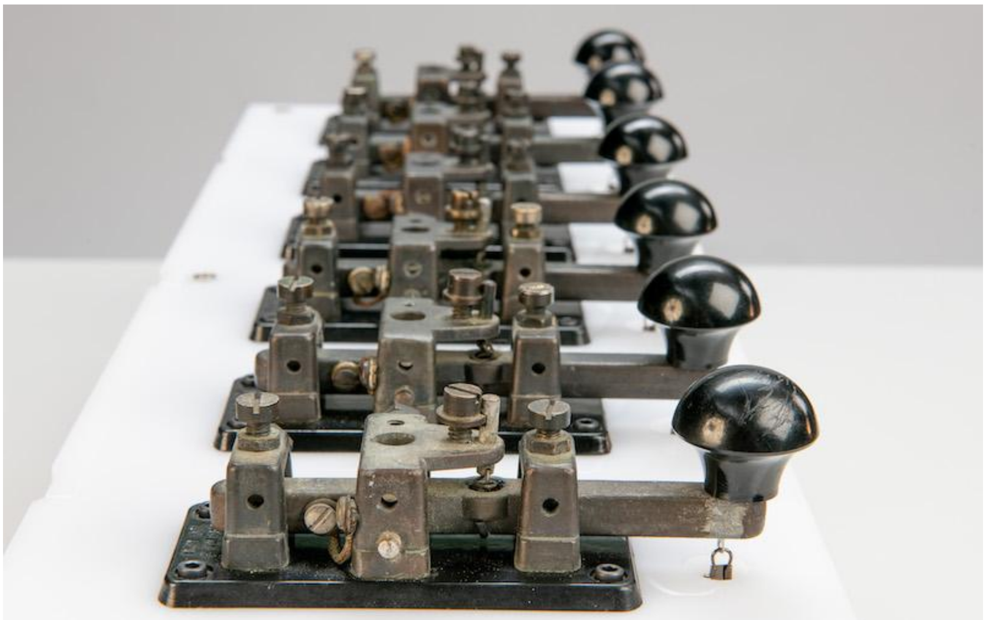


Figure 4.11. *Click::TWEET*'s primary sound producing objects – the telegraph keys

All power and interface connections have been made available from the rear panel of the enclosure as shown in Figure 4.12.

Figure 4.12. Rear panel connections

Two additional elements of the work reinforce an audiovisual relationship with the telegraph keys. Early telegraph systems operated a normally closed (or continuously active) circuit so that "when the transmitting equipment was idle, a steady battery was applied to the line" as a continual test of a telegraph circuit. [174][175] The always-on presence of the active telegraph circuit is represented in *Click::TWEET* by a 600 Hz sine tone. This tone is similar to, and inspired by, the tone frequency used in telegraphic communications. The sine tone is programmed and generated within the Processing environment, and sent out the Raspberry Pi's audio connector to the Dayton amplifier. The sine tone waits for a signal to disrupt its presence. Each dot or dash is heard as a break in the sine tone, an absence, presenting a perceptual disconnect to the visual movement of the telegraph key as it makes a mark to represent the same symbol. When a message transmission is complete and *Click::TWEET* waits to replay another message, a continuous tone is heard as the presence of the active circuit. The use of the sine tone, based around the frequency of wireless telegraphic transmission indicated previously, provides a further aural, but somewhat disruptive, connection to the visual movement of the telegraph keys and the inherent rhythm of the replayed message. The presence of the sine tone represents both a physical and abstract manifestation of the always-on presence of the electric telegraph circuit as it waits for the always-on connected presence of social media to trigger an event.

4.2.3.3 Morse Code as Click::TWEET's Expressive Logic

The Morse Code character set used for *Click::TWEET* is based on the International Telecommunication Union (ITU) recommendation for International Morse code[21]. [176] This allows a character set to be used that includes letters, figures and punctuation. There are six Morse elements (dots and dashes) used to construct these character representations. Using this character set allows an extended range of symbols used in Twitter messages to be encoded, especially non-alphanumeric symbols prevalent in Twitter messages. A table of characters used is shown in Table 1 below. *Click::TWEET'*s use of six telegraph keys is directly related to the maximum number of Morse elements in the character set being used. For a composition that uses a one to one relationship between Morse elements and telegraph keys, this allows the maximum number of elements to be represented across the keys. This is further elaborated on in section 4.4.4.1.

[21] See the International Telecommunication Union's (ITU) recommendation for the definition of Morse code characters at https://www.itu.int/rec/R-REC-M.1677-1-200910-I/

Table 1. *Click::TWEET'*s Morse Character Set

Character Symbol	**Morse Code**	**Character Symbol**	**Morse Code**	**Number Symbol**	**Morse Code**	**Punctuation Symbol**	**Morse Code**
a A	.-	n N	-.	1	.----	.	.–.–.–
b B	-...	o O	---	2	..---	:	–––...
c C	-.-.	p P	.--.	3	...--	?	..––..
d D	-..	q Q	--.-	4	....-	'	.––––.
e E	.	r R	.-.	5	.....	-	–....–
f F	..-.	s S	...	6	-....	/	–..–.
g G	--.	t T	-	7	--...	(	_.__.
h H	....	u U	..-	8	---..	)	–.––.–
i I	..	v V	...-	9	----.	"	.–..–.
j J	.---	w W	.--	0	-----	@	.––.–.
k K	-.-	x X	-..-			=	–...–
l L	.-..	y Y	-.--			;	_._._.
m M	--	z Z	--..			+	._._.

As Morse elements (the dots, dashes and spaces) are received, the tapping of the telegraph keys reveals the inherent rhythms of messages through the material transformation of Twitter's digital media stream. The selection of messages from Twitter's archive, or by listening to Twitter's live message feed in real-time, is based on the use of keywords or a keyword phrase. The keyword phrase "What hath God wrought?" has been used to query Twitter's message archive. This keyword phrase is used to acknowledge the first Morse coded transmission between distant locations in 1844. [177]

This section has provided a description of *Click::TWEET*'s material, functional and aesthetic implementations. The next section presents the material conceptualisation of the connection between the telegraph and Twitter. Using a material approach to media archaeology, a number of perspectives are drawn together that explore the material possibilities of obsolete media through an engagement with the telegraph key. In this way, the relationship between these two forms of social media are drawn together through *Click::TWEET*.

4.3 A Media Archaeological Approach to Revive an Inoperative Past

Having detailed the technical and aesthetic aspects of the work, this section is dedicated to a discussion of various approaches to the ideation of *Click::TWEET* as an audiovisual composition. First, the section describes Shintaro Miyazaki's form of rhythmic analysis that builds on Ernst's concept of the media archaeological ear. Next, it describes a method of listening to, and through, telegraphic noise as a counterpoint to Ernst's media archaeology of recorded media. Last, the section presents an appropriation of Miyazaki's form of rhythm analysis as a way of making Twitter messages perceptible through an audible, yet obsolete, media artefact - the telegraph key.

As described previously in section 2.2.4, a close listening to sounds' audible characteristics can establish a meaning for those sounds; they become signs that can be interpreted as forms of "possible data for perception and knowledge" through variations in their sonic characteristics. [154] However, beyond Ernst's media archaeological ear, a privileging of sonic detail was well established before sound recording and reproduction technologies made novel use of hearing. A history of listening to signal processing extends back to the electric telegraph where operators listened to the clicking of the telegraph sounder to translate the material sound created by electrical impulses into alphabetic symbols, words, sentences, and lastly, into readable forms of inscription.

Miyazaki has adopted a media archaeological approach through the auralisation of signals to listen to the rhythm, noise and melodies of machinic processes. He considers the use of this approach as a way of overcoming what he perceives to be an aesthetic of blindness, a term used to describe a focus on the non-visual senses. This blindness has, over the decades, privileged the visual over listening as a source of knowledge by the dominance of codified processes that now allow machinic forms of self-monitoring to be represented through visual interfaces. Extrapolating Ernst's media perspective of the 'event', when the media themselves are seen as dynamic and active agents in the way they store, process and transmit signals, Miyazaki's approach emphasises the significance of the auditory and tactile senses through engagement with media [50]. Extending Ernst's functional or operative level of engagement in the digital realm, Miyazaki defines a process of "revealing machinic processes, signals, oscillations and rhythms to human perception". [178] His term for this process is the *algorhythm*, a neologism of the words algorithm and rhythm. Understood as the "real physical, dynamic and noisy, erroneous rhythms produced by discreet step-by-step formalistic, static, and abstract symbolic instructions", the *algorhythm* oscillates "in-between the symbolic and real physical structures." [67] Miyazaki defines the algorithm as the:

> vibrational, pulsed and rhythmized signals constituted both by transductions of physical fluctuations of energy and their oscillations as well as by abstract and

logical structures of mathematic calculations that act in-between the real and the symbolic. [68]

As such, Miyazaki's close technical analysis of the "demodulated noises, rhythms and other sounds", as a form of rhythm analysis gives a humanly perceptible sonic presence to what was once an audible machine operativity. [178] This can be considered a return to the listening to signals that have since been rendered almost inaudible through the abstraction, automation and assimilation into the functionality of technological progress.

4.3.1 Listening To and Listening Through Noise

Originally intended to be interpreted visually by reading the dots and dashes inscribed onto paper tape, listening became the dominant interface between the electromagnetic pulses, heard as clicks, and the transcribed message. Telegraph operators listened to the sounds of the electric telegraph as a more efficient process for decrypting messages. Listening to sound in this way has been described as a form of audile listening, a technique that separates listening from the other senses so it can be "intensified, focused, and reconstructed." [154]

Through the separation of listening from the other senses, the telegraph operator was able to frame sounds as interior, those to be analysed and therefore interpreted, and exterior, those considered noise. Whereas this differentiation of 'interior' and 'exterior' sounds separated the message from the medium, Ernst's media archaeological ear, discussed in *Digital Memory and the Archive*, inverts this listening paradigm. [50] Embracing all sounds of the medium, the media archaeological ear listens beyond the primary sound of the recorded medium to decipher non-musical articulations as a media archaeological event. Inscriptive media, one that "precipitates phenomena onto surfaces (pages, scores, screens, memory devices, etc.), are generally associated with recording and storage awaiting revivification, reproduction, repetition, and more storage". [179] However, unlike Ernst's revival of these past media, the telegraph did not reproduce stored sound. Transported as an electrical impulse, the telegraph, as a transmission medium, linked sound events, making them audible as a sonic trace, a click. Listening to these as interior sounds, the sounds of a distant message were heard in the form of an indexical code. The experienced telegraph operator, prioritising the code as a matter of efficiency, listened to the beats in and of themselves as a "sonic surrogate for the letter or word." [180] Similar to how an operator listened to the audible pulses as a symbolic proxy of words, *Click::TWEET's* near erasure of the semantic meaning of the tweet focuses an audience's listening on the indexical level of the telegraph as a series of rhythmic pulses.

4.3.2 Sonifying Twitter

The compression of time and space by advances in communication media identified by Murthy in section 4.1 can be characterised by forms of electric and electronic transmission and inscription media. The speed of transmission and the transition between physical states of energy and matter (transmission and inscription) in contemporary media technologies is much too fast to be perceived directly by human senses. Differentiating between a live (as analogue) and real-time (as digital) signal transmission process, Ernst suggests a metabolic slowing down of the speed is necessary as a way of sonifying the signal transmission to bring it within human audible ranges. For Ernst and Miyazaki, time axis manipulation, as a form of slow motion, is a technique for the analysis of time-critical processes. In this way signals and their inherent oscillations and rhythms can be slowed and amplified to become audible to human perception. [25] [150] Such a process of manipulating a signal's time axis to make dynamic changes in signal oscillations and transients perceivable to the human ear is a sonification technique called *audification*. This technique is considered to be the direct mapping of any "data dimension to an elementary sound pressure level contributing the creation of a waveform." [106]

Inaudible information can be revealed in other ways. If as Miyazaki states, the *algorhythm* oscillates "between code and signal, between the symbolic and the physical side of (computational) media", creatively appropriating an obsolete media and returning it to an operative state is one way to hear the otherwise inaudible. [178] The electric telegraph's dots and dashes serve as a way of sonifying the nature of coded signal transmission. [53] Appropriating obsolete telegraph keys and foregrounding their sound making qualities, *Click::TWEET* replays variations of Morse encoded Twitter messages. Through the changes of material state between inscription, the tweet, and transmission, the replayed tweet can be considered a form of media archaeological reverse engineering as a way of slowing down the present through the past. In this way, the work cuts through the noise of Twitter, unravelling selected content to be re-presented by *Click::TWEET*, as a potential bridge between seeing and hearing. Making tweets audible in this way requires the erasure of content. *Click::TWEET* ignores images, video and some forms of punctuation that are not re-presented in the international standard used as a reference for this work. Similar to a telegram's linguistic compression, which could lead to multiple interpretations of meaning, the removal of content from a tweet can produce a re-interpretation or reconstruction of meaning or render the message's context meaningless. [181]

As an audiovisual installation and as an interpretative relay for the retransmission of Twitter content, *Click::TWEET* draws attention to the entangled historical lineage of media technologies through a connection between distantly related media. To roll out a well-used phrase, the medium is the message. Playing the messages in this way re-presents, what some consider, one noisy medium – the socio-communication of social media and the noise of signal processing that is inaudible to direct human perception – through another (acoustic key clicks). As such, this creates a presence of telegraphic communication within the contemporary realm of social media. *Click::TWEET* can be considered a return to the material representation of media through the physical re-presentation of Twitter messages transported as invisible digital media through the physical materiality of the telegraph key. Thus, by re-engaging the material analogue world in tandem with the digital it can be considered a return to the tactility of pre-digital media. [21]

This section has presented Shintaro Miyazaki's form of rhythm analysis, the *algorhythm*, as a way of hearing the otherwise inaudible digital processes and signals. The work has informed a method for slowing down the digital transmission of Twitter messages to make them audible as Morse encoded messages. Utilising obsolete telegraph keys, *Click::TWEET*, as an audiovisual installation, draws a media archaeological connection between the distantly related technologies of telegraphy and social media. The next section discusses methods used in the compositional elements of the work. Specifically, the section draws on Henri Lefebvre's analysis of rhythms to describe *Click::TWEET*'s various compositional forms.

4.4 Compositional Implementation

This section describes *Click::TWEET*'s various compositional forms as expressive rhythmic patterns. Following a brief introduction, the section presents the replay modes used to extract messages from Twitter. Following this is a description of how Morse code's temporal and structural logic is used to determine a meter for message replay. Next Henri Lefebvre's *Rhythmanalysis* is employed as a way to contextualise and describe the various compositional forms used in *Click::TWEET*. This is followed by descriptions of each of these compositional forms.

4.4.1 Morse Code's Rhythm

A single telegraph key has a limited sound palette. With timbral variation and pitch limited to the micro-level differences afforded by the erosion of each mechanism over time, *Click::TWEET* is largely reliant on the iteration of a single telegraph key's rhythmic patterns as the primary compositional element. It is, in part, the little errors and irregularities in the materiality of the telegraph keys that gives a tactility to an otherwise monotonic rhythm as micro offsets in the beat add a hint of musical groove. Underlying this manifest expression of rhythm is a temporal logic in the form of Morse code and its use of just two rhythmic values.

If rhythm is characterised by meter, accents, beats, and pulse, Morse code provides these as an isochronous sequences of patterns, based on the time unit of the dot. As Sterne notes, operators listened to Morse as a series of rhythms that did away with words. In parallel, one of *Click::TWEET'*s artistic outcomes is to construct a series of rhythms by manipulating the use of Morse encoded messages. [154] Considering that a method of learning Morse code is through the adoption of other prosodic forms of rhythm such as music and poetry, what does it mean to listen to *Click::TWEET* with no or little prior knowledge of Morse code? [171] [182]

Following Jason Hall, *Click::TWEET* encompasses a set of processes as an idea or abstraction of rhythm from one medium to another through the reinterpretation of Twitter's micro-poetic forms. Mediated through the electric telegraph's machine-like pulsing, Morse encoded patterns of sound are heard as recurring units of rhythm. [180] Thus, by manipulating Morse code's expressive and coordinating functions, *Click::TWEET* is the acoustic realisation of a machine prosody.

4.4.2 Replay Modes

Click::TWEET utilises two message replay modes that are available through the Twitter4j software API. These are an 'archive' mode and 'live' mode. The mode is selected by a change in the software. Archive mode uses Twitter's search method to return a collection of tweets matching a specified query. These are stored in a database in Processing awaiting revivification, reproduction, and repetition. The search word or phrase is configured by using keywords within the query method.

Live mode uses Twitter4j's Stream class to listen for messages containing a keyword or phrase match as it is transmitted live by Twitter. This mode has two purposes. First, it can be used for audience interaction: an audience can send a tweet containing keywords as a way to explore the rhythmic patterns in phrases, word or character sequences in their messages. By engaging an audience in this way, it may also allow them to reflect on the interwoven temporalities that exist between past and present media technologies. Second, with social media platforms expanding and evolving and the amount of information seen by some as overwhelming, there can be a sense of getting lost in the noise of social media. Rather than endlessly scrolling through inane posts, advertising content and reading expanded conversations, this mode could be seen as a slowing down of digital signal transmission in a return to earlier electric forms of communication by creating anticipation (a long wait) for a message to arrive.

4.4.3 Meter

Against the impact of 19th century technologies that shaped new rhythms in everyday life, Hall describes a new prosody for the measure of sound patterning: one influenced by the "mechanical imperatives of the period". [180] He argues that Coventry Padmore's assertion of meter as an abstract system of "spacing marked by an immaterial yet mentally perceived beat" detached patterns of meter from linguistic units of syllables and words, instead linking it to an "abstract beating of the ictus." [180] The emphasis on abstraction and proportionate time spacing as a series of "isochronous intervals", or temporal regularity, made electric telegraphy an appropriate counterpart for this new prosody. If the sound of electric telegraphy is heard as the "measured rhythmic movement of clicks or beats", Morse code's operating provisions (the symbolic translations and signalling measures) is the abstract rule against which this material form of communication is interpreted. [180]

Just as the dot duration is the basic unit of time measurement in Morse encoded transmission, it is used as the basis for the tempo for *Click::TWEET*'s compositions. The tempo is set by established transmission standards determining the word per minute code speed as a measure of proficiency in transmitting and decoding Morse code. While a number of mechanisms exist for determining this code speed, the two used for *Click::TWEET* are the PARIS and CODEX transmission speed standards. PARIS represents an average word length for plain text English in Morse code. CODEX represents material that consists of longer letters that appear as frequently as short letters (e.g., J, X). One determination of Morse code's meter is based on the time taken to transmit either PARIS or CODEX 20 times per minute. As such, these provide quantised time periods of 60 ms (PARIS) and 50 ms (CODEX) for each mark and space (see Table 2). These have been used to determine the measure for message playback for *Click::TWEET*. In a musical context, these provide tempos of 125bpm for PARIS and 150bpm for CODEX. A notated example using PARIS and CODEX at their respective tempos is shown in Figure 4.13. The tempo of the work is able to be changed when *Click::TWEET* is initialised by selecting one of the timing standards.

Table 2. Morse Elements and Determination of Measure

Morse element	Time Unit	PARIS Time (ms)	CODEX Time (ms)
. (dot)	1	60	50
- (dash)	3	180	150
Element space	1	60	50
Letter space	3	180	150
Word Space	7	420	350

Figure 4.13. Morse Code Timing Standards as Musical Notation using PARIS and CODEX

4.4.4 *Rhythmanalysis as Context and Concept*

Henri Lefebvre's treatise on rhythmanalysis has been discussed within the context of this thesis in section 3.7. Therefore, this section discusses the application of rhythmanalysis as it has been employed in *Click::TWEET* as compositional scaffold. If Lefebvre's linear rhythms are modelled on abstract quantitative clock times, so Morse code's meter, based on the dot (refer to Table 2), is the abstract measure of time for its signal transmission. As such, it is the operator, keying the encoded message, that adds a physiological articulation of rhythm to Morse code's abstract measure. However, *Click::TWEET's* expressive forms are not solely framed by Lefebvre's concepts of the rhythmic patterns inherent in the "experience and knowledge of the body." [149] As Lefebvre notes, a "rhythmanalyst is capable of listening to a house, a street, a town as one listens to a symphony, an opera." [149] Accordingly, a rhythmanalyst is capable of listening to the machinic processes of inscription and transmission posited by Ernst and Miyazaki as a material and "lively rhythmic performative, tactile and physical environment." [66] Drawing on Miyazaki's *algorhythmic* approach as a method of making an otherwise visual medium audible and Lefebvre's *Rhythmanalysis* as a conceptual approach for each composition, three expressive forms of message replay can be elaborated. Again, these three forms are characterised by eurhythmia, rhythms of equality, polyrhythmia, rhythms of diversity and arrhythmia, rhythms of disturbance. These are elaborated further in the next three sections. Examples of these expressive forms have been presented in the video documentation for the work.

Click::TWEET's video documentation shows the creative and rhythmic forms of expression within the context of Lefebvre's characterisation of *Rhythmanalysis*.[22] Each of *Click::TWEET*'s rhythmic forms are titled after these characterisations. Eurhythmia shows the smoother rhythmic patterns of a single message played across the six telegraph keys. Polyrhythmia begins with a more machine-like rhythmic pattern from which moments of syncopation and polyrhythms emerge. Arrhythmia appears similar to Polyrhythmia. However, with the different timing introduced into this form, duplicated messages become nonsynchronous as Morse code's structural logic is disrupted. Applying Miyazaki's algorhythmic concept of an abstract and logical structure of mathematic calculations to Morse code and the telegraph key, provides the structural logic for an abstract measure of sound patterning. The telegraph keys' clicks are the manifestation of these abstractions as material acoustic rhythms. In the absence of a human agent, *Click::TWEET* explores a series of compositional forms through the agency of the machine. The repetition of a linear time, and moments of rupture and antagonism that manifest as a difference in the materiality of each key, can be explored and experienced through the rhythmic pulse of electric telegraphy.

4.4.4.1 Eurhythmia

As discussed, eurhythmia, as a state of rhythmic resonance, is a state characterised by the synchronisation of different rhythms into a cohesive whole. It involves a form of rhythmic coordination as a distinct way to express how the experience of space and time may interact. [149]

Stanley Blue, quoted in Lyon, argues that eurhythmia contains elements of arrhythmia in the form of irregular "pauses, breaks and off-beats." [152] Eurhythmia, as it is represented in *Click::TWEET*, considers each Morse encoded character as a discreet and fleeting rhythmic pattern. In this way, each space between characters and words is a disruption to a pattern that may be resolved by the emergence of a new pattern. This is more noticeable in the elongated pause between words. Eurhythmia translates the message's individual characters into their equivalent Morse code and replays each character's Morse elements sequentially across the

[22] Video documentation for the work is available at https://www.dunham.co.nz/works/tweet

keys. Using six telegraph keys allows for the maximum character elements in *Click::TWEET*'s Morse code character set to be represented in the work (refer to Table 2). A notated example is shown in Figure 12. Playing the message in this way exposes the characteristic nuances of each key's physical properties and material sound. The sonic property of the object's sound is heard as each key is engaged and disengaged. Replaying messages in this way also connects the audio and visual elements as a way to emphasise the rhythmic patterns inherent in the Morse code. The Eurhythmia video introduced in section 3.8.2 is the realisation of this mode.

Figure 4.14. *Eurhythmia* Notated Example

4.4.4.2 Polyrhythmia

Michel Alhadeff-Jones considers Lefebvre's polyrhythmia to be an environment where heterogeneous rhythms co-exist simultaneously without being coordinated with each other. [156] In the absence of synchronisation, one has to focus on each of them separately, and eventually successively, in order to grasp their own specific rhythms.

Polyrhythmia plays a different message on each key. A notated example is shown in Figure 13. This mode exhibits moments of synchronisation, syncopation, and disturbance through the threading of the messages' rhythmic patterns. The very machine-like rhythmic structures are more evident in this compositional form. As each message is completed, the key rests. With the completion of each message and the resting of the associated key, the more machine-like rhythmic patterns gives way to syncopated rhythms. As further messages are completed, the rhythmic patterns become more synchronised until, finally, a single key completes its transmission. The Polyrhythmia video introduced in section 3.8.2 is the realisation of this mode.

Figure 4.15. *Polyrhythmia* Notated Example

4.4.4.3 Arrhythmia

Arrhythmia is characterised by the provisional or permanent lack of synchronisation between rhythms. [156] It can, subjectively, be perceived as a lack of harmony expressed as a form of dissonance. Dawn Lyon notes that a Rhythmanalyst is interested in this discordant form for "its potential to generate creative differences". [152] Morse code has been variously described as a variable length time patterned or duration-related code based on standardised code components and its signalling process. Any great variations in the timing of a Morse code transmission would introduce confusion into the signalling process as a form of arrhythmia.

Arrhythmia, as a form of pattern disruption, is based on Myron Wish's mid-1960s research on signal confusability in Morse code. [183] Wish's pattern disruption method was to vary the silent intervals between each adjacent pair of tones within each character. Instead of each silent interval conforming to Morse code's single time unit, Wish used either single unit (dot) or three unit (dash) intervals. To this purpose, Wish's signal confusability can be perceived as a form of arrhythmia in the original Morse encoded message. Describing these signals as rhythmic patterns, Wish noted each silent interval as a component of the signal "since the silence affects the rhythm of the signals." As such, Arrhythmia disrupts Morse code's signalling process by randomly changing the timing of the space elements used between each individual character from a dot length to be either a dot or dash length. Not only do the individual characters lose their semantic meaning but Morse code's temporal logic is disrupted as the dash length space blurs the boundary between characters. *Click::TWEET* inserts Wish's structural variations into all character forms used with the work. Table 3 provides an example of Wish's second model. Morse code's temporal length is shown as the first sequence for each example character. Wish's system are the subsequent variations.

Table 3. Wish's Rhythmic Pattern Variations

Signal (char i)	Temporal Length	Signal (chars)	Temporal Length
.(1).	3	.(1).(1).	5
.(3).	5	.(1).(3).	7
		.(3).(1).	7
		.(3).(3).	9

These structural variations have been applied to the composition algorithm to randomly add variable length element gaps to the replay of the message. Arrhythmia is most noticeable when applied to a polyrhythmic form. An example of Arrhythmia applied to Polyrhythmia is shown in Figure 1.1. This example uses the same messages used in Figure 4.15. Intentionally left to chance, Polyrhythmia can select the same message to be replayed on different keys. However, these same messages are desynchronised through the timing variations introduced by arrhythmia thereby creating a rhythmic variation from the same message content. The Arrhythmia video introduced in section 3.8.2 is the realisation of this mode.

Figure 4.16. *Arrhythmia* Notated Example

4.5 Discussion

Utilising the telegraph key's physical properties and historic materiality in an artistic context alongside Twitter as social media creates an awareness of characteristics manifest in earlier media that remain in contemporary media. The foregrounding of the telegraph key as the visibly present sound object also foregrounds its functional operativity, not just by its mere presence but by actively retransmitting messages. This process of retransmission can be considered analogous to Twitter's retweet function where a member resends (retweets) another member's message. In this way, the materiality of the telegraph key can be heard as a noisy past that continues to reverberate in the noisy world of social media. As such, *Click::TWEET* can be considered a return to the material representation of media through the physical re-presentation of Twitter messages, normally transported as invisible digital media, through the physical materiality of a set of telegraph keys. Through their performative presence, we can hear the present through the past via a temporal connection between the telegraph as an early form of social media and Twitter, a contemporary social media platform. By enabling the ability to hear the present through the past in this way, *Click::TWEET* reconfigures the historical existence of the telegraph, as an obsolete technology, within a broader history of social media.

Unlike Ernst's perspective of the object being a container of knowledge where the nonhuman forms of knowledge are exposed through the operative use of technologies, *Click::TWEET* draws on various narrative forms to connect the electric telegraph and Twitter. Noting that artefacts, as a part of a larger assemblage, get some of their meaning from what is written about them, these narratives are, in part, used to inform the operative elements and presentation of the work. [184] The ideation and realisation of *Click::TWEET* has adopted and adapted media archaeology approaches as a way to capture the “randomness of events" and to "seize the various perspectives, to disclose dispersions and differences.” [185] In this context, the telegraph key may be culturally obsolete, as its surrounding systems no longer exist, yet it continues to be operatively functional.

As a potential bridge between a primarily visual media and a noisy acoustic one, *Click::TWEET* connects obsolete and contemporary social media by appropriating the telegraph key as an artefact from electric telegraphy. This form of communication, through the rhythmic clicking of the telegraph’s contacts, used sound as a specific set of practices for listening to Morse encoded messages. [154] Just as the electric telegraph network was a link between sounds connected at a distance through electric impulses, *Click::TWEET* transliterates Twitter’s messages into Morse encoded transmissions through the acoustic clicking of the telegraph keys’ contacts. This approach provides a media archaeological short circuit between historically separated times to provide a new modality for the listener’s engagement with, and interpretation of, Twitter messages by listening to what is primarily a visually communication medium through a distantly related transmission medium. By returning the telegraph keys to an operative state and foregrounding the sounds associated with electric telegraphy, this research project excavates the agency of the machine, a shift from understanding media history through discourse alone, to consider it through the use and remediation of a material artefact. [31]. As such, *Click::TWEET* can be considered one of a number of connections between earlier forms of mediated communication, from the printed book through the technological innovations and socio-economic changes of the 19th and early 20th centuries to early computer based collaboration systems, and contemporary social media platforms.

Exploring different ways to replay messages can be a way of interpreting and unfolding the patterns and rhythms within the encoded message. Where the replay mode allows it, a continuous sine tone plays, only interrupted by a key’s actuation. This acknowledges that telegraph systems were always on as a method of knowing whether the communication circuit was live and as a metaphoric connection with an ‘always on’ social media. At the same time the sine tone heard as an absence against the mark, or click, of the telegraph key, is a perceptual antagonism to the rhythm of the replayed message.

Acting as a temporal bridge between the storage and transmission interfaces of Twitter and the telegraph's rhythmically pulsed clicks, Twitter's digital environment of zeros and ones, by way of Morse code's abstract and immaterial beat, is given material form through the array of telegraph keys. Morse code is a text-based communication medium and as such the rich visual content able to be included in a tweet cannot be represented by Morse code. As previously noted in section 4.1.1, Twitter content such as emojis, images, videos, and some text characters are not able to be played by *Click::TWEET*. Therefore each message's content is reduced to its base Morse elements by removing symbols that are not represented in the Morse system. As noted in section 4.1.1, both Twitter and telegraphic communication received criticism for their brevity, threatening longer and more elaborate forms of communication, and contributing to a general dumbing down of society through the "impoverishment of grammar, vocabulary, spelling and so on." [22] *Click::TWEET*'s need to 'dumb down' Twitter's messages can be perceived as being a part of the moral decline of communication which both technologies have been accused. Whilst the first two works have utilised obsolete media as the sounding object, the next chapter presents and describes *Click::REVU* which utilises two different perspectives of sight to sound to create a work that expresses the presence of past forms of media through a contemporary media artefact.

Art is what happens when you take an object
out of context and give it a new thought
- Marcel Duchamp

Chapter 5. *Click::REVU*

5.1 Introduction

Described as a factory for "the mass production of suffering, pain and broken bodies", the First World War resulted in the need to physiologically reconstruct human bodies thus producing an increased demand for prosthetic technologies. [186][187] One area of sensory loss was sight. Whilst braille had been available as a tactile substitute for sight since the early 19th century, technological innovation surrounding the war years provided an opportunity for other forms of sensory prosthetic devices to "relieve the disabilities of the blind." [188] One such device was a little-known invention called the *Optophone*. The Optophone is a device designed to "substitute the ear for the eye" by making optical signals audible and is just one example of a larger family of similar devices exploring the zones of sensory modalities such as the phonograph, telephone and optical telegraphy. [189] Fascinated with the relationship of electricity and light and the conductive properties of selenium, Edmund Edward Fournier d'Albe's early experiments and research led him to develop a means of providing a "complete electrical substitute for the eye." [188] However, the Optophone was not just a prosthetic device in medical terms. In a parallel development, it was conceived as an apparatus blurring the "distinction between art and engineering." [190] As a member of the Berlin Dada following the First World War, Raoul Hausmann's fascination with the human/machine interface explored the impact of technology on the mind and body through his artistic practice. Claiming no knowledge of Fournier d'Albe's research and development, Hausmann's Optophone was, for him, an "attempt to push the limits of scientific and technological discourse to a symbolic and aesthetic level beyond the utilitarian use" imagined for Fournier d'Albe's Optophone. [191]

The research objective of the work presented in this chapter is to blend physical elements of Fournier d'Albe's and Hausmann's conceptualisations of the Optophone and optophonetics to the ideation and realisation of an object-based sound installation. As media archaeology, the research is informed by a relationship between contact image sensor (CIS) technology prevalent in low cost multifunction printers and the Optophone via the light sensing technologies developed through the 20th century. Intrinsically, the Optophone shares a media genealogy with optical devices developed in the early 20th century as precursors to later developments that include the automated conversion of images into machine-readable text (optical character recognition), image sensors embedded in digital cameras and scanning technologies and the compact disc. This relationship between past and present forms of optical media informs a conceptual and aesthetic approach for the appropriation of one such form of media, the CIS mechanism, to create the sound-based installation *Click::REVU*. This chapter presents the ideation and realisation of *Click::REVU* informed by the relationship between the parallel developments of Fournier d'Albe's and Hausmann's optophonic research and Hausmann's expressive optophonetic language developed during the early 20th century. Indeed, Hausmann's concept for his Optophone can be traced back through his development of an optophonetic form of poetry which is discussed in sections 5.1.3 and 5.1.3. The research is informed by material and imaginary media archaeology in the ideation and realisation of an electromechanical sound installation using contemporary media to establish a connection with past mediatic devices and ideas whose traces remain in the present.

The remainder of this section provides an overview of optophonic developments that inform the ideation and creation of *Click::REVU*. These are the scientific and engineering developments and uses of the Optophone as well as the Dadaist ambitions of an optophonetic art form. A brief review of subsequent research into the use of sight to sound technologies within scientific and artistic practice concludes the section.

5.1.1 Beginning to Hear the Light

Edmund Edward Fournier D'Albe's impetus to develop an opto-audio device stemmed from his interest in the electrical possibilities of light and, specifically, the ability for selenium to conduct electricity when illuminated. [188] As a sonification device, the Optophone translated optical data to sound. First demonstrated at the London Optical Convention in 1912, the exploring Optophone (see Figure 5.1) was a device to aid visually impaired people with orientation in their environment. [191]

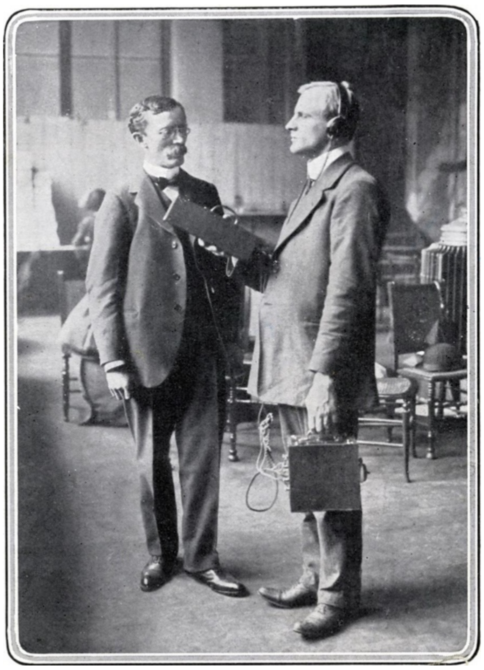


Figure 5.1. The Exploring Optophone

Fournier d'Albe stated that the blind could navigate around obstacles by listening through an adapted telephone receiver to hear series of clicks or rasping generated by differences in light intensity. A review of the event in the Scientific American Supplement described the sensitivity of the instrument as allowing "moonlight to be very audible, and the sun roars" and "the world of light could thus be made to 'sing' to the blind." [192] However, the instrument was not without criticism. One critique was of need. "The blind problem is not to find lights and windows but how to earn your living." [188] With this in mind, Fournier d'Albe presented a redeveloped Optophone to The Royal Society in 1914.

5.1.1.1 Reading by Means of Musical Motifs

The reading Optophone was "designed with the object of enabling blind persons to 'read' ordinary letter press by means of the ear." [189] With this development, d'Albe added a musicality to the tones used to represent text as sound. Using a numbered ratio from the musical scale, the reading Optophone produced a series of eight notes; G, C, D, E, G, B, C, E[23], from which "both concords and discords could be obtained according to the letters exposed." [194] The physical structure and features of the Optophone and details of rotating disk used to allow light to pass to the sensors for tone production is shown in Figure 5.2.

[23] This frequency range was incorrectly reported in the Scientific American (Nov. 1914) as frequencies of 24, 27, 30, 32, 36, 40, 45, and 48. These 'frequencies' were, in fact, the number of holes in successive circles in the rotating disk used in the Optophone. [193]

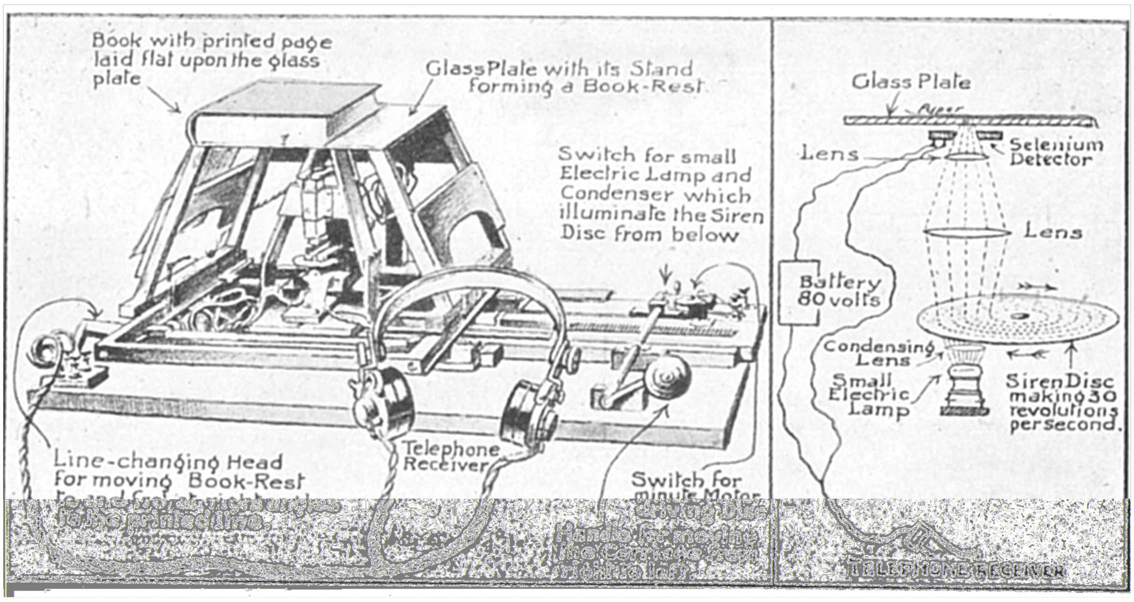


Figure 5.2. The Original Type-Reading Optophone
(Image from The Moon Element [188])

In what was termed a "white-sounding" Optophone, the black letters were read by omitting notes from the scale rather than by what notes were sounded. As a form of subtractive synthesis, white space was heard as a discordant "chaos of notes" with a letter characterised by the absence of a note or notes as it was read by the Optophone. [193]

Figure 5.3. The Type-Reading Optophone
(images courtesy of Blind Veterans UK)

Further developments to address institutional resistance to the device as much as any technological advances produced the type-reading Optophone (shown in Figure 5.3) in 1918. Rather than placing a static page with text onto a bed for reading, this device featured a mechanical carriage capable of moving a 'tracer' across and along to scan a page.

In 1920, Fournier d'Albe, along with optical engineers Archibald Barr and William Stroud, were issued a patent for "new and useful improvements in Optophones." [195] Two improvements are notable. First, was a reversal of the action for reading text. These later Optophones were termed "black-sounding" because, as a form of additive synthesis, it was the letters themselves that produced sound, thus producing no sound in the intervening "white" space. The second improvement was that the number of concentric circles in the rotating disk were reduced from eight to five. As such, the tonal range was reduced to G, C, D, E, G. An indication of the frequency range is provided in Fournier d'Albe's book, *The Moon Element*, and is shown in Figure 5.4 as 384-763Hz.[24] [196][197] Arguably, with these harmonised changes, it was easier to hear and learn the different chord variations in relation to the characters. [198]

Figure 5.4. The Black-Sounding Method of Text Reading
(image from The Moon Element [188])

As with the previous version of the Optophone, these notes, heard in this way, produced a rudimentary form of sound alphabet. Indeed, it may be that this new sound language was, as an "exploration of language as sound and sign, reduced to fragmentary form", a form of expression with similarities to Dadaist poetry. [199]

5.1.2 Poème Bruitist

The sound poem has been described as challenging the limits of natural language by altering the relationship between the arranged and ideal tension of sound and sense through the

[24] Fournier d'Albe originally used the notes C D E G B.
The frequencies used are based on scientific pitch using A432 tuning.

multiplication, reduction, or denial of semantic reference, while amplifying the phonetic and aural properties of language. [200] Whilst the roots of sound poetry can be found in oral poetry traditions, it is generally considered to have emerged from the avant-garde movement of the late 19th-early 20th century. The sound poem, largely developed by the Futurists and extended by Dada, was intended to denote language free of syntax and logical ordering to better convey intense emotion by freely deploying sound, especially onomatopoetic harmonies and glossolalia “to render all the sounds and noises of modern life, even the most cacophonous.” [200] In his manifesto *Distruzione della sintassi* (*Destruction of Syntax*) (1913) F.T. Marinetti’s *parole in libertà* (*words in freedom*) demands a “pared-down elliptical language, stripped of adjectives and adverbs, with verbs in the infinitive and mathematical signs and word pairings used to convey information more economically and more boldly.” [201] In Marinetti’s collection of poems published in *Zang, Thum, Thum* (1914), he recreates the 1912 siege of Adrianople as a “synthetic mimesis of the noise of modern warfare” through onomatopoeic and typographic references. [200] An example from his poem *Bombardamento* is shown in Figure 5.5.

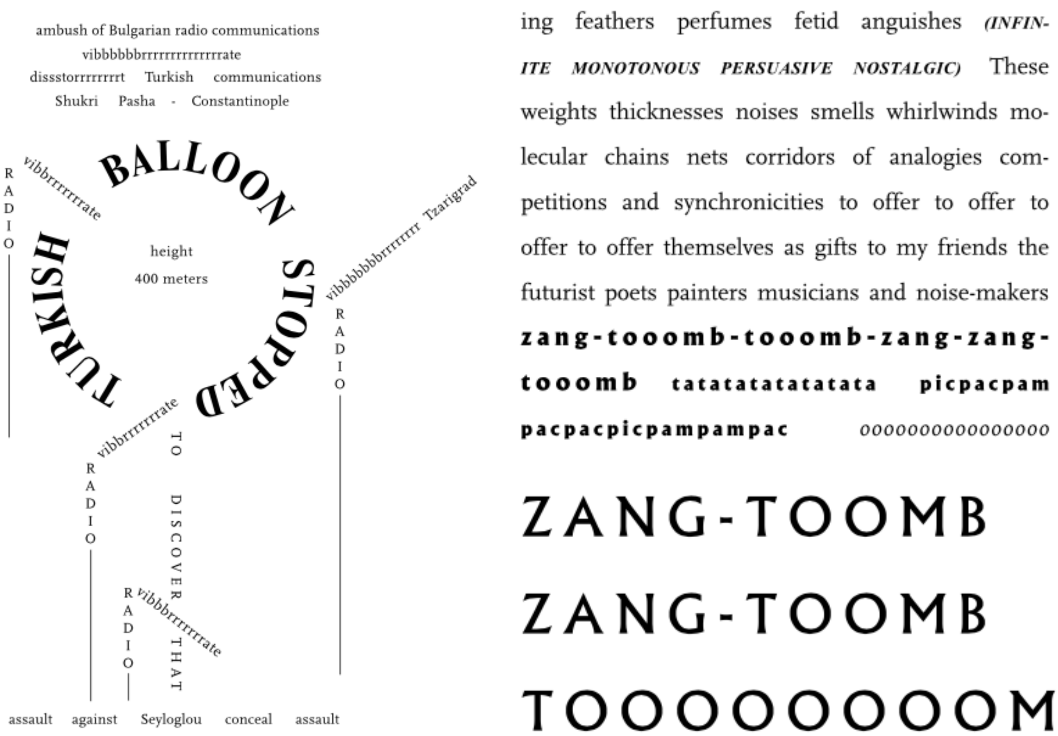


Figure 5.5. Excerpt of F.T. Marinetti's Bombardamento (1914)

Embracing the concepts of simultaneity and bruitism[25] from the Futurists, 'Meisterdada' Richard Huelsenbeck argues that, for Dada, simultaneity, as a "direct reminder of life", and bruitism, as a "kind of return to nature", are closely bound together.

> noise is a direct call to action. Music of whatever nature is harmonious, artistic, an activity of reason but bruitism is life itself … And so ultimately a simultaneous poem means nothing but "Hurrah for life!" [204]

Dada's simultaneous and bruitist sound poems have been described as "concerts of human and machine sounds, multiple poems read simultaneously by different speakers, and poetry that renounced narrative connections between words." [205] In their use of simultaneity, the Dadaists attempted to increase the ambiguity and noise, as their sound poetry sought to break down communicative language, to achieve more direct forms of expression as commentaries of the "muddle, colors, and rhythms" of everyday life. [205][206] In their performance the poems produced a "dissonant assemblage of sounds and noises" to which an audience would, at times, "feedback" its own dissatisfied voice. [206][207]

Hausmann intended his optophonetic poetry to break language free from its rational and conceptual straitjackets from which the "German language had degenerated and no longer expressed authentic human experiences." [208] As a form of expression and an exploration of language, Dada's sound poetry was not unique. However, it is arguably Hausmann's use of chance through the typesetter's irregular selection of type and his breaking of the sound poem into letter poems with the emphasis on the brevity of the single letter that differentiated his optophonetic works from other works of the time. [205][209] Hausmann's use of typographical variations as a signifying strategy in his poster poems provided a form of notation for the performance of the text as shown in Figure 5.6. [210]

[25] Bruitism is the use in music of sounds taken from an extra-musical source or context. [202] For the Futurists, musical noise was taken from modern life. In his manifesto, *The Art of Noise*, Luigi Russolo suggested the Futurist derives "far more pleasure from ideally combining the noises of trams, internal combustion engines, carriages, and noisy crowds" than from the "harmonies of the great masters." [203]

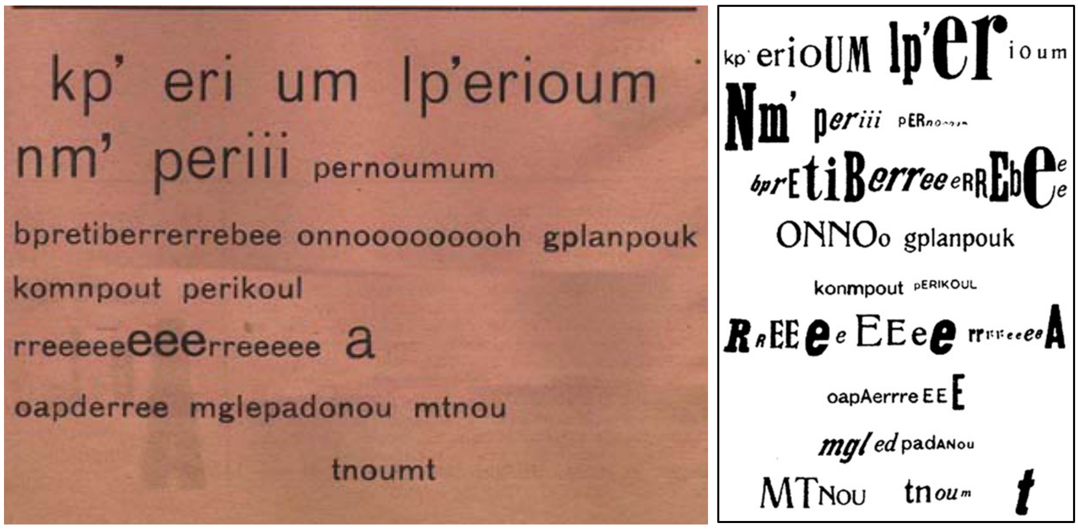


Figure 5.6. Examples of Raoul Hausmann's poster poem kp'erium (1919)

(Images courtesy International Dada Archive, Special Collections and Archives, University of Iowa, reproduced with permission)

Bringing a mechanical form of production to his writing, Hausmann sought to "liberate the characters from the regime of semantics" for the instruction of performance of the text as an exploration of the materiality of speech and language. [199] Arguing that what began as typographic 'play' resulted in Hausmann's exploration of human physiology, Cornelius Borck contends Hausmann's fusion of sound and vision in his optophonetic performances revealed the 'disabilities' of the human body; the gap between human senses. [187] Hausmann's perception of the role of language as being simultaneously visual and acoustic was applied to his ideation of the Optophone. As an optophonetic extension of the human body, he perceived a way to generate art decoupled from conventional meaning and familiar perceptual visual and acoustic structures. [211]

5.1.3 Seeing Sound, Hearing Light

Raoul Hausmann's optophonetic poetry, as a splintering of language, could be considered a transformation of the visual to sound. While more expressive than the limited tones of the Optophone, nonetheless it could be considered an early prototypical relation of the technological device in its translation of signs into phonemes. [187] If Hausmann's early poetic tendencies have been described as the mechanical production of meaningless typographic assemblages, expressed through vocalisations that tested the limits of "the alphabet as a sound recording medium", what purpose was his research into the development of an optophonic device? [199] Insisting on the role of language as simultaneously visual and acoustic forms, Hausmann conceived of what he called an Optophone: a synaesthetic machine capable of transforming the sound of words into the simultaneous display of coloured lights (and vice versa). With a goal to simulate human sensory functions, Hausmann believed his Optophone to be more than just a prosthetic apparatus. He believed it to be a "cosmic mediator of perception for 'disabled' humans", a sensory organ capable of transforming the central cognitive ability of mankind by merging human nature and technology. [187] The purpose of Hausmann's Optophone appears twofold. First, he believed there to be a gap between human senses, one that could be supplemented by technology that "transformed and mobilised human perception" across that gap. [187] Second, while envisioning the Optophone as a "materialisation of synaesthesia in the form of a symphony of light and sound" he was also attempting to decouple audiovisual forms from conventional meaning, as he had attempted to do with his sound poems and photomontages. [187][212] Hausmann described the technical functionality of his optophonic device in the early 1930s, however, as a forerunner to Zielinski's *Variantology* discussed in section 2.2.4, the device never materialised. Hausmann later described his device in Jean-François Bory's 1972 biography, *Prolégomènes à une monographie de Raoul Hausmann* (On the Subject of Raoul Hausmann):

> The Optophone (is) based on a selenium cell placed in front of an arc lamp, a loudspeaker of which varies the brightness in proportion to the sounds emitted. The selenium cell, whose conductivity increases as a function of the light particles received, then makes it possible, through a series of resistors, to record by sound (disc burning) the light it receives. So what appears as an image becomes sound in the intermediate station. It is then sufficient to reverse the process by mounting it in series so that the sound becomes an image. The selenium photovoltaic cell has been used in particular for light meters in photographic cameras, selenium reacting to light. [213]

Marcella Lista describes Hausmann's Optophone as having a "light keyboard" with "scores of keys" as a method for selecting and projecting colours that are intercepted by a photoelectric cell to translate light values to sound in real time. [214] Bridgit Schneider elaborates further stating that,

> by striking the keys, the person playing the Optophone would be able to send different series of "groups of spectral colors and bands of lines" to the optical system, which then would project "color-form performances," while at the same

time the photoelectric cell would transform the brightness and darkness values into electrical impulses and transmit them to the loudspeaker, where they would produce an "acoustic effect." [212]

From these descriptions we are able to conceptualise a physical manifestation of Hausmann's device. A crude hand drawn diagram of Hausmann's Optophone that accompanied his unsuccessful patent application is shown in Figure 5.7.

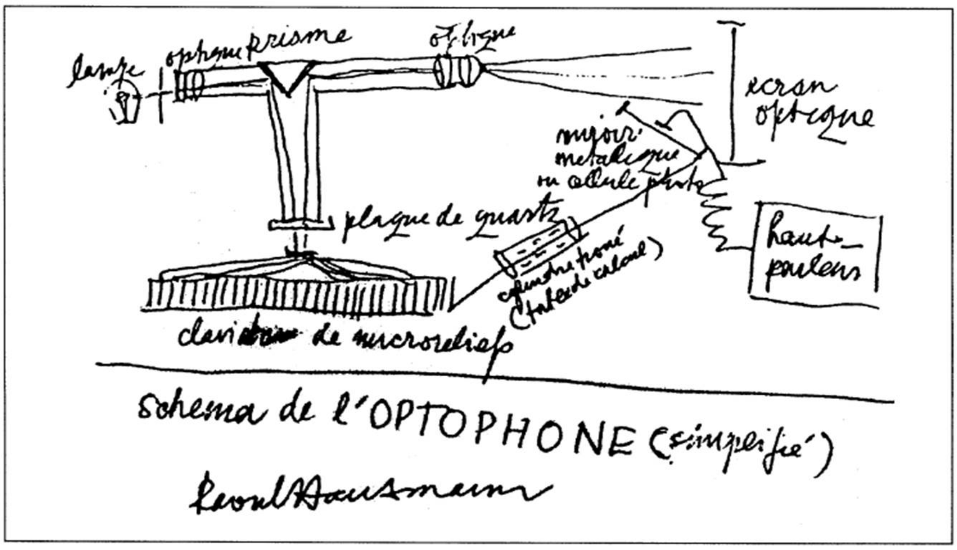


Figure 5.7. Raoul Hausmann's Simplified Diagram of the Optophone

5.1.4 Optophonic Science and Art

Whilst the development of prosthetic sight-to-sound technologies waned with the emergence of optical character recognition (OCR) technologies and speech synthesis, some research and development subsequent to Fournier d'Albe's original Optophone are worth highlighting. Initial suggestions and modifications to the original Optophone include A. A. Campbell Swindon's (1921) suggestion to amplify the Optophone, a suggestion effected by St. Dunstan's[26] in 1944. The selenium cells were replaced with photo-electric cells that increased the volume of sound and reduced ambiguities in the interpretation of light. Subsequent developments included further refinement to the focus of light on the cells. [198] RCA's Type

[26] St. Dunstan's is now known as Blind Veterans UK, a charity providing free support and services to vision-impaired ex-Armed Forces and National Service personnel

A-2 (circa 1946) included an electric stylus, advertised as a “pen that reads.” [215] The evolution of the stylus would lead to more far-reaching uses in many future technological developments. Further research produced a ‘letter reading’ machine, an early development in OCR technology. Other notable devices include the *Battelle Optophone* (1960s), Charles Carle’s *Lexiphone* (1963) and Mauch Laboratories *Visotoner* (mid-1960s), a self-contained battery operated Optophone, and the *Cognodictor* (mid-1970s), a recognition reading machine consisting of an optical scanner and a speech synthesis engine. [216] Adrian O’Hea’s (1994) research and development of a head worn device was similar in use to Fournier d’Albe’s exploring Optophone. Similarly, various research has been undertaken to develop devices that interpret three dimensional, or distance-to-object information, something increasingly commonplace with advances in image capture and analysis technologies. [217][218]

5.1.4.1 Reimagining the Optophone

The impulse to see music and hear colours has deep roots in the scientific revolution of the 1700s. Isaac Netwton’s *Opticks* detailed his experiements where he divided the colour spectrum into an “octave of seven colours”. [219] Louis Bertrand Castel’s ocular organ produced a colour for each note to perform a “new kind of music, enjoyed by the eyes.” [220] Predating Hausmann’s optophonic concept, Johann Gottlob Krüger’s Ocular Harpischord (1743) is a noted precedent for its reimagining of Castel’s idea. When a key or keys were played, a series of superimposed coloured lights would create colour chords in response to the sound. A number of inventors and artists imagined a choreography of light and sound by various means. Some manifestations include Frederick Kastner’s *Pyrophone* (c. 1870s), Alexander Wallace Rimington’s *Colour-Organ* (1893), Alexander Scriabin’s *Prometheus: The Poem of Fire* (1910), Vladimir Rossiné’s *Optophonic Piano* (1916), Thomas Wilfred’s *Clavilux* (1921), Alexander László’s *Sonochromatoscope* (1924), Charles Blanc-Gatti’s *Chromophonic Orchestra* (1933), and Stanton Macdonald-Wright’s *Synchronous Kineidoscope* (c. 1960s but it was a realisation of his work with Morgan Russell envisioned in 1913). [221] [222] These attest to earlier experiments into, and parallel developments of, the simultaneous presentation of sight and sound alongside Fournier d’Albe and Hausmann. However, a number of artistic reimaginings of the Optophone have been undertaken since their work.

Many literary examples of optophonetic writing exist particularly relating to sound poetry to which justice cannot be done within the constraint of this brief review. James Joyce’s *Finnegan’s Wake* (1939) is an example of the use of an optophonetic form of collage. For

Joyce, what he called 'sound-sense' was a way of experiencing text and gaining meaning from it through speaking and listening. He also considered this to be a way of breaking down boundaries between text-based and acoustic literature, oral poetry and forms of articulation not amenable to notation of any kind. [223] John Cage's mesostic[27] poems challenged rules of syntax and linear discourse similar to Hausmann. From these experiments he 're-wrote' Joyce's work as *Roaratorio, an Irish circus on Finnegan's Wake* (1979). [224]

Hausmann's Optophone influenced Francis Picabia's two canvases *Optophone I* (1922) and *Optophone II* (circa 1922-26). For Picabia, the two works illustrated a shift from the optical to the tactile in his use of nude silhouettes, a contradiction of Fournier d'Albe's Optophone (which was intended as a substitute for Braille). [214]

Figure 5.8. Picabia's Optophone and Optophone II

Contemporary renderings include Tiffany Chan et al.'s reconstruction, and Peter Keene's reimagining, of the Optophone. As media archaeological exercises, Chan's reconstruction and Keene's construction of the Optophone are practice-based methods of understanding media history through the tactile engagement with the "material particulars of historical mechanisms." [225] Such an approach provides an understanding of the presence of past media embedded in

[27] A mesostic is a poem or other text arranged so that a vertical phrase intersects lines of horizontal text.

contemporary culture and technology through a series of overlapping temporal layers. Chan et al.'s 'maintenance study' of reconstructing a reading Optophone is a "mode of inquiry into machine labour and maintenance of machine work." [226] Through this approach, Chan argues that the "labour point of view encompasses manufacturer, developer, and reader", a perspective that considers early Optophone readers as developers, who worked closely with manufacturers to recommend various technology updates during its product lifecycle. [226] Chan et al.'s remake of the Optophone does not seek to reconstruct an equivalent device nor to replicate previous experiences of the device. Rather they seek to highlight "what we cannot retrieve, repeat, or translate in the present" to foreground differences and absences as a refrain from "flattening the many versions of optophones into the optophone." [226][227] In this way they draw attention to historical absences by acknowledging the contributions of the early readers.

Peter Keene's reimagining's of the Optophone between 1999 and 2004 (shown in Figure 5.9) are based on a reading of Hausmann's original patent. He built three variations of the Optophone as audiovisual installations. He describes the first work as a "musical analogue computer", the second is an assemblage based on technologies of the period of Hausmann's conceptualisation of the Optophone including the theremin and television. The last work could be considered a data visualisation work, playing a series of recordings of Hausmann reciting his poems whilst triggering a series of light displays. [228]

Figure 5.9. Peter Keene's Reimagined Optophones (L-R: 1999, 2000, 2004)
(images courtesy of the artist, used with permission)

5.1.5 Summary

This section has presented an historical relationship between the Fournier d'Albe's Optophone as a medical prosthesis and Hausmann's Optophone as a dream machine. It has also briefly discussed research and works that have continued optophonetic development and creative use. The following section introduces an object-based sound installation that, through a media archaeological approach, is informed by the different perspectives relating to the Optophone's original developments. Titled *Click::REVU*, this work utilises characteristics associated with these unique developments to create an interpretation of the Optophone and optophonetics through a form of contemporary media technology. The work foregrounds the kinetic movement of a CIS mechanism as it scans, and captures data from the page of a document or image as a visual component of the work. *Click::REVU*'s unique sonic presence is informed by conceptualising the use of data as a typographic form of notation for optophonetic sound poetry. Appropriating a CIS scanner and using its light sensing technology to produce a form of typographic representation, the work reimagines the optophonic technology as an artistic re-presentation a century after its initial development. As such, *Click::REVU* is an audiovisual amalgam informed by a genealogy of connections between earlier media technology and ideology, and contemporary media. Using a media archaeological approach to the work's conceptualisation and realisation, *Click::REVU* connects contemporary mass-produced scanning technology to the technology of the Optophone and optophonetics in a relationship between the visual and aural senses.

5.2 Click::REVU

Click::REVU is an object-based sound installation that repurposes and foregrounds the CIS mechanism as the primary visual element for the work. In its intended use, the CIS mechanism (Figure 5.10) is generally concealed within a larger structure, analogous to an organ within a body. Removed from the shroud of darkness of its natural habitat and its support structures (e.g., interfaces to image formation, formatting and engine control) the CIS itself has become visually impaired as it struggles to see in its new environment. The mechanism's movement is reduced to a series of horizontal gestures, symbolic of its utilitarian and repetitious function. *Click::REVU* creatively appropriates and interprets aspects of both the real and imagined forms of optophonic media. The work incorporates the electromechanical material sounds produced from the CIS's movement with the discordant chaos of notes of Fournier d'Albe's early white-sounding Optophone whilst acknowledging the simultaneity and bruitism of Hausmann's sound poetry. As data sonification, *Click::REVU* maps data values to amplitude, frequency and modulation attributes utilised by the Teensy audio library. A simultaneity of pitched voices provides textural layers, that, as polyrhythmia, coexist and, as arrhythmia, clash with each other.

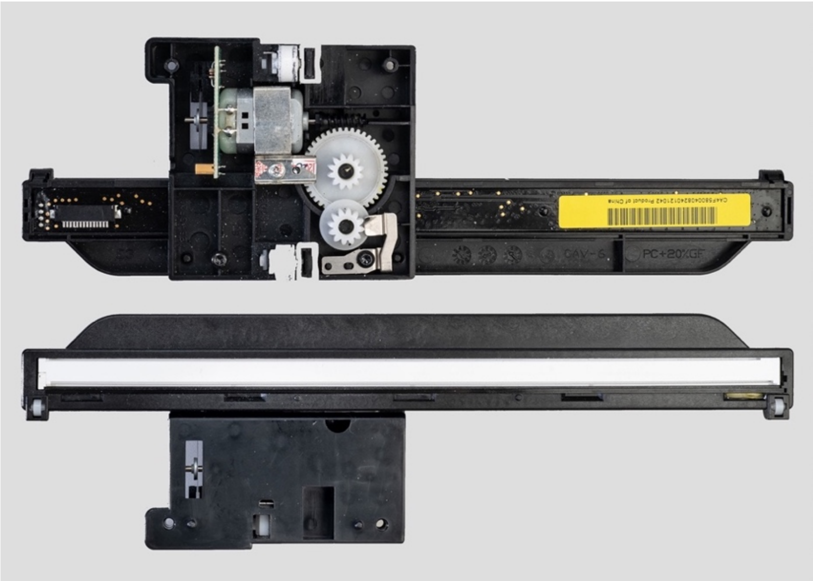


Figure 5.10. The contact image scanner mechanism

5.2.1 Overview

A Teensy microcontroller reads analogue data in real time, sent from the scanning mechanism, as it drifts along its well-worn path. The data provides the raw material for the generation of *Click::REVU*s sonic output, elaborated on in section 5.2.2.2

Click::REVU takes a minimalist approach with the structural layout of the work which is based on structural elements of its intended use, i.e., scanning as a series of repetitive linear movements. This structure is shown in Figure 5.12 and is elaborated on in section 5.2.1.1. The CIS moves horizontally with arrays of sensors registering tonal variations between light and dark. A custom-designed circuit board contains the necessary circuitry and components for motion drive and control, programmatic control, data capture, and voltage regulation. These components include a Teensy 4.1 microcontroller, an audio shield connected to the Teensy and a Pololu DRV8833 motor driver board. This is described further in section 5.2.1.1. A system overview is shown in Figure 5.11.

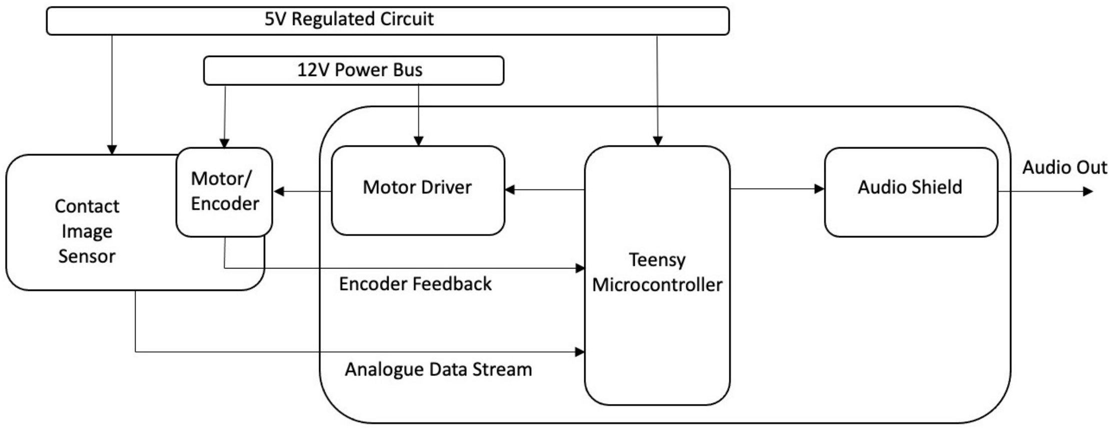


Figure 5.11. *Click::REVU* system overview

The microcontroller programmatically controls all functions of *Click::REVU* with a custom-developed software program *(sketch)*. The program captures data from the CIS, controls the motion and speed of the motor via the motor driver and controls the sound via the audio shield which outputs the sound to external speakers.

5.2.1.1 Technical Implementation

Click::REVU's primary structural element is a rectangular glass plate. This supports the structural, electromechanical, and some electrical components of the work. Looking through the sheet we can see a CIS and the track rail and gear rack needed to support its movement. The aluminium track rail provides support and guidance for the roller wheels on the CIS and also provides support for the two microswitches used as directional limit sensors for the CIS movement. The gear rack has two functions. It provides the necessary support to convert the rotational movement of the motor gears into linear motion and it provides a stabilising guide to reduce the amount of non-linear movement as the CIS moves along its horizontal plane. The gear rack is constructed from acrylic supported with a strip of aluminium to ensure the rack remains rigid over its length. A flexible cable connects the CIS scanner and motor functions to a circuit board. The CIS motor is controlled via a Pololu 8833 motor driver board, using a pulse width modulated (PWM) output from the Teensy. The PWM signal regulates the speed of the motor. The structure is shown in Figure 5.12.

Figure 5.12. Structural plinth

Details of the custom-developed circuit board are shown in Figure 5.13.

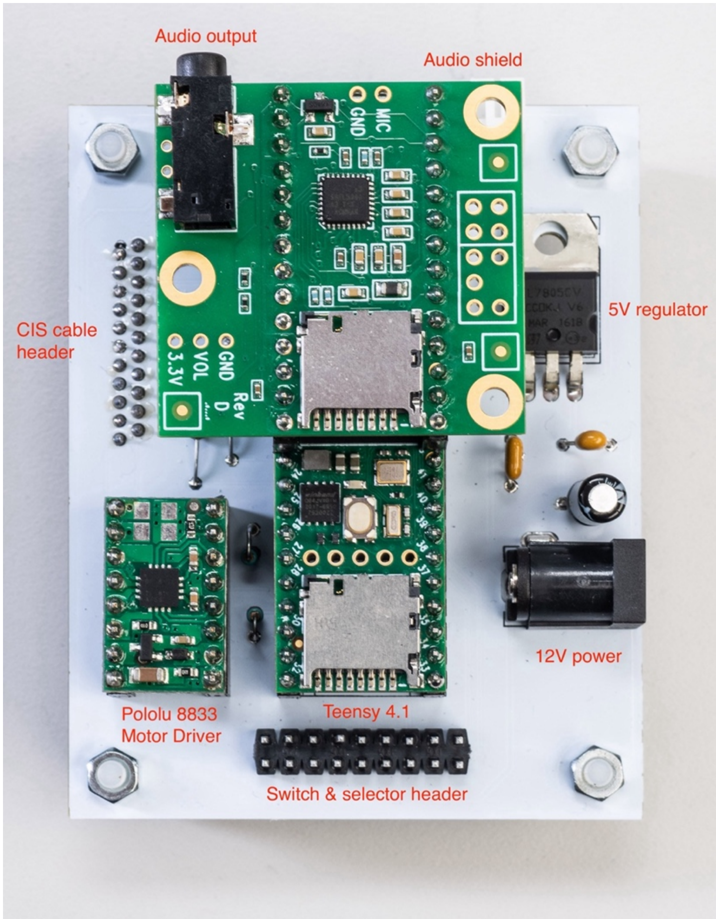


Figure 5.13. *Click::REVU* circuit board

As noted in the previous section, the circuit board hosts the following components and interfaces. These are the Teensy microcontroller, the Pololu 8833 motor driver, the Teensy audio shield, connectivity to the CIS, power input and regulation and an I/O connector for additional functions such as mode selection if required. The circuit is powered with a 12V 1A power pack with 5V regulated circuit provided for the Teensy controller and the CIS. Two pull-down resistors (R3, R4) are used on the motor control lines. The purpose of these resistors is to ensure the motor control lines are not floating when there is no signalling from the Teensy. This prevents spurious motor activity. This circuitry is shown in Figure 5.14.

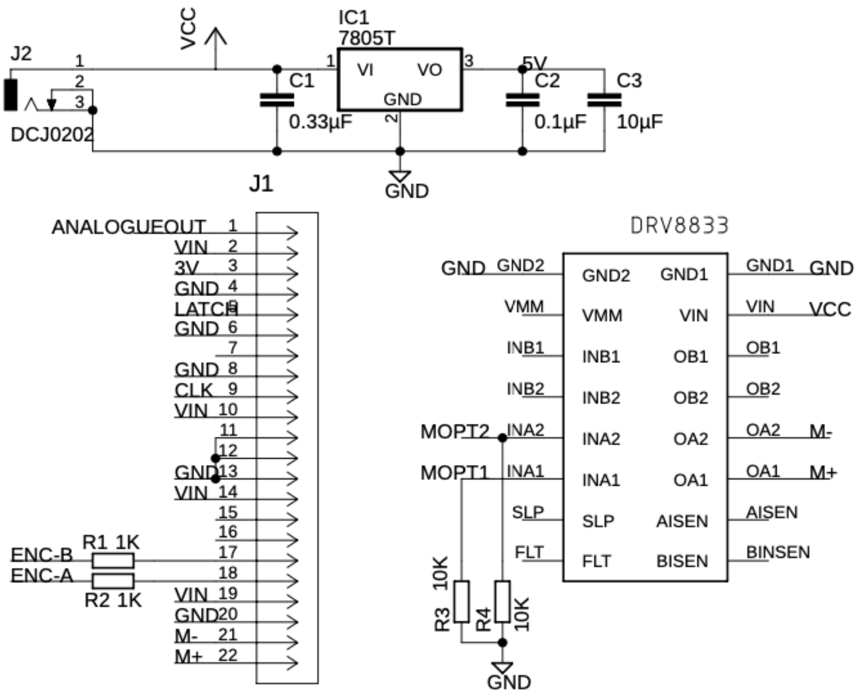


Figure 5.14. Power, motor, and flex connector circuitry

Two switches are included in the circuit. These micro-switches are used as sensors to control the limits of the CIS movement. Each switch is attached to a pin on the Teensy to read its state (on/off). When a switch is engaged (on), the corresponding Teensy pin is pulled to ground. This informs the program that the CIS is at the extreme range of its movement, to interrupt the motor's current direction and reverse its movement. This is discussed further in section 5.2.1.2.2.

5.2.1.2 *Software Implementation*

The custom-developed program used in *Click::REVU* performs three primary functions: the acquisition and control of data from the CIS, CIS motion control and audio synthesis and output. Multitasking, a function of the Teensy Threading library, has been used to allow the audio functions to run independently of the data and motion control functions. All functions are run within the main program loop. Figure 5.15 shows *Click::REVU's* program flow. The full program code is contained in the Appendix.

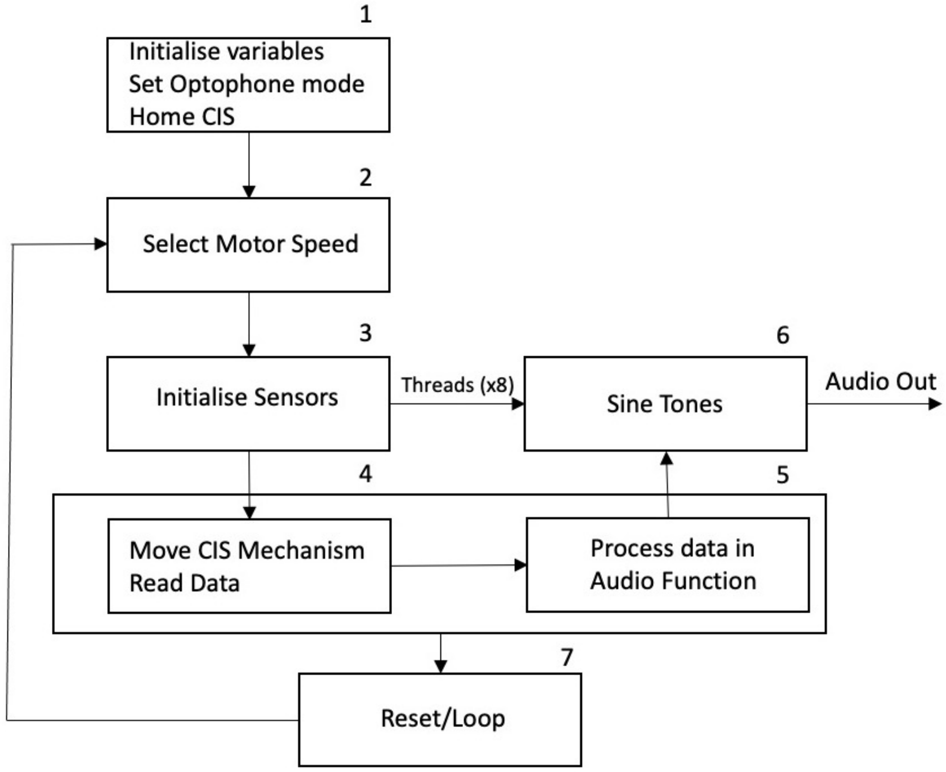


Figure 5.15. *Click::REVU* program flow

5.2.1.2.1 Data Acquisition and Control

With reference to Figure 5.15, the function begins by initialising system variables and spawning a thread process for operating the CIS (1). The process resets the CIS's LED array to a known state (3) before reading the values of the tonal differences as the CIS mechanism moves back and forth (4) . The values are read in real-time by the audio function[28] (5). The audio function spawns a separate thread process for each of the tones used by the audio engine

[28] The software for the CIS data acquisition and control functionality is based on Jean Perardel's Magic Frame touch interface. [229]

(6). The aforementioned process allows the integrated sequencing and control of the sound with the motion and scanning functions.

5.2.1.2.2 CIS Motion Control

The first operation on power-up is for the CIS mechanism to establish its home location (1). It does this by moving right to left until it activates the home limit switch. This function is shown in Figure 5.16 below. The function then selects a speed mode with which to move the CIS mechanism (2). The speed used by each mode is controlled by using different PWM values to affect motor speed. An example of the code is shown in Figure 5.17 .

```
void seekHome() {
  while (homeState == HIGH) {
    analogWrite(motorA1, 160);
    analogWrite(motorA2, 255);
    delay(1);
    motorStop();
    homeState = digitalRead(31);
    if (homeState == LOW) {
      counter = 0;
      delay(500);
```

Figure 5.16. Home detection example

```
void seekHome() {
  while (homeState == HIGH) {
//PWM SPEED CONTROL
    analogWrite(motorA1, 160);
    analogWrite(motorA2, 255);
    delay(1);
    motorStop();
    homeState = digitalRead(31);
    if (homeState == LOW) {
      counter = 0;
```

Figure 5.17. Motor Speed Control

The CIS mechanism's speed modes are based on the different scanning resolutions – known as DPI (dots per inch) modes – of the original multifunction printer. Although the original printer has numerous possible scanning resolutions that affect the mechanism's motion, *Click::REVU* utilises three concrete abstractions of those modes, 150, 300, and 600 DPI. These translate into different rates of linear motion for the CIS mechanism. As a way of introducing difference into the linear repetition of the mechanism's gesture the different speeds are randomly selected with each new bidirectional gesture This is discussed further in section 5.4.

The function reads the progress counter from the rotary encoder and utilises this count to determine its outer limit and home locations for the CIS mechanism. As a backup to the encoder count, the function 'listens' for any activation of the limit switches, and if engaged, stops movement in that direction. An example of these functions are shown in Figure 5.18. The purposes of the limit switches are to ensure the CIS mechanism does not continue to move in one direction past defined limits and to reset the encoder's count. This additional mechanism is required due to the encoder not providing a consistent and accurate count. After scanning and returning home, the function pauses before repeating the function (7).

```
//Encoder Interrupt
void updateEncoder() {
  int lastState = 0;
  int currentState = digitalRead(34);
  if (currentState != lastState && currentState == 1) {
    if (digitalRead(33) != currentState) {
      counter--;
    }
    else {
      counter++;
    }
  }
  lastState = digitalRead(34);
}
```

```
//Home Limit Switch Interrupt
void Home() {
  homeState = digitalRead(31);
  if (homeState == LOW) {
    counter = 0;
  }
}

//End Limit Switch Interrupt
void End() {
  endState = digitalRead(30);
  if (endState == LOW) {
    counter = 180000;
  }
}
```

Figure 5.18. Encoder and Movement Limit Functions

5.2.1.2.3 Audio Synthesis and Output

In the various writings of Fournier d'Albe's experiments and development of his optophonic devices, there is no single clear or concise description of the tone generating function of the Optophone. What does exist provides fragments of information to be pieced together or are embellished descriptions of the resultant audio output. To this, Fournier d'Albe did not describe the waveform that generated these frequencies, instead variously describing the sounds as "buzzing, like the whirring of a telegraph wire", as musical notes "embracing an octave" capable of producing chordal qualities and being "particularly pure and free from overtones." [188] The latter descriptions were associated with type-reading optophones, and suggest a sinusoidal waveform for the optophone's audio output.

Technical drawings and descriptions suggest otherwise. A drawing of the basic internal components of the black-sounding Optophone in Figure 5.19 shows a rotating perforated disk where pulses of light, as "regularly recurring flashes", shone through onto a selenium cell. [188] This would suggest a form of square wave being generated. However, as Fournier d'Albe notes, there was some light bleed that created interference between frequencies where "beats were heard, just as they are when neighbouring notes on a piano are struck together." [188] A detailed photograph of the rotating disk is shown alongside the drawing in Figure 5.19. Although the drawing shows a rotation speed of 30 revolutions per second, Fournier d'Albe stated the disk rotated "at about 20 to 30 revs. per second" as consistency of speed was desirable but not necessary. [188][194] The disk shown in the photograph suggests a rotation speed of approximately 20 revs. per second (e.g., Frequency / Slots = Revolutions), therefore a C at 512(Hz) / 24 slots = ~21 revs./sec).

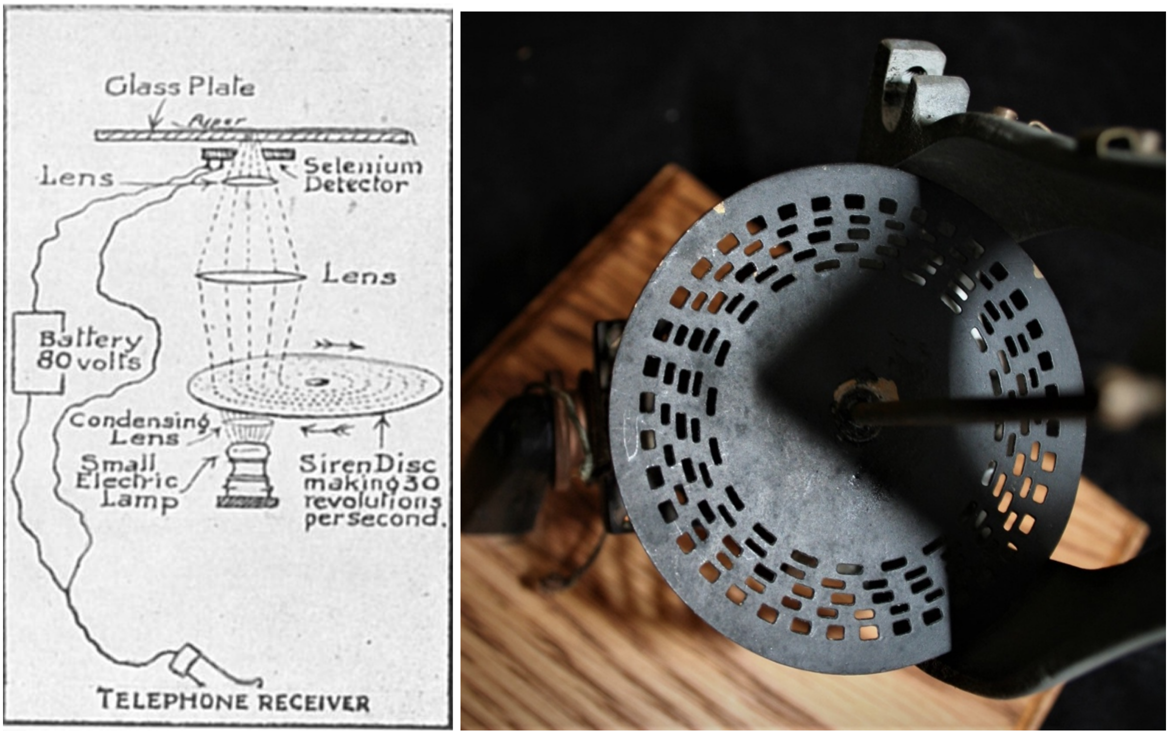


Figure 5.19. Drawing of the basic Optophone components alongside an original rotating disk. (Image courtesy HistoricTech.com, used with permission)

In the Barr and Stroud developed Optophone a second 'balancing' selenium cell was added. Whilst this addition was used to produce the black-sounding Optophone by using one cell to balance the light intensity of the other, the configuration of the cells had the effect of modifying the output signal. This could be interpreted as a form of modulation with the carrier signal being the balancing cell and the modulating signal being the reflected cell frequencies.

Click::REVU does not attempt to replicate Fournier d'Albe's Optophone but to use the available information to inform an interpretative rendition of such. Applying aspects of both the fanciful and technical descriptions of the Optophone's sound producing qualities with the modulating effect of the balancing cell provides the basis for *Click::REVU*'s audio synthesis approach. Using sine tones follows his description of the purity of the device's sound. However, the technical information suggests a square or pulse wave was generated. Modulating parameters of each waveform using the data collected from the CIS introduces elements of change to the otherwise static waveforms. This change, heard as rhythmic differences, is discussed further in section 5.4. A high level overview of the audio signal chain is shown in Figure 5.20.

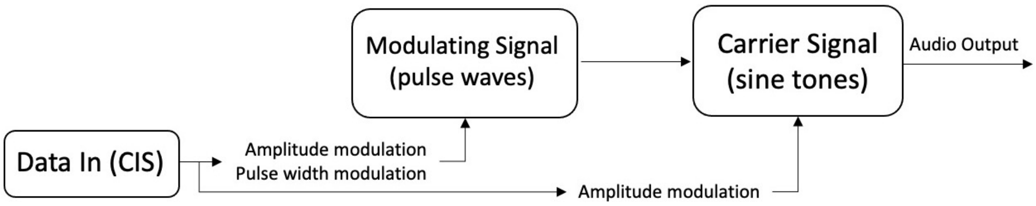


Figure 5.20. High level overview of *Click::REVU*'s audio synthesis approach

The frequency values used by Fournier-d'Albe were based on scientific pitch. These values are shown later in Table 5. Used in the white-sounding Optophone, these frequencies are used in *Click::REVU* to initialise each carrier signal (previously discussed in section 5.1.1.1). Each tone is spawned as an individual thread (6 in Figure 5.11) as noted in section 5.2.1.2.1. This allows the audio function to operate independently of the other main functions without conflicting with other elements of the program.

5.2.2 Aesthetic Considerations

The media archaeological approach used for *Click::REVU* interweaves elements of material and imagined forms of media. The work utilises the material reality of Fournier d'Albe's Optophone research with Hausmann's optophonic imagination and his optophonetic poetry. *Click::REVU* adopts Fournier d'Albe's concept of interpreting type based on bands of light, each keyed to a different frequency (shown previously in Figure 5.4). Fournier d'Albe's incorporation of musical elements for the Optophone is an aesthetic attempt to make the auditory output more attractive to listen to than the roaring noise and buzzing tones of the earlier exploring Optophone. This aestheticisation of sound is represented in *Click::REVU* through the use of modulated sine tones using frequencies in relation to musical scales. These perspectives, drawn together in the work, realise the creative potential of reviving the spectre of obsolete and unrealised media through a contemporary media object, the CIS.

Click::REVU exposes the CIS mechanism (shown in Figure 5.21) as an audiovisual element of the work, foregrounding the cyclic rhythm of the mechanism's movement.

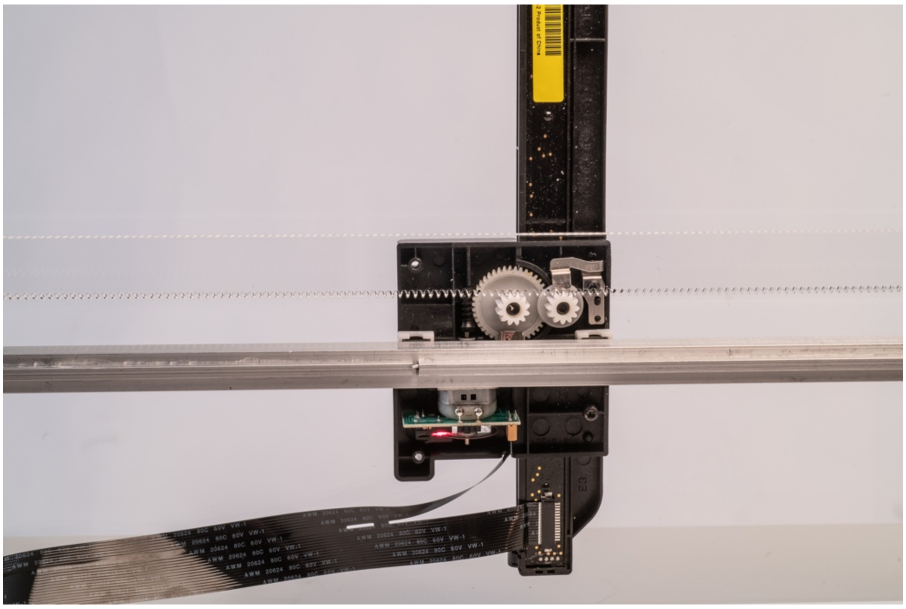


Figure 5.21. CIS electromechanics laid bare

Associated with this movement are the electroacoustic sounds discussed in section 5.2.2.1. In this way the inherent electroacoustic and electromechanical characteristics are integrated as audiovisual elements into the work.

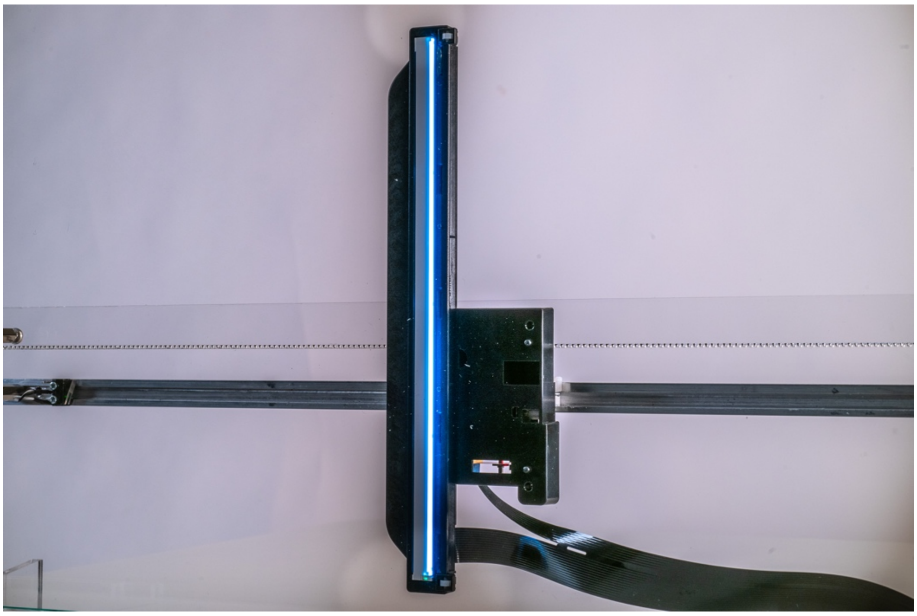


Figure 5.22. CIS with LED active

*Click::REVU'*s structure is fabricated from a clear sheet of glass to foreground and reinforce the CIS mechanism as the primary visual element of the work. This is shown in Figure 5.22.

5.2.2.1 The CIS as Sound Object

In its minimal electromechanical state, *Click::REVU* incorporates the sonic materiality of a single CIS mechanism as it moves in endless repetition into the overall sound of the work. This materiality is heard as an amalgam of subtle electromagnetic pulses energising coils, a worm drive twisting, cogs meshing, rollers squeaking and rattling and, off limits, switches clicking. From the repeated gestures and the minimal electroacoustic sounds emerge gradual changes to the audiovisual rhythm. Compounding this difference, the construction and assembly of the structural elements of the work produces subtle nuances in the rhythm of each mechanism.

5.2.2.2 Darkness and Light as an Expressive Logic

Click::REVU utilises analogue data values output from the CIS. The data from the CIS identifies lighter colour with a corresponding higher data value. The lower the value, the darker the luminosity. The data value has a 10 bit range from 0 - 1023. Three testing scenarios have been used to validate sensor functionality. The first test used a potentiometer to validate that the software sketch was reading values on the analogue input connection correctly. The software correctly read the full value range of 0 – 1023 from the potentiometer. The second test involved measuring and comparing the values ranges of two CIS mechanisms to ensure the sensor was producing valid, light varying readings. The third test involved repeating the second test with the sensors enclosed in a darkened space to see whether ambient light was affecting the sensor's light detection capability. The darkened space was achieved by placing a large box over the entire work. The results of the tests are summarised in Table 4 below.

Table 4. Sensor scenario testing results

Test #		Data value range	Mediam Value
1	Potentiometer	0 – 1023	-
2	Original sensor	338 - 1023	544
	New sensor	426 - 1023	537
3	Original sensor - darkened	341 - 1023	547
	New sensor - darkened	427 - 1023	540

The conclusion from the test results is that the CIS operating in *Click::REVU*'s environment will not fully replicate the operating conditions under which it would normally perform. Noting that the software is capturing the data correctly, this operating impairment is accepted as a part of the work itself and the captured data values are used.

The data range used by *Click::REVU* is arranged into strata to determine the value range applied to each frequency and is used to affect the presence and absence of sound by turning sine tones off or on. The use of a strata is based on Fournier d'Albe's light to tone representations used in the white-sounding and black-sounding Optophones. *Click::REVU*'s strata schema is created by dividing the data value ranges by the number of notes used in the work. Based on the data value ranges from scenario testing shown in Table 4, the strata range used is shown in Table 5. These frequencies and strata are used in *Click::REVU* to turn frequency tones off, as a white-sounding interpretation for an optophonic sound, in the audio synthesis function of the program. These, as compositional elements, are discussed in section 5.4.2.

Table 5. Frequency/note value to data value strata

Note/Frequency (Hz)[29]	**White-sounding Strata**
G (192)	< 478
C (256)	478 – 555
D (288)	556 – 633
E (320)	634 - 711
g (384)	712 - 789
b (483)	790 - 867
c (512)	868 - 945
e (640)	> 945

Having presented the various technical and aesthetic elements of *Click::REVU*, the next section is a reflective discussion of aspects of the ideation and realisation of the work. Having reflected on these aspects, some outcomes have informed the compositional approach discussed in section 5.4.

[29] The frequencies used are based on Fournier d'Albe's Optophone frequencies.

5.2.3 Reflective Discussion

Click::REVU has undergone a number of iterations as an outcome of reflecting on different elements of the work. Presenting earlier iterations of the work for feedback and discussion to a wider cohort raised the issue of intent and representation for the work. Essentially, *Click::REVU* had an identity crisis due to a lack of clarity between the physical and sonic representations. A re-reading of intentions for the work and the thesis has aided in clarifying what *Click::REVU* is. Looking back at the technical and aesthetic elements discussed and to the upcoming compositional approach, these intentions are considered within the context of the 'voice'.

An objective for this thesis' research is the reinterpretation of historic media relationships utilising each artefact's 'voice', or elements of it. To this, *Click::REVU*'s objective (see section 5.1) is to utilise conceptual elements of the earlier Optophones and optophonetics. In contrast to the previous works where the obsolete sound producing artefacts are present in some form, *Click::REVU* uses the CIS and associated componentry as a media archaeological prosthesis for obsolete media. Thus through media archaeology the notion of Baron et al.'s media ventriloquism (as described in section 1.3) is extended across technological epochs , by combining audiovisual technologies as the voice of the obsolete with the body of a contemporary form of media. As prostheses, both Fournier-d'Albe and Hausmann's works are considered audiovisual technologies in this context. These technologies, decoupled from their original bodies and combined with the CIS are constructed into something new as *Click::REVU*.

Earlier iterations of *Click::REVU* presented the CIS facedown as it was in its original environment on a white acrylic platen. If the CIS is a physical element of a media archaeological prosthesis, turned away looking through the cataractic membrane of white acrylic compounds the loss of visual acuity. This further inhibits the overall work's ability to vocalise what it sees. This aspect was a part of the work's identity crisis. Instating the glass platen which the CIS originally sat upon as a window for it to see through and turning it face the audience draws the work nearer to the purpose of the Optophone – a way to see the world. To this, the illusory body of the Optophone emerges through the CIS as it enables the vocalisation of variations of light and dark as the CIS detects differences in the ambience light of its environment it is exposed to. As such, *Click::REVU* conjures Fournier d'Albe and Hausmann's works a different kind of body by reshaping the actual visible body of the CIS. [230]

In presenting an amalgam of sound, *Click::REVU* has been informed by the various aural outputs of Fournier d'Albe's Optophones. *Click::REVU*s early sound synthesis included different output modes for the interpretation of data based on white-sounding and black-sounding Optophones. When voiced, a black-sounding rendition lacked the chaos of notes of a dissonant assemblage of sounds and noises, sounding more as an musical instrument. Thus, reflecting on the minimal approach to presentation and representation as a thematic construct, the provision of different modes contributes to *Click::REVU'*s identity crisis.

Rather than attempting to over-represent aspects of Fournier d'Albe and Hausmann's optophonic and optophonetic concepts, *Click::REVU* requires minimal elements from these in combination with the CIS to provide an interpretive relationship between genealogically related media. The audiovisual appropriation of these different media technologies and the reconfiguration of their relationship is a way through which to see the world expressed by a slowly moving chaos of notes and sounds. Bringing them together in this way reshapes the visible and/or audible bodies of the 'speaker' as a 'technovocalic' body. [231] As *Click::REVU*, such a body, a combination of voice and image dependent on technology for its existence, is capable of generating possibilities outside its original mediatic forms. The next section presents the conceptual approach for the compositional strategies of the work.

5.3 Imagining a Creative Media Archaeology

Having detailed the material, functional and aesthetic aspects of the work, this section discusses the method employed for ideation of *Click::REVU*'s aural rendition. As Hausmann's *Optophone* remained only a concept (supported by minimal documentation), it is largely left to the imagination to interpret his intention. Adopting an experimental and speculative media archaeological approach is one way of exploring the artistic potential of unrealised media. Doing so can create intriguing parallels and connections between real and imagined media to inform the ideation and realisation of an idiosyncratic optophonic creation.

Both Ernst and Fickers and van den Oever (discussed in section 2.2.4) approach media archaeology as an excavation of past media through an operational engagement with, and re-enactment of, past media artefacts, focusing on their materiality. Neither are interested in reconstructing "authentic historical experiences." [46] Instead, they are interested in the temporality ascribed to these devices as sensorial traces of past articulations, their intriguing noises, smells, functionality, and physical construction. Such non-discursive insights into the past can also stimulate our imagination, allowing one to "reflect critically on the hidden or nonverbalized, sensorial, corporal (sic), and tacit knowledge" through an engagement with these artefacts. [46] [21]

If Kluitenberg describes imaginary media as compensatory machines, sites where irrational desires are projected, Hausmann's vision of a sensory prothesis was to compensate for what he perceived to be a deficiency of man. Unlike material media archaeological approaches used in *Click::RAND* and *Click::TWEET*, *Click::REVU* does not reveal the working of the Optophone through itself. Instead, it reconstructs a form of expression based on the practical realisation of Fournier d'Albe's prosthesis, and the performative explorations of optophonetics and the imagined materialisation of Hausmann's Optophone. *Click::REVU* utilises elements of simultaneity and bruitism from his concept of optophonetics, reimagined through a form of contemporary media, not as a synaesthetic device tightly coupled to sight and sound but as an interpretive object-based sound installation. Paraphrasing Eric Kluitenberg's claim that "excavating the media cultures of the past is important not only in itself", the Optophone and optophonetics has provided inspiration for developing a compositional approach which is discussed in the following section. [6]

5.3.1 It Was Just My Imagination

Simone Natale and Gabrielle Balbi posit that media archaeology has contributed to shaping the study of the imaginary in media studies by "taking into account … elements of the imaginary and fantastic" as pieces of evidence relevant to historical analysis. [232] They argue for a defined approach for the reception of media pertaining to those dreams of speculation, predictions, and other fantasy. However, Eric Kluitenberg contends an archaeology of imaginary media should not be defined by a singular formula to designate what they are, what their essence or nature is or what it might be. His archaeological approach to imaginary media excavates "mankind's dreams of the ultimate communication medium" focusing on mediatic imaginations that remain unrealised as potential and possible media – media dreamed or fantasised with visions of how "human communication can be reshaped by means of the machine." [233] He observes a recurrent theme of such devices is of them becoming compensatory machines for the perceived flaws and deficiencies of human interpersonal communications.

An archaeology of imaginary media offers varying perspectives for the excavation and discovery of media. Some may have remained nothing more than unrealised dreams but have still influenced or appeared in part in other forms of media. In introducing *What is Media Archaeology?*, Jussi Parikka writes that imaginary media research has been an integral part of the media archaeological discourse, and is “emblematic of the drive to find important ideas and contexts outside actually existing technologies.” [5] In concluding his review of the various forms and formations of imaginary media in research, Parikka provides three areas of focus. First, media imagined or non-existent but worthy of exploration as a “reservoir of weird ideas” that might provide blueprints for future media design. [5] Second, media as technological dreamworlds invested with “weird desires and social constructions.” [5] Examples associated with this area are the worlds of the fantastic and alien and the technologies created by early science fiction writers. Last, as technical media, those of the “non-solid, non-phenomenological worlds” of electro-magnetic fields, algorithmics, formulations, at speeds beyond human comprehension. [5] In this last area, Parikka argues that a materialist notion of imaginary media has been interlinked with non-human technical media since the early 19th-century. As discussed in section 2.2.4, Zielinski’s provisional classification of imaginary media include “*untimely media/apparatus/machines*, … *conceptual media/apparatus/machines* and … *impossible media/apparatus/machines*” [48] One such example of the latter is Nikola Tesla’s never completed *Wardenclyffe Tower* (see Figure 5.23).

Figure 5.23. Nikola Tesla's Wardenclyffe Tower circa 1904

He envisaged the facility would be able to transmit electrical power wirelessly alongside communications and radio signals. The tower would serve as a giant resonating and communications mechanism to reach the spirits of the deceased, a global transceiver of psychic energy and communication. [234] To this can be added Paul de Marinis' *The Messenger* (1998/2005) and *Fragments of Jericho* (1993) (discussed in section 2.3) as untimely or conceptual media that provide blueprints for future media design.

5.4 Compositional Approach

This section describes *Click::REVU*'s compositional approach that, in its duration, coexists and clashes as a series of repetitious and discontinuous rhythms. Henri Lefebvre's rhythmanalysis (discussed in section 3.7) is used as the basis for describing the compositional approach. Noting that mechanical rhythms imposed by technology through linear repetition are depicted as "monotonous, tiring and even intolerable", *Click::REVU*'s repetitious sequences expose moments of difference in the rhythm's return or reappearance as something new and unforeseen. [149] Following a brief introduction of the musical motif used in the work a description of its 'performance' in *Click::REVU* is discussed.

5.4.1 Click::REVU's Musical Motif

Click::REVU's sonic presence combines the 'musicality' of Fournier d'Albe's reading Optophone with the electroacoustic materiality produced by the movement of the CIS mechanism previously described in sections 5.1.1.1 and 5.2.2.1 respectively. *Click::REVU* uses the notes G, C, D, E, G, B, C, E as described in section 5.2.2.2.

Click::REVU utilises Lefebvre's polyrhythmia and arrhythmia as the basis for its compositional forms. The scanner mechanism's repetitive gestures and the fixed frequencies of the sine tones appear homogenous, however each movement exhibits moments of difference in their return and repetition. The scanner mechanism returns and rests after reaching the outer range of movement. Each sine tone passes through its zero crossing point[30] during each frequency cycle. The simultaneity and diversity of sine tones create a form of polyrhythmia, as diverse rhythms interact to maintain a metastable equilibrium between them. Arrhythmia exists as a dysfunctional interrelation of rhythms experienced by introducing discontinuity to the sine tones through the irregular presence and absence of sound. This is discussed in section 5.4.2. In addition to the interruption of linear rhythms, cyclic rhythms are at play in *Click::REVU* as

[30] Zero crossing is a point in which a function changes sign. For a sine tone, this is when the amplitude of the frequency cycle passes through zero on the y axis. [126]

the "cyclical and the linear exert a reciprocal action they measure themselves against one another; ... everything is cyclical repetition through linear repetitions." [149] At a macro level, the work's rhythms are modulated by the mechanism's electromechanical and programmatic movement. This relationship, modulated by slow changes in environment light, do not interrupt the rhythms but modify them through the light's diurnal cycles. This interaction between the mechanical and organic elements, experienced by the creation and discovery of new rhythms through repetition and difference, presents a novel interpretation of an optophonic work in *Click::REVU*.

5.4.1.1 Simultaneity and Bruitism

Click::REVU appropriates the concepts of simultaneity and bruitism from the performance of the Dada sound poem. Simultaneity is manifested in the creation of distinct 'voices' as different frequencies. These voices can be heard as a multitude of voices is exemplified by the concordant and discordant tones that meet and collide. Within this chaos of notes, the changes of light and dark are heard through minimal tonal variations. This discontinuity, as a form of arrhythmia, desynchronises the relationships between the sine tones, causing varying elements of discordance between the tones over time. Therefore, an arrhythmia occurs in the cycle's return and renewal. In conjunction with this, the visual movement of the scanner mechanism adds a visual rhythm to the work.

Click::REVU does not use the articulatory elements of the Dada poème bruitist. In this work bruitism is expressed through elements of a sound aesthetic related to Luigi Russolo's concept of an art of noises, a concept borrowed by the Dadaists. *Click::REVU'*s bruitism is represented by the repetitive use of sonic material reduced to the basic elements of sine tones, clicks, and electromechanical friction. Within the limitation of pitch and timbre and the simplicity of texture and structure, the sonic output is manifested by "repetitive modules, static harmonies, drones, and silences." [74] Such a reductionist approach draws from elements of audiovisual materialism described in section 2.4. While *Click::REVU'*s program logic instantiates a form of gestural repetition through the fixed timing of the software looping functions, the work's sonic periodicity is effected by the irregular rhythmic qualities inherent in the CIS mechanism and the variable interpretation of shades of light and dark. This creates a series of cyclic rhythms whose patterns are expressed through their own time scales. These time scales are determined by the DPI 'density' or speed of movement of the CIS mechanism and the scanning rate of the sensor, determined by the software program.

5.4.2 Sounding White

The representation of Fournier d'Albe's early reading Optophone, as *White*, reads a data value from within the programmed strata range and applies it to affect a specific tone function.[31] This begins with a wavering drone comprising a chaos of notes. As the data values are read, tones change at different intervals. Interfering with the drone's rhythmic texture by the imposition of small movements in the individual frequencies is a way of introducing rhythmic difference. By disrupting the continuous repetition of each sine tone, the drone's rhythm becomes cyclic through the variations introduced in the process of return and renewal.

5.4.2.1 Bruitisme in White

Hausmann waged an attack against language and its conventional uses by further 'atomising' the word poems of the Zurich Dada to letters in his poems, expressed as noise and perceived as meaningless nonsense. *Click::REVU* fragments the letter as a granulation of the sound produced by variations of light and dark. These variations, translated into a presence and absence of sound, interfere with the discordant drone by imposing discontinuous moments within the individual sine tone frequencies. In addition, a by-product of this discontinuity is embraced as a part of the resulting sound. Heard as clicks, these are an artefact of the disruption to the sine tone as it is turned off and on at varying points of its cycle at varying amplitudes of the waveform. This granulation of an already fragmented reading of the letter adds a further textural layer to the soundscape.

5.5 Discussion

Utilising a form of contemporary media technology to interpret past media creates an awareness of characteristics as traces of the past in the present. Unlike the use of previous material media archaeological approaches, *Click::REVU* does not reveal the working of the Optophone through the object itself. Instead, it reconstructs a form of expression based on the practical realisation of Fournier d'Albe's prosthesis, and the performative explorations of optophonetics and the imagined materialisation of Hausmann's Optophone. *Click::REVU* utilises elements of simultaneity and bruitism from his concept of optophonetics, reimagined through a form of contemporary media, not as a synaesthetic device tightly coupled to sight and sound but as an interpretive object-based sound installation. Reimagining the past through

[31] Video documentation for the work is available at https://www.dunham.co.nz/works/revu

the present, *Click::REVU* reconfigures the complementary existence of the Optophone and optophonetics within a broader history of optical technology and sensory prosthetics.

Whilst a material media archaeology approach has partially informed the ideation and realisation of *Click::REVU*, an experimental approach has also been adopted to realise this work. This form of experimentation is not in the form of historical re-enactment advocated by Fickers and van den Oever as "a heuristic concept of historical understanding." [41] Instead, it is through experimentation and speculation emerging from the imagination that the capability of the CIS mechanism has been explored as an interpretative medium for the Optophone and optophonetics. From this perspective, it is not the object or artefact alone that is Ernst's 'container of knowledge' in itself where the materiality of media without human narrative forms its own systems of relations (discussed in section 3.6). Such containers, as a part of a larger network and sets of actions, do not in themselves reveal their full meaning. In the absence of a physical present Optophone, knowledge must be drawn from historical archives to understand both the technical operating principles and cultural contexts in which the early optophonic forms existed. In drawing these together, *Click::REVU* is a spatio-temporal bridge between contemporary forms of related audiovisual media and Fournier d'Albe's and Hausmann's optophonic worlds.

As Daffyd Jones argues, the simultaneous poems of the Dada are "patently not poems without words." [235] What might initially appear to be 'verse ohne worte' (verses without words) in the sound poem are only produced from a product of the words. Even *Click::REVU* in its re-presentation of sound simultaneity relies on visual elements as the basis for its sound abstraction. However, bruitism takes this further towards the sound poem by further dissolving syntactic meaning. In bruitism, Hausmann separated the word into individual phonemes, using a primitivism of noise in his poetic expressions. In *Click::REVU*, bruitism comprises drones and clicks as a compositional aesthetic in its fragmentation of the letter to produce an arrhythmic hodgepodge of tones. Hausmann envisioned his use of simultaneity extending beyond the use of optophonetics to the Optophone as the material expression of light and sound. It remained an immaterial dream. *Click::REVU* is one creative possibility of Hausmann's intention.

Having presented my portfolio of works, the next chapter presents a framework developed through the artistic use of data sonification as a method of facilitating the organisation of sound. This framework has been used in each of the works as a way of transforming data from one medium to another as a way of allowing the artefacts under inquiry to articulate this transformation through their own 'voice'

Ecouter c'est tendre l'oreille
(To listen is to stretch the ear)
- Jean Luc Nancy

Chapter 6. Media Archaeological Sonification

6.1 Introduction

This research has articulated the exploration, understanding and interpretation of various forms of communication media. Their technical and socio-cultural conditions of existence are articulated through a series of sound-based art works. Similar to the works discussed in Chapter 2. *Click::RAND*, *Click::TWEET*, and *Click::REVU* share a common set of methodological approaches, aesthetic qualities, and expressive modalities. Irrespective of the methodology, aesthetic, and sound, these works can be contextualised as media archaeological sound-based works. As discussed in section 2.4, the works are represented through an audiovisual materialism that incorporates physical material, objects or artefacts, and their visual qualities as expressive elements. However, this framing can be explored further to solidify the context for this research's creative work.

The artefacts employed within each work are primarily drawn from forms of communication media. These are interpreted through visual representations (the written page, the screen, the scanned image) and re-presented through aural interfaces (the telegraph key, the electromechanical relay, the Optophone). Each of the visual artefacts has been chosen in part because they exist within a larger internetworked ecosystem both physically and socioculturally. The RAND Corporation's book is now freely available as a set of digitally based files from their website. Twitter is a part of a relentless stream of information from digital communication platforms. Optical information can be either transmitted via, or stored digitally on, some computing systems. Each work within this research's creative portfolio defamiliarises these visual representations by re-imagining a media archaeological rendering of, and a genealogical connection between, past and contemporary media technologies in the audiovisual domain. As discussed in the chapters focused on the works, the obsolete artefacts used have a genealogical relationship with the contemporary forms of media that has emerged through investigating their technical and socio-cultural conditions of existence. The relay, itself appropriated and repurposed from telephony, was a component in the development of large-scale computing devices.[32] The telegraph was a forerunner to mass communication media. The Optophone's light sensing capability is now prevalent in a diverse range of contemporary media. Equally important is that each of these obsolete artefacts have some sound producing capability that is employed in this research's creative output. Through a process of transformation, each work's source information is defamiliarised then refamiliarised as a series of sound events. Each transformation creates a 'deformance' (a portmanteau of deform and performance) as an interpretative reading of the past in the present to expose relationships between the obsolete and contemporary forms of media.[33][115] While each work represents different media relationships, they share a common approach where information is extracted as data, transformed and re-presented in another medium. Through this process, a strong interlinking principle is that sound events are mediated through data sonification techniques.

This chapter introduces the concept of the artistic use of data sonification not only as a principle but one informed by the aforementioned approaches and methods of aesthetic and compositional representation described in the previous chapters. The purpose is threefold. The first is to detail the approach developed and tested during the creation of these works. As such, data sonification is a novel means of facilitating the organisation of sound, allowing data from different source media (described in chapters 3, 4 and 5) to be mapped to sound parameters utilised by another form of media. Second, data sonification, as a method of media archaeological experimentation, is used as an approach to facilitate the creative shaping of an historical narrative. Third, each work utilises the 'voice' of the obsolete artefact, or elements of it thus anthropomorphising what may be considered disembodied or immaterial informational technologies and processes. These methods of research and modality represent the relationships between the visual domains of the original sources and the acoustic domains expressed through the obsolete artefacts used in the works.

[32] A referential relationship exists between these media. The development of the inter-continental telegraph facilitated the discovery of selenium's (used in the Optophone) light sensing properties. Selenium was later used for the semi-automated control of relay-based switching systems. The telegraph system is itself a relay system in the way messages were forwarded between stations.

[33] For McGann and Samuels, deformance is a disruption to, or reorganising of, a text's original order, to draw our attention to possibilities of meaning that we might not have otherwise seen or heard within the context of this research. [236]

The next section presents the use of data sonification as a specific tool for creativity and expressivity in media archaeologically-informed sound-based art. Following this, the chapter presents an approach for the representation of media archaeologically-informed sound-based art. *Click::RAND*, *Click::TWEET*, and *Click::REVU* are presented as exemplar works of an interdisciplinary approach using data sonification that specifically draws on the materiality of media artefacts as an expressive modality. The chapter concludes with a brief discussion highlighting the novel symbiosis of sonification and media archaeology as a representational approach for sound-based art.

6.2 Sonification and Media Archaeology: a Combinatory Approach

If a bounded definition of sonification, as discussed in section 2.6, is applied, little evidence exists of its use in media archaeologically based sound art. Indeed, the use of the term and its application within media archaeology would be considered audification by some proponents of the auditory display community, simply because the outcomes are the direct translation of waveforms into sound with minor processing for the signal to become audible; this includes "all sound recordings", the "vibrational data of mechanical waves" and "physical processes outside the mechanical domain" e.g., electromagnetic waves. [237] Time axis manipulation (a technique that forms the basis for Ernst's media archaeological approach) of sound recording data is noted as the simplest form of intentional audification. To this, Ernst differentiates between a functional sonification and 'epistemological sonification'. Functional is in the sense that sonification follows certain principles to aid the understanding of the data e.g., a higher pitch for increasing data values, a lower pitch for decreasing values. Ernst's epistemological perspective of sonification, as sonicity, in its essential temporal nature, refers to the "subliminal message behind the apparent musical content." [17]

The application of higher level sonification techniques is equally relevant as a media archaeological approach to reinterpret historic relationships between different forms of media by utilising the specific qualities of them to interrogate media history. Such a combinatory approach to inquiry constitutes a creative exploration of, and change in, the sensory comprehension of data to generate new interpretations between seemingly unrelated forms of media. A common approach to the application of these techniques has been used in the development, and the realisation, of a framework for *Click::RAND*, *Click::TWEET* and *Click::REVU* (see Figure 6.1). Within the time constraints of this research, the portfolio of works serves as varied examples to support the framework established in this thesis. The key ideas and framework developed are not specifically linked to these specific media. The framework can be adapted and extended to examine relationships between past and present media utilising a range of such mechanisms.

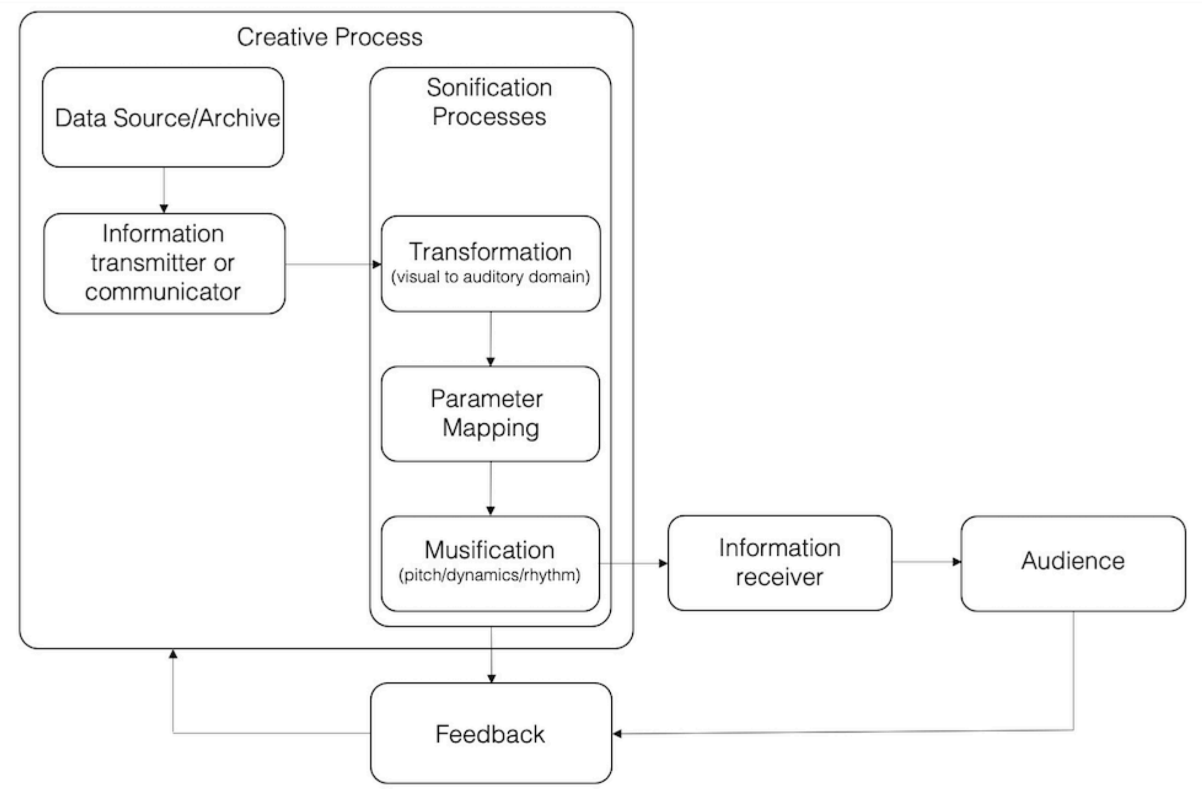


Figure 6.1. High-level Research Framework to Sonification

The overarching approach is based on media archaeological approaches. Therefore, the archive can also refer to the multiplicity of information sources able to be referenced. In this context, interrelationships are developed between different media. As is shown in Figure 6.1, across all three works some form of data is utilised. The sonification process transforms the data into a format that can be utilised to manipulate the sound-producing object. Parameter mapping is the key sonification technique employed in this research's works. This technique and its use are elaborated on in section 6.2.1. Following this, musical elements are included to organise the data output and the expressivity of the sounding object. The purpose of a feedback mechanism is twofold. First, critical feedback through the creative process is used as a part of a works development and refinement processes. This is informed by the interactions between practice and theory through reflection, design iteration and validation discussed as an overall research approach in section 1.5. Second, audience feedback is one way of assessing the critical success of the work and such feedback can be applied to further iterations of the work.

The alternative representation of data as a media archaeological method of inquiry is used to realise different outcomes unique in the works' diversity of inquiry and intent. The framework uses the sender-message-receiver communication model as a useful heuristic for its representation. However, the insertion of data sonification techniques as a defamiliarising agent of one form of communication (e.g., the printed page, Twitter, a visual prosthesis) is refamiliarised by way of another communication medium, sound.

6.2.1 Parameter Mapping as a Sonification Technique

Parameter mapping is, arguably, the "simplest way to continuously map data to sound and the most established and widely used sonification technique." [106] It maps data attribute values and changes in one or more of those values to trigger or effect a change or changes in the sonic event. Practitioners argue that parameter mapping, as an event-based process, should not be completely arbitrary or overly complex as the perceptual interactions of an abundance of varying parameters may obscure data relations and confuse the listener. [106][238] Neuhoff states that learning from past sonification research efforts should focus on "perceptual spaces where audition performs well and individual differences are smallest." [108] He suggests abandoning simple parameter mapping dimensions like pitch and loudness. Instead, leveraging "audition's temporal advantage" whilst exploiting spatialisation as an audiovisual aesthetic approach may prove a more constructive approach. [108] With each work's limited sonic palette, a reductive approach to parameter mapping as an access tool, in Landy's terms, may have the advantage of eliciting the most interesting results from small changes in the data sources.

Through a series of rhythmic compositions, each work developed in this thesis leverages audition's temporal advantage through the repetition of interwoven patterns of sound and/or the disruption of these, either naturally or by intervention, or through an audience's perception of a periodic pulse or 'beat'. The use of such rhythmic methods as compositional elements has been discussed in sections 3.8, 4.4, and 5.4. A further tool used to engage an audience in *Click::RAND* and *Click::TWEET* is to create an audiovisual relationship between the sound and movement of those rhythms through the iterative use and spatialisation of sounding objects. For *Click::REVU*, the disruption of patterning and the perceptual dissonance between movement and sound provides a different form of temporal perception. This approach to data sonification as a media archaeological reinterpretation of historical relationships is a way to unlock the past by utilising the specific sonic qualities of the source materials. In this way, data, as an abstraction of reality, is given concrete form through its sonification in this research in the pursuit of generating new forms of knowledge.

Each work makes use of limited number of parameters. *Click::RAND* utilises the single sound of the electromechanical relay (described in section 3.3.3.1) and the temporal regularity associated with digital signal transmission in the work. *Click::TWEET* utilises the sound of the telegraph key along with the electronic sound of a sine tone associated with telegraphic signal transmission (described in section 4.2.3.2), and the temporal properties associated with Morse code's signaling elements. Both works iterate the artefacts and sound as a further audiovisual strategy to enhance the use of the limited sound parameters. *Click::REVU* utilises a range of musical notes to produce a drone-like sound (described in section 5.2.2), whilst data parameters affect each note to create a presence or absence of sound. In this work, our ability to perceive changes in periodic waveforms is affected by the irregular temporality of the work.

6.2.2 Click::RAND

To recap, *Click::RAND* (shown again in Figure 6.2) uses sets of random digits and normal deviates from The RAND Corporation's book *A Million Digits with 100,000 Normal Deviates*.

Figure 6.2. *Click::RAND*

The work reduces the data to an indexical structure to express it as series of rhythmic patterns through sets of electromechanical relays. Each selected random digit is both symbolically transposed and materially transposed not only from the tactile material of the book but also from the intermediate materiality of the stored media file to the audiovisual materialism of the relays (see section 2.4.1). The overarching relationship is between the book and the work itself. One representation of this is the transposition of the book's 5×5 number grid layout to the work as a 4×5 grid of relays thus forming a symbolic relationship between the work and the original source. The row from which the digit is selected within the 5×5 grid is mapped to the corresponding row of relays used to represent the binary number. Prior to the audiovisual display of the transposed digits, each bit (binary digit) of the binary integer is mapped to a corresponding relay from right (least significant bit) to left (most significant bit). In this way, parameter mapping is used to achieve audiovisual spatialisation by the row and relay placement of each bit. This is represented in the research framework shown as Figure 6.3.

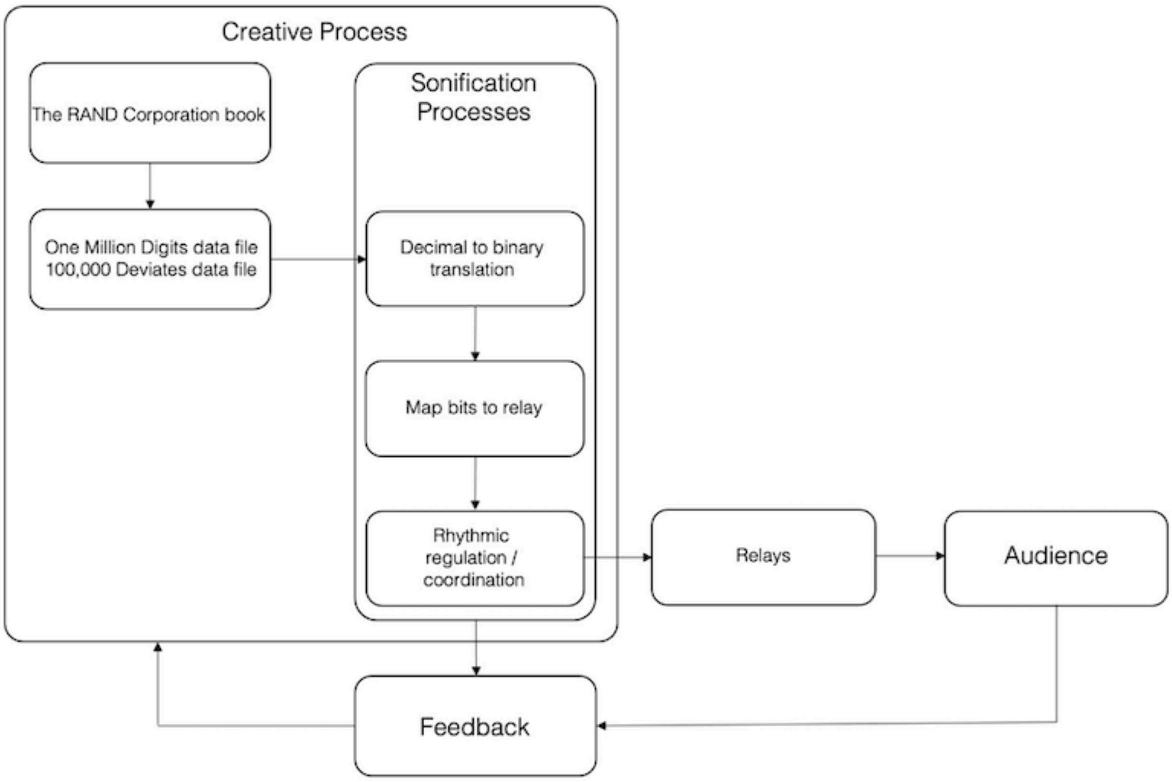


Figure 6.3. *Click::RAND*'s use of the research framework.

Treating the inherent time-scales of data and sound differently is often used as a sonification technique to bring the inaudible to within the range of human hearing or to reveal interesting phenomena. [8] Typically, this technique has been used to re-present the electronically-read binary numbers at humanly perceptible speeds, thus slowing down the speed at which electronic information is read and transmitted. This technique is used by Miyazaki and discussed previously in section 4.3. The arbitrary assignment of a quantised time period used in the work's compositional forms (described in section 3.8) thus reduces the sound to a similarity of audiovisual movement as a way to foreground the rhythmic elements of the data patterns.

Sonifying the data sets of The RAND Corporation's book has provided a method to explore, through the absence and presence of sounds, the rhythmic elements of binary encoded information. This has been more fully described in the work's compositional strategies in section 3.8. Mapping values as data bits and temporal values has allowed the data to be re-presented as a series of transverse rhythms and layers that compete against or complement each other.

6.2.2.1 Critical Evaluation

Click::RAND has been successful in representing an historical relationship between the historical use of large random number sets in early electromechanical computing and exploring and exposing the rhythmic patterning embedded in the sets binary representations. The work has benefited from a reflective process that has been informed by feedback and observation of it in situ in a performance venue. This feedback was used to inform the final work. The work has been exhibited both nationally and internationally in a range of venues including a performance space, exhibitions and galleries. To date, it has been used as an education tool at school career expos and informational forums as well as gallery spaces. The work is supported by a programme note elucidating the concepts informing the work (see 8.1.1). The success of Click::RAND is supported by related papers of the work being accepted at two international conferences. Feedback for the work has found it to be based on some interesting concepts that have been well realised. The work has been described as mesmerising and beautiful in its minimalism. The minimalistic approach to data mapping has resulted in an elegant reinterpretation of the random number books text. *Click::RAND* can be exhibited in a range of spaces to a range of audiences.

6.2.3 Click::TWEET

Similar to *Click::RAND*, *Click::TWEET* (Figure 6.4) reduces the data of the Twitter message to an indexical structure and is expressed it as a series of rhythmic patterns through a set of telegraph keys.

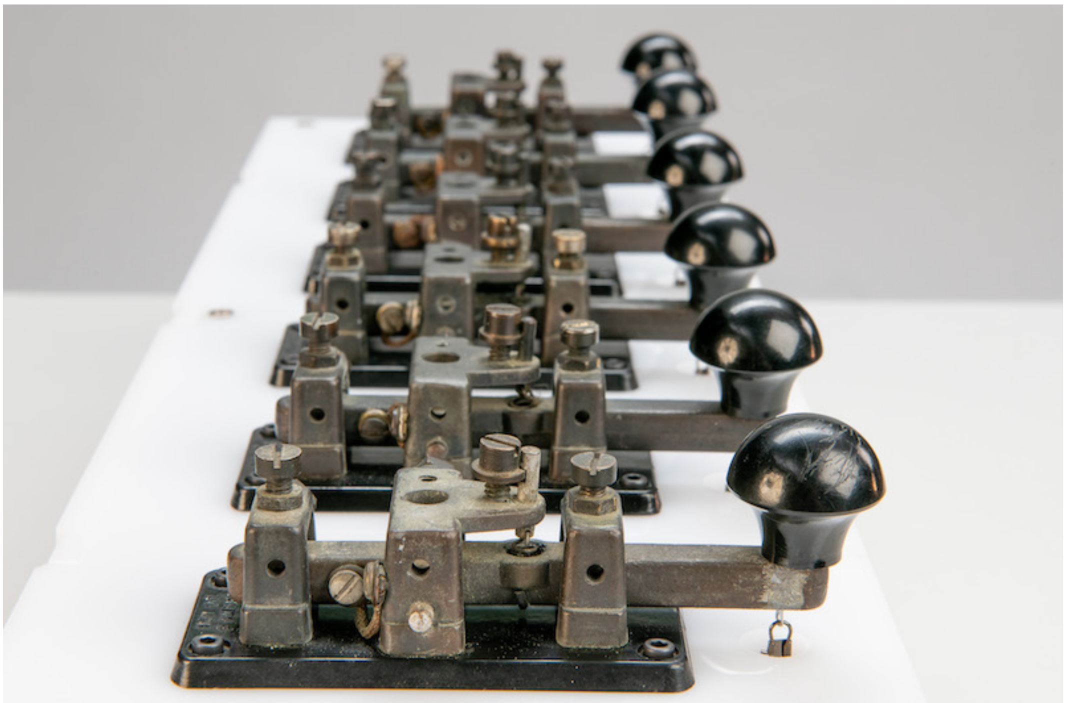


Figure 6.4. *Click:TWEET*

Each message is reduced to individual characters that are mapped to their Morse encoded equivalent representation then separated into their individual symbols of dots and dashes. Each symbol representing the Morse encoded character is mapped to a physical telegraph key. Such a technique is used to reinforce the indexical nature of the data by audiovisually spatialisating sound and movement. Each message, when played by the telegraph keys, is experienced as a rhythmic performance. This process is represented in the research framework shown as Figure 6.5 on the following page.

The temporal manipulation of the data to reduce the Twitter message's transmission speed is based on Morse code's signalling properties, discussed in section 4.2.3.3. This timing standard is used in all of *Click::TWEET'*s compositional forms. However, *Arrhythmia*, as a form of pattern disruption, varies the silent intervals between each adjacent character by mapping arbitrary changes in their temporal values. This pattern disruption, as signal confusability, is described in section 4.4.4.3.

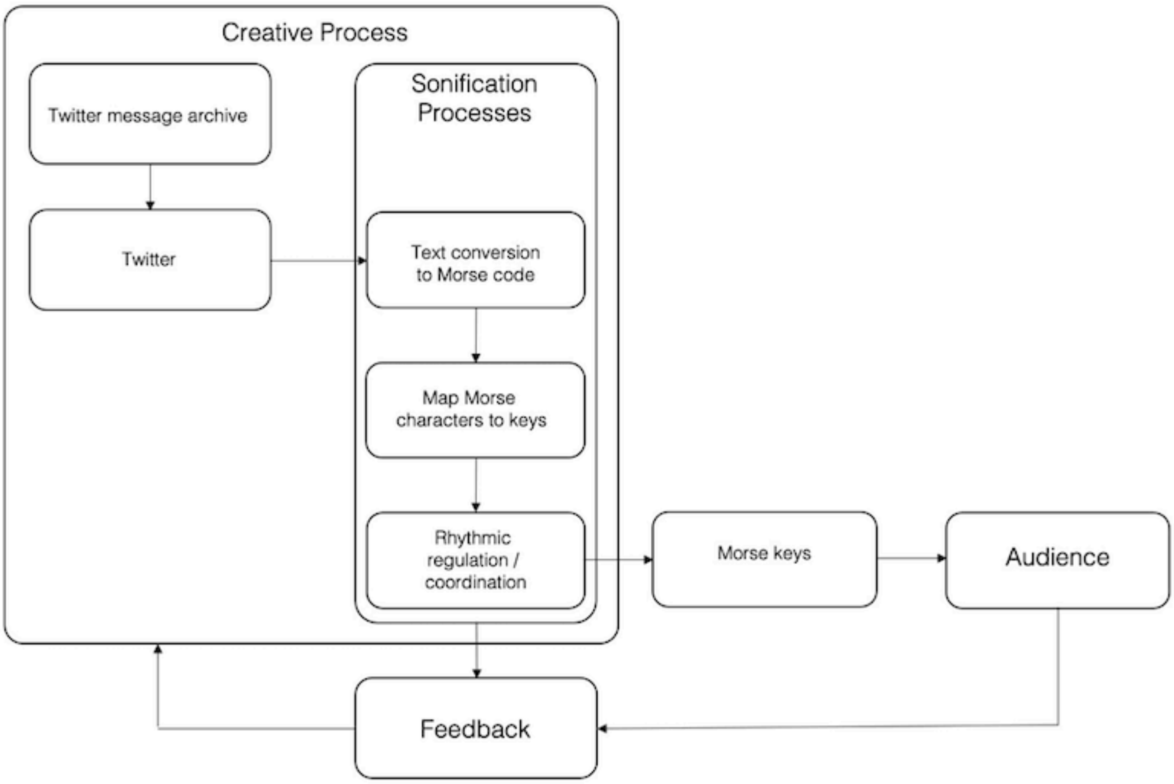


Figure 6.5. *Click::TWEET*'s use of the research framework.

By sonifying Twitter messages as Morse encoded transmissions, a machine-like prosody inherent in Morse code's signalling logic can be heard in the rhythms of the replayed messages. *Click::TWEET*, as a creative work, can be considered a return to more traditional modes of transmission as a form of 'sonic orality' where information was transmitted through the medium of sound.

6.2.3.1 Critical Evaluation

Click::TWEET has been successful in representing parallel social media modalities and in expressing this as a sound based installation. This is supported by acceptance of the work and related papers to national and international conferences and exhibitions. Feedback for the work has included:

- "… a compelling sound art installation."
- "… a nice instantiation of a media archeological research-creation project."
- "…the concept is theoretically robust …relevant to our society today concerning technology and certainly makes people think."
- "… appreciate the parallel modalities of telegraph and social media use (communication with a limited coded repertoire)."
- "The installation is highly polished. The minimal design makes it a beautiful art piece for the audience to enjoy."

Click::TWEET is intended for exhibition in a gallery space supported by a programme note elucidating the concepts informing the work (see 8.1.2).

6.2.4 Click::REVU

Imagining a contemporary rendering of the Optophone and optophonetics as a media archaeological approach (described in Chapter 5. *Click::REVU* (Figure 6.6) utilises a 'sight-impaired' optical sensor to affect sound through the detection of differences in changes in light and darkness.

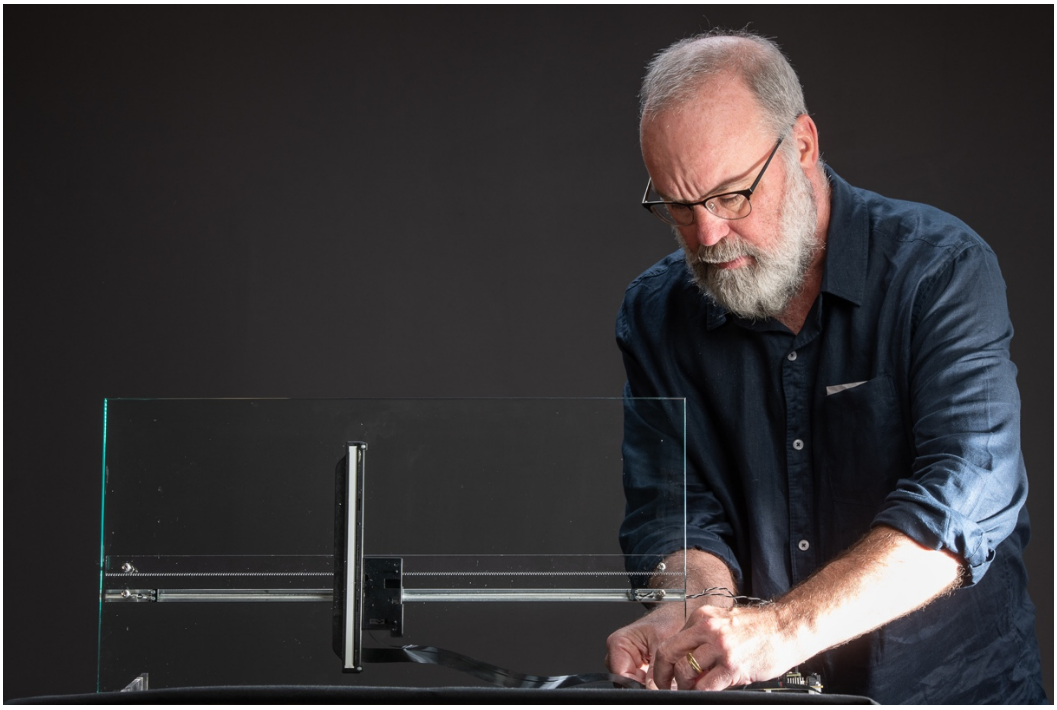


Figure 6.6. *Click::REVU*

The tone frequencies, based on the musicality of Fournier d'Albe's sonification of light and dark used for his reading Optophone, are turned off or on based on a reading of the data. As such, there is no quantitative temporal grid used in the work. Instead, irregular disruptions to each tone are heard as small individual differences within the overall timbre. This approach, as arrhythmia, is an irrational mapping of time and space that reduces the text to a series of fundamental drones and clicks. This process is represented in the research framework shown as Figure 6.7.

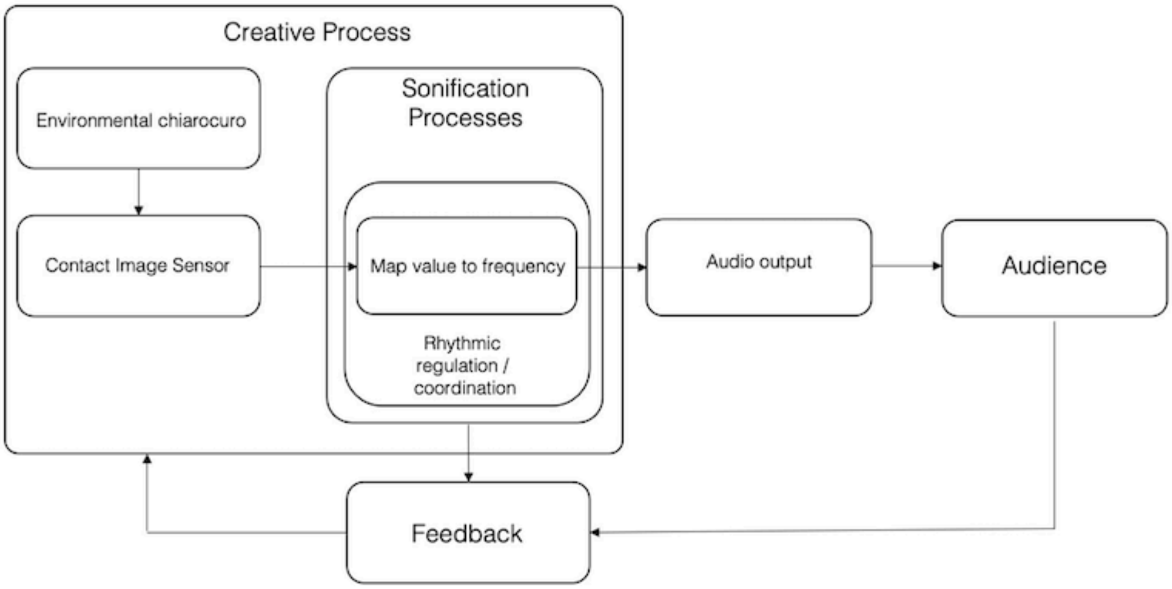


Figure 6.7. *Click::REVU*'s use of the research framework.

Approaching the conceptualisation and realisation of the work through media archaeology and data sonification, *Click::REVU* imagines a form of optophonetics that is an interpretation of both material and immaterial forms of early 20th century Optophones. Thus, as primary sources for knowledge and interpretation, these artefacts inform the creation of a work expressed through a distantly related, but contemporary form of media, the contact image sensor scanner.

6.2.4.1 Critical Evaluation

Representing an historical relationship between the Optophone and contemporary digital imaging media technologies, *Click::REVU* has benefited from a reflective process that has been informed by feedback and observation during its development. The result is an obfuscation of the role of the scanner, what it sees when scanning and therefore the data it captures. As such, this lends the work to being interactive and site specific work as it responds to the ambient light of its environment. The work and a related paper have been accepted to national and international conferences and exhibitions. *Click::REVU* is intended for exhibition in a gallery space supported by a programme note elucidating the concepts informing the work (see 8.1.3).

6.3 Discussion

Through a series of sound-based installations, this research has introduced the novel symbiosis of sonification with media archaeologically-informed sound-based art. This interdisciplinary combination provides a new perspective for the representation of information. *Click::RAND*, *Click::TWEET* and *Click::REVU* explore the musicality of numeric sequences in space and time through the rhythmic and spatialised patterns created by the absence and presence of data. As sound-basic music, this research utilises several access tools facilitated by data sonification to enhance audience perception and reception of the works. The works show that sonically engaging results can be obtained by creating abstract relationships between source data and the sounding object.

As an art method, defamiliarising obsolete and contemporary media relationships through media archaeology approaches, combined with data sonification techniques, provides a new perspective for the listener's engagement with, and interpretation of, sound by hearing the present through the past. By interfacing the appropriate data source with a form of obsolete media, a sonically interesting interpretation of data can be achieved. Connecting the past to the present in this way extends the temporal boundary from which new phenomena may emerge when listening to the sounds of these works.

The debates about sonification as science or art will continue. Where the practitioner sits on the science/art continuum will depend on their discipline or their intention for using data sonification. However, the interdisciplinary combination of sonification, media archaeology and rhythmanalysis can form a harmonious association between such divergent ways of thinking. This association, expressed through consonant and dissonant points of difference, can open new creative potential and ideas by attentively listening to what each voice has to say.

Having presented this thesis' portfolio of works and a framework for the transformation of data from one medium to another, the thesis concludes with the next chapter highlighting the achievements of this research.

Chapter 7. Conclusion

This chapter summarises this thesis' achievements. In addition to this, future work is discussed and the research's novel contributions are highlighted.

7.1 Summary

7.1.1 Motivations and Objectives

One motivation for this research has been to explore the potential of media archaeology as a method for reinterpreting historic relationships between different forms of obsolete and contemporary media. The primary strategy employed in this research has been to examine social and cultural aspects of media, their various technical conditions of existence, and the relationships between them. These relationships have been represented through a series of sound-based works. In implementing these strategies, an amalgam of disciplines including music, engineering, and computer science along with elements of philosophy and sociology have been utilised. A key purpose of this research has been to develop a more structured or practical approach as an aesthetic method of media archaeological representation by conceiving, designing and constructing a series of sound-based artefacts as exemplars of working in the meduim. This approach has been developed utilising the key concepts presented in Chapter 1. These are a material approach to media archaeology, an audiovisual form of representation and data sonification. To achieve this purpose, the stated objectives were to:

– evoke concrete relationships between obsolete and current media technologies through a portfolio of sound-based works. These are informed by their historical, theoretical, sociocultural, and technological relationships,

- develop an approach for exploring new methods of inquiry into the obsolete object's engagement and relationship with current media technologies that also investigate alternative perspectives of historical representation.

To achieve these objectives, this research has designed and developed a series of new sound-based works revealing synergistic relationships and genealogical connections between different media. These connections are expressed by the artefacts themselves and through the written thesis. Employing a practice-based approach to research is one way, as Rekret states in section 2.2.3, of connecting the art of working with material objects with scholarly research. Experiencing this close working relationship with the artefact and from the insights gained by moving between practice, research and evaluation provides an understanding of the intent and context of the research, one that may not necessarily be revealed if the artefact was used as mere illustration.

7.1.2 Background and Related Repertoire

As discussed in Chapter 2, media archaeology continues to struggle with a crisis of identity and intellectual home – if only to be acknowledged as a field of research in its own right – and not just a branch of a pre-existing discipline, for example, media theory, history or art. Not only has the intent of the media archaeology been contested, so have the approaches or methods employed in undertaking such research. A review of various theoretical and material perspectives of media archaeological research suggests that an approach based on a material engagement with media artefacts has the potential to expose the experiential possibilities they afford through creative practice. However, solely focusing on the materiality of the artefact can overlook its socio-contextual conditions of existence and how these may be manifest in contemporary forms of media.

What emerges from the literature and repertoire review is the lack of an established method of representation for media archaeological sound-based art in which the artefact is a significant focal point of the work. As discussed in section 2.4 a physical manifestation of a material approach to media archaeology is the *object-based sound installation*. This category foregrounds the visibly embodied articulations of the artefact as an essential aesthetic element of such works. Providing visual emphasis of the audiovisual performance of automated mechanical objects is a key strategy for highlighting its material form as an aesthetic element of the artwork. The wider lens of *audiovisual materialism* encapsulates the object-based sound installation and further extends media archaeology's material approach into a variety of sound-based disciplines by integrating some form of physical material, objects or artefacts. Expressing relationships between past and contemporary media through a media archaeological lens within this context provides a form of representation for sound-based art. In order to examine the validity of this form of representation, a portfolio of sound-based works has been conceived, developed and realised.

7.1.3 Portfolio of Works

Three sound-based installations have been developed as a result of this research. These are:

- *Click::RAND,* employing random numbers and relays as primary sources of input and output data;
- *Click::TWEET,* employing Twitter messages, Morse code and telegraph keys for its input and output data and sounding object; and
- *Click::REVU,* employing the light sensing capability of a commodity scanner mechanism to generate data that is utilised through an audio synthesis engine. The resultant sound output is based on concepts of early 20th century optophonic devices.

Irrespective of the diversity of data sources and sounding mechanisms used, each work draws on forms of communication media as artefacts. To reiterate, these are interpreted through visual representations (the written page, the screen, the scanned image) and re-presented through aural interfaces (the telegraph key, the electromechanical relay, the Optophone). Each of the visual artefacts has been chosen in part because they exist within a larger internetworked ecosystem both physically and socio-culturally as discussed in section 6.1. The conceptualisation and realisation of each work share a common set of methodological approaches, aesthetic qualities and expressive modalities. To recap, these are media archaeological methods and approaches, utilising the material presence of, and foregrounding, the sound-producing object to explicitly connect sound and source expressed through the 'voice' of the artefact. Representing relationships between the visual domains of the original sources and the acoustic domains expressed through the obsolete artefacts, each work gives a voice to what would more generally be considered immaterial or disembodied objects.

Presented and discussed in Chapter 6. data sonification techniques are employed as a method of organising each work's sonic output and to facilitate the creative shaping of narrative. Henri Lefebvre's *rhythmanalysis* provides a compositional form and structure to the listening experience of each work by articulating different rhythmic representations employed within them. As a study of rhythms in all facets of everyday life, Lefebvre's concepts are applied to the material presentation of everyday objects as a form of media archaeological rhythm analysis.

7.1.3.1 Click::RAND

Click::RAND (Figure 7.1) utilises sets of random digits and normal deviates from The RAND Corporation's book, *A Million Random Digits and 100,000 Normal Deviates*. Reducing the digits to an indexical structure, where an interpretative sign or series of signs are used to refer to a symbol or object (discussed in chapters 1 and 3) the work expresses them as series of rhythmic patterns through sets of electromechanical relays. Utilising the dispassionate listening of Wolfgang Ernst's approach to media archaeology, the relay's sound-making qualities and the isochronous meter of digital signal processing have been incorporated into the work. Using Henri Lefebvre's rhythmanalysis as a framework for shaping materials experienced aurally provides a context for the compositional realisation and experience of *Click::RAND*.

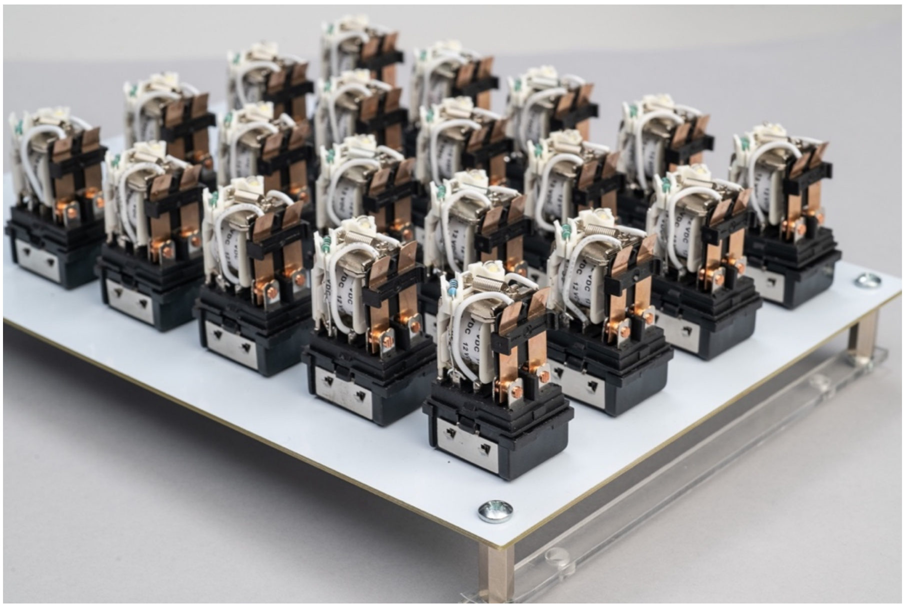


Figure 7.1. *Click::RAND*

As such, both forms of embodiment, that of the object and the audience serve the rhythmanalyst as primary sources for the interpretation of knowledge. Since developing and completing the work, *Click::RAND* has been selected as one of 14 artworks to be exhibited at the International Conference on New Interfaces for Musical Expression (NIME) 2021.[34]

7.1.3.2 Click::TWEET

Similarly to *Click::RAND, Click::TWEET* (Figure 7.2) utilises a visual form of media as its input source. The work employs telegraph keys to replay a series of Twitter messages as Morse code. The work highlights the influence communication media continue to exert as they transform relationships, facilitate new cultural networks, and mediate and unsettle people's everyday experiences. To this end, *Click::TWEET* bridges past and present forms of social media. Opposing perspectives of social media are discussed. Is it a 21st century phenomena based on a set of Internet-based technologies or is it a complex social formation facilitated by technology that has existed for centuries? Such perspectives are presented to contextualise the historical connection between telegraphy and Twitter. Informed by the *algorhythm*, a media archaeological method (discussed in section 4.3) used to listen to and analyse digital signal transmissions, Twitter's messages are made audible as Morse encoded messages. Along with a reduction in message content that cannot be represented by Morse codes character set (e.g., images, emotive icons, etc), the messages are listened to at an indexical level rather than for semantic meaning. Contextualised within Henri Lefebvre's characterisations of rhythmanalysis, three compositional forms are utilised. Presented as *Eurhythmia* (rhythms of equality*), Polyrhythmia* (rhythms of diversity) and *Arrhythmia* (rhythms of disturbance), these forms are a way of exploring the sounds and rhythms of the encoded messages. Whilst Lefebvre considers rhythms in all facets of everyday life, he does not specifically consider the role of non-humans in his urban milieu. However, as Miyazaki has shown (see section 2.3.1) a close listening to signals, noise and fluctuations of communication transmissions can provide a method of exposing the rhythms of machinic processes. The use of this method becomes evident when listening to the machine-like prosody of Twitter messages replayed through the telegraph keys. The result is that rhythms emerge from Morse code's structural logic. Representing a return to earlier modes of technological communication, where information is expressed through the medium of sound, *Click::TWEET* can be considered a form of sonic orality vocalised by the telegraph key. Since developing the work, *Click::TWEET* was selected for exhibition at the International Conference on New Interfaces for Musical Expression

[34] The submission can be viewed at http://nime2021.org/program/#/installation/37

(NIME) 2020. The work was also one of 14 artworks selected and exhibited at the International Conference on New Interfaces for Musical Expression (NIME) 2021.[35]

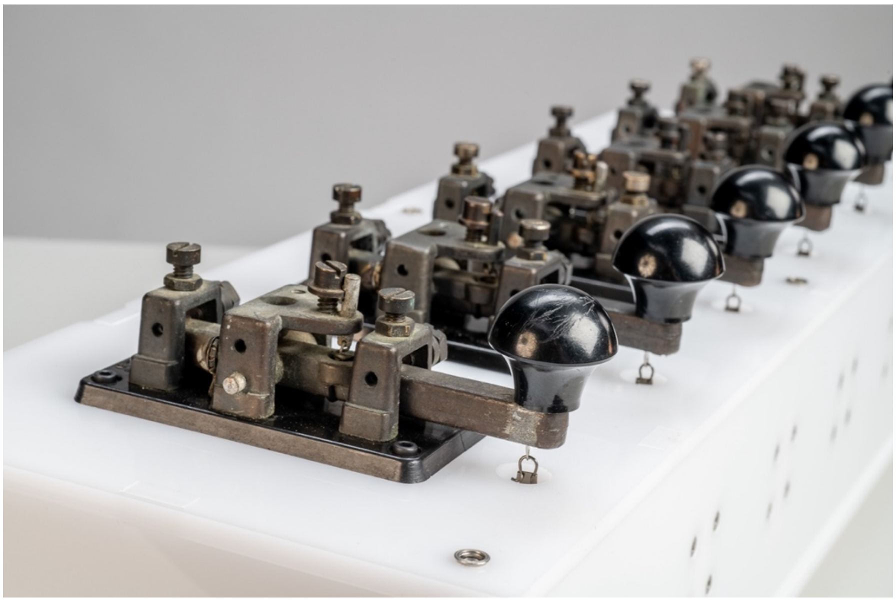


Figure 7.2. *Click::TWEET*

7.1.3.3 Click::REVU

Unlike the previous works, the Optophone is not physically present as an object in *Click::REVU* (Figure 7.3). The work employs physical characteristics of the reading Optophone's sound output and abstract characteristics associated with the Berlin Dadaist Raoul Hausmann's artistic research of optophonics and optophonetic poetry. Utilising a scanner mechanism from a multifunction printer, *Click::REVU* uses the data captured when scanning to create a fluctuating soundscape through the presence and absence of modulated sine tones as a form of optophonic expression. Framed within elements of Henri Lefebvre's rhythmanalysis, the combination of rhythms, as polyrhythmia, experience continual moments of arrhythmic disruption. As cyclic rhythms of return and renewal, arrhythmic differences disrupt the continuity of otherwise repetitious or linear rhythms. As a media archaeological sound-based artwork, the ideation of *Click::REVU* has conceived a form of optophonetics through the interpretation of both material and immaterial forms of early 20th century Optophones. These archival sources of knowledge have been reinterpreted in developing and

[35] The submission can be viewed at http://nime2021.org/program/#/installation/36

realising this work, expressed through a genealogically related contemporary form of media, the contact image sensor scanner.

Figure 7.3. *Click::REVU*

7.1.4 Media Archaeological Sonification

Following the presentation and discussion of the portfolio of works, Chapter 6. sought to present a framework to facilitate the organisation of sound. This framework evolved as the works were developed to provide a common aesthetic approach. Reflecting on the presentation of each work, I was drawn to each as a media archaeological form of audiovisual display. Although encapsulated within a wider lens of audiovisual materialism, each work shares an approach where information was extracted from visual media, transformed and re-presented aurally. Accordingly, the use of data sonification techniques to facilitate the organisation of sound is a key element throughout these works. As has been discussed in chapters 2 and 6, the fields of media archaeology and auditory display are not without their tensions and contestations regarding means and methods. Arguably, the use of data sonification as a technique utilised in media archaeological inquiry and represented as sound-based art has not been widely employed. Similarly, the material representation of obsolete media has not been utilised in data sonification to allow the artefact's voice to be heard. This necessitated the development of a framework for the use of sonification techniques to facilitate new perspectives for the representation of information within media archaeological inquiry. The framework has been critically examined in relation to the portfolio of works to validate the use of these techniques in this context. What has evolved is a flexible framework that can be adapted and extended to examine relationships between past and present media utilising a range of such mechanisms and supporting its applications within media archaeological research. Specific outcomes from the use of this framework to develop the portfolio of works have resulted in a number of peer reviewed academic and artistic papers and exhibitions. These are elaborated on in section 7.3.2.

7.2 Future Work

With media archaeology positioning itself as an inter- or trans-disciplinary field, a number of opportunities exist to extend this research and create sonically interesting works employing obsolete media. In creating my portfolio of works, a focus has been to define and refine approaches and techniques used within my artistic practice that have been developed and utilised throughout this research. However, a creative stasis may insinuate itself into artistic practice without continued further development of this approach. Two areas on ongoing research are considered. First, continuing an archival examination into genealogical relationships between obsolete and contemporary forms of media may include further blue sky moments similar to those described in Chapter 1. Rather than rely solely on narrative histories, engaging with the tactile and material nature of artefacts and considering the artefact as an instrument for performance may reveal unexpected relationships that some possible cumulative narratives may, in fact, mask. Similarly, considering oral histories as archaeological archives may provide another source for media archaeological research. An example of this approach is less traditional or lesser known media archives like MAVTech (the National Museum of Audio Visual Technology) or the Awarua Communication Museum[36]. Offering a unique range of cinematic and communication media not found in traditional museums, such archives can provide innumerable old media that could be examined and employed to create new sound-based works similar to those presented in this research.

The second area is the continued development of existing practices and techniques. Identifying artefacts with a wider timbral range will provide additional material that is able to be employed in future works. However, these developments must be mindful of not creating arbitrary object/sound relationships in which sound is used for sound's sake rather than

[36] MAVTech is located in Foxton, New Zealand (https://www.foxton.org.nz/attr-mavtech.html). The Awarua Communications Museum is located outside Invercargill, New Zealand (https://www.awaruamuseum.co.nz/). Both hold unique media collections relating to New Zealand's film and communication history.

supporting a conceptual and referential relationship between forms of media. In parallel to this, increasing the number of artefacts utilised in works will provide larger scale installations similar to the approach used for *Click::RAND*. Doing so will not only increase the interplay between a work's sounds but provide a more immersive audience experience through the iterative use of sounding objects and its installed environment. Examples of works utilising this method include Stephen Cornford (discussed in section 2.5) and Zimoun's many works utilising d.c. motors. Considering these observations, two possible areas for extending this research and creating future works are now discussed.

The works realised in this research are characterised as installations. Creating works as instruments would add a performative element to them. As a method of operative engagement with the media, a human perspective would bring a visual human/machine expressivity to the work and show how media archaeological research can be utilised in a performance context. Speculating on the example of the telegraph, human engagement was purposeful in that it produced an outcome—bringing an immediacy to communication. Extending this engagement into a form of instrumentality, the operator as an interactive participant with the object or the artwork extends a once operational engagement to one of performance. Similarly, the object becomes an active participant through the interaction between the artefact and performer, engendering a form of agency from that relationship. Through this interactive engagement, as a media archaeological performance, a renewed appreciation of the expertise or virtuosity of the early telegraphic operations may emerge through the artwork.

Extending the use of sonification techniques can be a way to increase expressivity and interaction with object-based installations. To this, extending the current framework to respond to user actions can be a way of increasing audience interaction and engagement with a work. Developing a dynamic model as opposed to a statically mapped set of parameters provides a method of enabling real-time interaction with evolving information sources. A model of this type may simply include a method of triggering a work as has been described for *Click::TWEET* (described in section 4.2.2.1) or be extended to analyse certain characteristics or types of data within a defined set of metrics. Such a model may be developed further to provide responsive interactions with an audience. These interactions can be developed to also respond to changes in environmental parameters, thus creating a work whose output inherently evolves in response to a multiplicity of actions.

7.3 Novel Contributions

This section summarises the key novel contributions of my research. In addition to the research presented in this thesis these contributions include peer reviewed academic and artistic papers and exhibitions listed in section 7.3.2.

7.3.1 Research Contributions

- Developing a framework for the application of data sonification techniques in media archaeological research to facilitate the organisation of sound in this context. The application of this framework is evidenced in the portfolio of works and the acceptance of four peer reviewed publications and eight exhibitions related to these.
- The design and development of an original series of electromechanical artworks that are explicitly media archaeological in context:
    - *Click::RAND* (five refereed exhibition outputs)
    - *Click::TWEET* (three refereed exhibition outputs)
    - *Click::REVU* (pending exhibition, 2022)
- Establishing a creative framework for sonic reinterpretation and transformation of visual forms of sensory media.
- Employing data sonification techniques and the representation of data to enable physical artefacts to 'speak' in their own 'voice'.
- Providing a representational context for media archaeological sound-based art alongside a more diverse range of works within the wider lens of *audiovisual materialism*. As a method of representation, in which the artefact is a significant focal point of the work, it foregrounds the material and audiovisual qualities of obsolete media in such works and extends media archaeology's material approach into a variety of sound-based disciplines.

7.3.2 Research Outputs

This section presents the peer reviewed proceeding publications and exhibitions as a result of this research, reaffirming the novel contributions outlined above. Full publications and examples of each work are available at www.dunham.co.nz.

7.3.2.1 Refereed Publications

P. Dunham, "The Sounds of Obsolescence in the Age of Digital Re-Production" in *Proceedings of the 7th Conference on Computation, Communication, Aesthetics & X (xCoAx)*, Milan, Italy, 372-374. July 3-5, 2019

P. Dunham, M, Zareei, D. McKinnon, D. Carnegie, "*Click::RAND*. A Minimalist Sound Sculpture" in *Proceedings of The International Conference on New Interfaces for Musical Expression*, Birmingham, UK (online), 139–142. July 3-5, 2020

P. Dunham, M. Zareei, D. Carnegie, D. McKinnon, "*TWTTRGRAPH*: I Wish to Speak With You. A Telegraphic Sound Iinstallation" in *Proceedings of the 26th International Symposium on Electronic Art (ISEA2020)*, Montreal, Canada, 153-180. October 13-18, 2020

P. Dunham, M, Zareei, D. McKinnon, D. Carnegie, "*Click::RAND*#2. An Indeterminate Sound Sculpture" in *Proceedings of The International Conference on New Interfaces for Musical Expression*, Shanghai, China, (online), June 15-18, 2021

P. Dunham, M. Zareei, D. Carnegie, D. McKinnon, "*Click::REVU*. An Optophonic Sound Installation" to *the 27th International Symposium on Electronic Art (ISEA2022)*, Barcelona, Spain, June 10-16, 2022.

P. Dunham, M. Zareei, D. McKinnon, D. Carnegie, "Material Media Sonification: sounding the visibly present artefact," Organised Sound (Forthcoming 2022).

7.3.2.2 Installations

Click::RAND. Installation at the Pyramid Power Festival. May, 2019. Pyramid Club, Wellington, New Zealand.

Click::RAND. Installation at the Science and Technology Expo. May, 2019. Lower Hutt, Zealand.

Click::TWEET. Installation at the International Conference on New Interfaces for Musical Expression. July, 2020. Royal Birmingham Conservatoire, Birmingham, England (deferred due to COVID-19).

Click::RAND. Multiple installations at Tuning into the Pandemic. November, 2020. Massey University, Wellington, New Zealand.

Click::TWEET. Installations at Tuning into the Pandemic. November, 2020. Massey University, Wellington, New Zealand.

Click::RAND. Installation at the International Conference on New Interfaces for Musical Expression (NIME2021). June, 2021. NYU, Shanghai, China.

Click::TWEET. Installation at the International Conference on New Interfaces for Musical Expression (NIME2021). June, 2021. NYU, Shanghai, China.

Click::RAND. Installation at Ars Electronica Garden Aotearoa. September 2021. University of Auckland, Auckland, New Zealand.

Click::REVU. Online presentation at Indeterminate Instructures. Objects, Signals and Architectures, Aotearoa Digital Arts Network, December 2021, Wellington, New Zealand.

7.3.2.1 Media

Click::TWEET. Faculty of Engineering, Victoria University of Wellington social media marketing. Access at https://tinyurl.com/3mrr2nmd, November 2021.

Click::RAND. Faculty of Engineering, Victoria University of Wellington social media marketing. Access https://tinyurl.com/yu9vcxkj, December 2021.

"RAND's Got Rhythm" featured in *RAND Review*, Dec/Jan issue, January 2022.

7.3.2.2 Submissions Awaiting Review and Pending Exhibitions

Click::REVU. Installation at Ars Electronica Garden Aotearoa. June, 2022. Victoria University of Wellington, Wellington, New Zealand.

7.4 Coda

In concluding this thesis, the motivation to explore the potentials of media archaeology has resulted in the development of a framework for inquiry and representation through sound-based art. The framework has been developed and refined as a part of the creative process that has resulted in the ideation and realisation of three media archaeologically-informed sound-based artworks. The works themselves afford access to the framework, as well as novel experiences, through the aesthetic phenomena they engender. Each work has explored historical, theoretical, sociocultural, and technological connections between obsolete and current media technologies in their conception and realisation. Thus, in achieving the objectives stated in Chapter 1. this research has produced three artworks that articulate the historical relationships between obsolete and contemporary forms of media expressed through the materiality of their own 'voices' or elements of them. As a result, this thesis presents a novel approach to media archaeological research in both critical and creative forms. Incorporating physical material, objects or artefacts, and their visual qualities as expressive elements facilitated by the artistic use of data sonification techniques, the works give voice to what would more generally be considered immaterial or disembodied objects.

Chapter 8. Appendices

8.1 Programme Notes

8.1.1 Click::RAND

Click::RAND

Paul Dunham

Click::RAND is an object-based sound installation that, through a media archaeological approach, connects the electro-mechanical relay as an artefact of electro-mechanical relay-based calculating machines and publications of large random number sets as historically related media artefacts. Through the relay, *Click::RAND* is the sonic articulation of The RAND Corporation's book, *A Million Random Digits with 100,000 Normal Deviates*.

Re-presenting the book's decimal characters as their binary equivalent, as the transference from one symbolic form to another, is a way of allowing the relay to 'speak' with its own voice. As such, giving a 'voice' to *A Million Random Digits with 100,000 Normal Deviates* through the operative presence of the relay echoes the book albeit in a way that breaks it apart and represents it in a new way. A way that reproduces it through a different medium and with a new temporality, leaving traces of the past through this technologically produced voice.

Eurhythmia

Eurhythmia, as a state of rhythmic resonance, is a state characterised by the synchronisation of different rhythms into a cohesive whole. It involves a form of rhythmic coordination as a distinct way to express how the experience of space and time may interact. *Eurhythmia*, as it is represented in *Click::RAND*, considers each binary encoded digit as a discreet and fleeting rhythmic pattern. Reading the 1,000,000 digits in sequence, *Eurhythmia* replays them as five parallel digits. Each space between binary 'bits' is a disruption to a pattern that may be resolved by the emergence of a new pattern.

Polyrhythmia

Polyrhythmia is an environment where heterogeneous rhythms co-exist simultaneously without being coordinated with each other. In the absence of synchronisation, one must focus on each of them separately, and eventually successively, to grasp their own specific rhythms. Replaying randomly selected digits in binary format, *Polyrhythmia* exhibits moments of synchronisation, syncopation, and disturbance through the threading of each binary digit's rhythmic patterns.

Arrhythmia

Arrhythmia is characterised by the provisional or permanent lack of synchronisation between rhythms. This discordant form has the potential to generate creative differences. *Arrhythmia* disrupts the regularity of binary patterning by randomly changing the timing of the elements used between and for each individual character. The random tempo elements are provided by the Gaussian deviate data set associated with the random digits. In this way, the individual digits lose their semantic meaning with the disruption of the binary temporal logic.

8.1.2 Click::TWEET

Click::TWEET

Paul Dunham

The ideation and realisation of *Click::TWEET* has been informed by characteristic similarities between Twitter, the telegraph and Morse code. Their different material and lexical features have been utilised in creating a sound installation that re-presents the interwoven temporalities between these historical and contemporary media technologies. By perceiving the social in media in this way, lines can be drawn between past social practices and technological invention and today's social media platforms.

Utilising social media and obsolete objects, *Click::TWEET* uses telegraph keys to replay a series of Twitter messages as Morse code thereby creating a presence of past media alongside contemporary media technologies. Acting as a temporal bridge between the storage and transmission interfaces of Twitter and the telegraph's rhythmically pulsed clicks, Twitter's digital environment of zeros and ones, by way of Morse code's abstract and immaterial beat, is given material form through the array of telegraph keys. Tweets are selected using the keyword phrase, "What Hath God Wrought?" as a reference to the first long distance telegraph message.

Contextualised within Henri Lefebvre's characterisations of Rhythmanalysis, three compositional forms are presented as *Eurhythmia*, rhythms of equality, *Polyrhythmia* , rhythms of diversity and *Arrhythmia*, rhythms of disturbance. These forms are a way of exploring the rhythms of the encoded messages. Listening to the various rhythms inherent in Morse code's structural logic presents a machine-like prosody in the way the messages are replayed.

8.1.3 Click::REVU

Click::REVU

Paul Dunham

Click::REVU blends physical and abstract characteristics of the Optophone, an early sonification device designed to “substitute the ear for the eye” by making optical signals audible. The work creates an illusory presence of the device through a scanner mechanism from a multifunction printer. The work depicts a form of optophonics informed by a relationship between contact image sensor (CIS) technology, prevalent in low-cost multifunction printers, and the Optophone via the light sensing technologies developed through the 20th century. Intrinsically, the Optophone shares an indeterminate genealogy with these early optical devices. These devices were precursors to later developments that include the automated conversion of images into machine-readable text (optical character recognition), image sensors embedded in digital cameras and scanning technologies and the compact disc.

Click::REVU foregrounds the CIS mechanism as the primary visual element for the work. In its intended use, the mechanism is generally concealed within a larger structure, analogous to an organ within a body. Removed from the shroud of darkness of its natural habitat and support structures (e.g., interfaces to image formation, formatting and engine control) the CIS itself has become visually impaired and struggles to see clearly in its new environment.

White

The representation of the early reading Optophone, is expressed as the composition *White*. As such, all tones are present until interrupted by darker tones. The simultaneity and diversity of these tones create moments of harmony and discord as diverse rhythms interact to maintain a metastable equilibrium between them. An arrhythmic presence exists as a dysfunctional interrelation of rhythms experienced by introducing discontinuity to the sine tones through the irregular presence and absence of sound. At a macro level, the work’s rhythms are modulated by the mechanism’s electromechanical and programmatic movement. This relationship, modulated by slow changes in environment light, does not interrupt the rhythms but modifies them through the light’s diurnal cycles.

8.2 Software Links

The software for *Click::RAND* is available at https://github.com/pauldunham/RAND.

The software for *Click::TWEET* is available at https://github.com/pauldunham/TWEET.

The software for *Click::REVU* is available at https://github.com/pauldunham/REVU.

Chapter 9. Bibliography

[1] J. Burges, "Adorno's Mimeograph: The Uses of Obsolescence in Minima Moralia," *New Ger. Crit.*, vol. 40, no. 1, pp. 65–92, 2013, doi: 10.1215/0094033X-1812577.
[2] M. Goble, "Obsolescence," in *A New Vocabulary for Global Modernism*, E. Hayot and R. L. Walkowitz, Eds. Columbia University Press, 2016, pp. 146–168.
[3] J. Sterne and M. Akiyama, *The Recording That Never Wanted to Be Heard and Other Stories of Sonification*. Oxford University Press, 2011. doi: 10.1093/oxfordhb/9780195388947.013.0115.
[4] S. Feld, "Acoustemology," in *Keywords in sound*, D. Novak and M. Sakakeeny, Eds. Durham ; London: Duke University Press, 2015, pp. 12–21.
[5] J. Parikka, *What is Media Archaeology?* Cambridge, U.K.: Polity Press, 2012.
[6] E. Huhtamo and J. Parikka, Eds., *Media archaeology: approaches, applications, and implications*. Berkeley, Calif: University of California Press, 2011.
[7] C. Kelly, *Cracked Media: the sound of malfunction*. Cambridge, Mass: MIT Press, 2009.
[8] L. Gitelman, *Scripts, grooves, and writing machines: representing technology in the Edison era*. Stanford, Calif: Stanford University Press, 1999.
[9] N. Bassett and J. Archer, "'Enjoy your feeling': A media archaeology of material publics.," *Commun. Public*, vol. 2, no. 3, pp. 239–252, 2017.
[10] L. Landy, *Understanding the Art of Sound Organisation.* Cambridge, Mass: MIT Press, 2007.
[11] P. Valiquet, "Hearing the Music of Others: Pierre Schaeffer's Humanist Interdiscipline," *Music Lett.*, vol. 98, no. 2, pp. 255–279, 2017.
[12] B. M. Downs, "Sound Unseen: Acousmatic Sound in Theory and Practice. By Brian Kane. Oxford: Oxford University Press, 2014, xii + 318 pages," *Music Theory Spectr.*, vol. 38, no. 1, pp. 118–121, 2016, doi: 10.1093/mts/mtw003.
[13] E. Rose, "Translating Transformations: Object-Based Sound Installations," *Leonardo Music J.*, vol. 23, pp. 65–69, 2013.
[14] M. H. Zareei, "Audiovisual Materialism," *Organised Sound*, vol. 25, no. 3, pp. 362–371, Dec. 2020, doi: 10.1017/S1355771820000321.
[15] C. Kelly, "Materials of Sound: Sound As (More Than) Sound," *J. Sonic Stud.*, no. 16, Aug. 2018, Accessed: May 11, 2021. [Online]. Available: https://www.researchcatalogue.net/view/456784/456785
[16] M. Goddard, "Opening up the black boxes: Media archaeology, 'anarchaeology' and media materiality," *New Media Soc.*, vol. 17, no. 11, pp. 1761–1776, Dec. 2015, doi: 10.1177/1461444814532193.
[17] W. Ernst, *Sonic Time Machines*. Amsterdam: Amsterdam University Press, 2016.
[18] P. Sinclair, "Sonification: what where how why artistic practice relating sonification to environments," *AI Soc.*, vol. 27, no. 2, pp. 173–175, May 2012, doi: 10.1007/s00146-011-0346-2.
[19] E. Huhtamo, "Resurrecting the Technological Past," *InterCommunication*, no. 14, 1995.
[20] G. Lovink, "My First Recession. Critical internet Culture in Transition." Institute of Network Cultures, Amsterdam, 2011.
[21] W. Ernst, *Digital Memory and the Archive*. University of Minnesota Press, 2013.
[22] W. Strauven, "Media Archaeology: Where Film History, Media Art, and New Media (Can) Meet," in *Preserving and Exhibiting Media Art*, V. Hediger, J. Noordegraaf, B. Le Maitre, and C. G. Saba, Eds. Amsterdam: Amsterdam University Press, 2013, pp. 59–80. doi: 10.1515/9789048513833-005.
[23] A. Monea, "Media Genealogy and the Politics of Archaeology — Introduction," p. 19, 2016.
[24] E. Huhtamo, "Art in the Rear-View Mirror: The Media-Archaeological Tradition in Art," in *A Companion to Digital Art*, C. Paul, Ed. Hoboken, NJ: John Wiley & Sons, Inc, 2016, pp. 69–110. doi: 10.1002/9781118475249.ch3.

[25] M. Mäkelä, "Knowing Through Making: The Role of the Artefact in Practice-led Research," *Knowl. Technol. Policy*, vol. 20, no. 3, pp. 157–163, Oct. 2007, doi: 10.1007/s12130-007-9028-2.
[26] G. Hertz, "Archaeologies of Media Art | CTheory," 2010. https://journals.uvic.ca/index.php/ctheory/article/view/14750/5621 (accessed Apr. 12, 2021).
[27] J. Baron, J. Fleeger, and S. W. Lerner, "Introduction: Theorizing Media Ventriloquism," in *Media Ventriloquism*, Oxford University Press, 2021, pp. 1–18. doi: 10.1093/oso/9780197563625.003.0001.
[28] L. Candy and E. Edmonds, "The role of the Artefact and Frameworks for Practice-based Research.," in *The Routledge Companion to Research in the Arts*, M. Biggs and H. Karlsson, Eds. London: Routledge, 2010, pp. 120–137.
[29] H. Smith and R. Dean, "Introduction: Practice-led Research, Research-led Practice Towards the Iterative Cyclic Web," in *Practice-led Research, Research-led Practice in the Creative Art*, Edinburgh: Edinburgh University Press, 2009, pp. 1–38.
[30] B. Bolt, "Heidegger, Handability and Praxical Knowledge," presented at the Australian Council of University Art & Design Schools, Canberra, Australia, Sep. 2004.
[31] J. Parikka, "Operative Media Archaeology: Wolfgang Ernst's Materialist Media Diagrammatics," *Theory Cult. Soc.*, vol. 28, no. 5, pp. 52–74, Sep. 2011, doi: 10.1177/0263276411411496.
[32] W. Benjamin, *Illuminations*. London: Fontana, 1973.
[33] T. Adorno, *Minima Moralia. Reflections on a Damaged Life*, English translation. London; New York: Verso, 2005.
[34] Philipp Dominik Keidl, "Toward a Public Media Archaeology: Museums, Media, and Historiography," *Mov. Image*, vol. 17, no. 2, pp. 20–39, 2017, doi: 10.5749/movingimage.17.2.0020.
[35] T. Elsaesser, "Media archaeology as symptom," *New Rev. Film Telev. Stud.*, vol. 14, no. 2, pp. 181–215, Apr. 2016, doi: 10.1080/17400309.2016.1146858.
[36] M. Goddard, *Guerrilla networks: an anarchaeology of 1970s radical media ecologies*. Amsterdam: University Press, 2018.
[37] M. Foucault, *Archaeology of Knowledge*. London ; New York: Routledge, 2002.
[38] T. Druckery, "Foreword," in *Deep Time of the Media*, Cambridge, Massachusetts: The MIT Press, 2006, pp. vii–xi.
[39] B. Roberts, "Media Archaeology and Critical Theory of Technology," in *New Media Archaeologies*, Amsterdam: Amsterdam University Press, 2019, p. 21.
[40] S. Zielinski, *Variations on media thinking*. Minneapolis: University of Minnesota Press, 2019.
[41] A. Fickers and A. van den Oever, "Experimental Media Archaeology: A Plea for New Directions," in *Technē /Technology: researching cinema and media technologies: their development, use, and impact*, Amsterdam: Amsterdam University Press, 2014, pp. 272–278.
[42] F. A. Kittler, *Gramophone, film, typewriter*. Stanford, Calif: Stanford University Press, 1999.
[43] D. Tonuk and T. Fisher, "Material Processuality: Alternative Grounds for Design Research," *Des. Cult.*, vol. 12, no. 2, pp. 119–139, May 2020, doi: 10.1080/17547075.2020.1717779.
[44] M. G. Kirschenbaum, *Mechanisms: new media and the forensic imagination*. Cambridge, Mass: MIT Press, 2008.
[45] J. Drucker, "Performative Materiality and Theoretical Approaches to Interface," *Digit. Humanit. Q.*, vol. 007, no. 1, Jul. 2013.
[46] A. Fickers and A. van den Oever, "Doing Experimental Media Archaeology. Epistemological and Methodological Reflections on Experiments with Historical Objects of Media Technologies," in *New Media Archaeologies*, Amsterdam: Amsterdam University Press, 2019, pp. 45–68.
[47] S. Zielinski, *Deep time of the media: toward an archaeology of hearing and seeing by technical means*. Cambridge, Mass: MIT Press, 2006.
[48] S. Zielinski, "Modelling Media for Ignatius Loyola. A Case Study on Athanasius Kircher's World of Appartus between the Imaginary and the Real," in *Book of Imaginary Media. Excavating the Dream of the Ultimate Communication Medium*, Amsterdam: Debalie and NAi Publishers, 2006.
[49] W. Strauven, "Media Archaeology as Laboratory for History Writing and Theory Making," in *New Media Archaeologies*, Amsterdam: Amsterdam University Press, 2019, pp. 23–42.
[50] W. Ernst and J. Parikka, *Digital memory and the archive*. Minneapolis, MN: University of Minnesota Press, 2013. Accessed: Apr. 08, 2020. [Online]. Available: http://public.eblib.com/choice/publicfullrecord.aspx?p=1204682
[51] J. Bennett, *Vibrant matter: a political ecology of things*. Durham: Duke University Press, 2010.
[52] G. Cox and M. Riis, *(Micro)Politics of Algorithmic Music*. Oxford University Press, 2018. doi: 10.1093/oxfordhb/9780190226992.013.22.
[53] W. Ernst, "As Slow as Possible? On the Machinic (Non-)Sense of the Sonic Present and Digital Indifference toward Time," *ASAP/Journal*, vol. 4, no. 3, pp. 671–688, 2019, doi: 10.1353/asa.2019.0044.
[54] A. Groom, "Introduction," in *Time*, London: Whitechapel Gallery, 2013.

[55] G. Hertz and J. Parikka, "Zombie Media: Circuit Bending Media Archaeology into an Art Method," *Leonardo*, vol. 45, no. 5, pp. 424–430, Oct. 2012.
[56] "Bernie Lubell interactive wood machines." https://bernielubell.com/text.htm (accessed Apr. 20, 2021).
[57] "Bernie Lubell installations 1980 - 1990." https://bernielubell.com/03etioinstall.htm (accessed Apr. 20, 2021).
[58] R. Wakkary, W. Odom, S. Hauser, G. Hertz, and H. Lin, "Material Speculation: Actual Artifacts for Critical Inquiry," *Aarhus Ser. Hum. Centered Comput.*, vol. 1, no. 1, p. 12, Oct. 2015.
[59] E. Huhtamo, "Thinkering with Media: On the Art of Paul De Marinis," in *Buried in Noise*, Heidelberg: Kehrer, 2011, pp. 33–39.
[60] I. Beirer, S. Himmelsbach, and C. Seiffarth, Eds., "The Edison Effect," in *Paul DeMarinis: Buried in Noise*, 1. Aufl., Heidelberg: Kehrer, 2011, p. 127.
[61] P. De Marinis, "The Messenger," 1998. http://pauldemarinis.org/MessengerText.html (accessed Feb. 25, 2019).
[62] D. Cressman, "A Brief Overview of Actor-Network Theory: Punctualization, Heterogeneous Engineering & Translation," Simon Fraser University, Canada, Apr. 2009. Accessed: May 16, 2019. [Online]. Available: http://summit.sfu.ca/item/13593
[63] G. Hertz, "Methodologies of Reuse in the Media Arts: Exploring Black Boxes, Tactics and Archaeologies," Dec. 2009, Accessed: Apr. 23, 2021. [Online]. Available: https://escholarship.org/uc/item/5r8842r6#author
[64] J. Parikka, "New Materialism as Media Theory: Medianatures and Dirty Matter," *Commun. Crit. Stud.*, vol. 9, no. 1, pp. 95–100, Mar. 2012, doi: 10.1080/14791420.2011.626252.
[65] "Reed Ghazala * Designing 'circuit-bent' instruments," 2000. http://www.anti-theory.com/texts/Sound_on_Sound/index.html (accessed May 10, 2021).
[66] S. Miyazaki, "AlgoRHYTHMS Everywhere: A Heuristic Approach to Everyday Technologies," in *Off Beat: Pluralizing Rhythm*, J. H. Hoogstad and B. Stougaard Pedersen, Eds. Brill | Rodopi, 2013, pp. 135–148. doi: 10.1163/9789401208871_010.
[67] S. Miyazaki, "Algorhythmics: Understanding Micro-Temporality in Computational Cultures," *Comput. Cult.*, no. 2, Sep. 2012, Accessed: Apr. 22, 2021. [Online]. Available: http://computationalculture.net/algorhythmics-understanding-micro-temporality-in-computational-cultures/
[68] S. Miyazaki, "Urban sounds unheard-of: a media archaeology of ubiquitous infospheres," *Continuum*, vol. 27, no. 4, pp. 514–522, Aug. 2013, doi: 10.1080/10304312.2013.803302.
[69] D. Lyon, "Key methodological orientations in doing rhythmanalysis: The body as central, displaced or insufficient," in *What is Rhythmanalysis?*, Bloomsbury Academic, 2019. doi: 10.5040/9781350018310.
[70] S. Hinds, "Algo-rhythmics," Aug. 07, 2017. http://blogs.cim.warwick.ac.uk/outofdata/2017/08/07/algo-rhythmics/ (accessed May 27, 2021).
[71] B. House, "Machine Listening:: WAVENET, Media Materialism, and Rhythmanalyis," *APRJA*, vol. 6, no. 1, p. 9, 2017.
[72] D. McKinnon, "Woven, torn and stitched: The fabrication of Sound," in *The Oxford Handbook of Sound Art*, Oxford: Oxford University Press, 2021.
[73] E. Rose, "Reflection," *Ethan Rose - Reflection*, 2012. http://www.ethanrosemusic.com/reflection (accessed May 07, 2021).
[74] M. H. Zareei, D. Mckinnon, D. A. Carnegie, and A. Kapur, "Sound-based Brutalism: An emergent aesthetic," *Organised Sound*, vol. 21, no. 1, pp. 51–60, Apr. 2016, doi: 10.1017/S1355771815000370.
[75] M. H. Zareei, D. A. Carnegie, and A. Kapur, "Physical Glitch Music: A Brutalist Noise Ensemble," *Leonardo Music J.*, vol. 25, pp. 63–67, Dec. 2015, doi: 10.1162/LMJ_a_00937.
[76] "Zimoun." https://www.zimoun.net/ (accessed Apr. 23, 2021).
[77] "MARTIN MESSIER | SEWING MACHINE ORCHESTRA INSTALLATION." https://martinmessier.art/sewingmachineorchestrainstallation.html (accessed Apr. 22, 2021).
[78] "MARTIN MESSIER | PROJECTORS." https://martinmessier.art/projectors.html (accessed Apr. 22, 2021).
[79] M. Riis, *Machine Music. A Media Archaeological Excavation.* Denmark: Aarhus University Press, 2016.
[80] M. Riis, "The Media Archaeological Repairman," *Organised Sound*, vol. 18, no. 3, pp. 255–265, Dec. 2013, doi: 10.1017/S1355771813000228.
[81] "Stephen Cornford." https://stephencornford.net/index.html (accessed Apr. 21, 2021).
[82] "Stephen Cornford • Archipelago." https://stephencornford.net/Archipelago.html (accessed Apr. 21, 2021).
[83] N. Bernier, "CEC — eContact! 19.2 — Editorial by Nicolas Bernier," *CEC | Canadian Electroacoustic Community*, 2017. https://econtact.ca/19_2/editorial.html (accessed May 10, 2021).
[84] N. Bernier, "Five Object-based Sound Compositions," University of Huddersfield, Huddersfield, 2013.
[85] N. Valdano, "Interview with the artist Nicolas Bernier — LABoral Centro de Arte y Creación Industrial," 2014. Accessed: May 10, 2021. [Online]. Available:

http://www.laboralcentrodearte.org/en/files/2013/bloglaboral/entrevista-al-artista-canadiense-nicolas-bernier/view
[86] N. Bernier, “CEC — eContact! 19.2 — Lumière, matière, science, fiction: Réflexions sur la relation son et lumière dans le cycle d’œuvres « frequencies » par Nicolas Bernier,” *CEC | Communauté électroacoustique canadienne*. https://econtact.ca/19_2/bernier_frequencies.html (accessed May 10, 2021).
[87] N. Bernier, *frequencies (a) | nicolas bernier*, (Aug. 29, 2012). Accessed: May 10, 2021. [Online Video]. Available: https://vimeo.com/48493242
[88] D. Marletta, “Ars Electronica Prix - Nicolas Bernier: between frequencies and dichotomies • Digicult | Digital Art, Design and Culture,” *Digicult | Digital Art, Design and Culture*, 2013. http://digicult.it/news/ars-electronica-prize-winners-nicolas-bernier-between-frequencies-and-dichotomies/ (accessed May 10, 2021).
[89] B. N. Walker and M. A. Nees, “Theory of Sonification,” in *The Sonification Handbook*, Berlin: Logos Vertag, 2011, pp. 9–39.
[90] P. Vickers, “Sonification and Music, Music and Sonification,” in *The Routledge Companion to Sounding Art*, London: Routledge, 2016, pp. 135–144.
[91] S. Barrass, “The aesthetic turn in sonification towards a social and cultural medium,” *AI Soc.*, vol. 27, no. 2, pp. 177–181, May 2012, doi: 10.1007/s00146-011-0335-5.
[92] T. Bovermann, J. Rohrhuber, and A. de Campo, “Laboratory Methods for Experimental Sonification,” in *The Sonification Handbook*, Berlin: Logos Vertag, pp. 237–272.
[93] G. Kramer *et al.*, “Sonification Report: Status of the Field and Research Agenda,” *Fac. Publ. Dep. Psychol.*, Mar. 2010, [Online]. Available: https://digitalcommons.unl.edu/psychfacpub/444
[94] A. Supper, *The Search for the “Killer Application”: Drawing the Boundaries around the Sonification of Scientific Data*. Oxford University Press, 2011. doi: 10.1093/oxfordhb/9780195388947.013.0064.
[95] T. Hermann, A. Hunt, and J. G. Neuhoff, “Introduction,” in *The Sonification Handbook*, Berlin: Logos Vertag, 2011, pp. 1–6.
[96] F. Grond and T. Hermann, “Aesthetic strategies in sonification,” *AI Soc.*, vol. 27, no. 2, pp. 213–222, May 2012, doi: 10.1007/s00146-011-0341-7.
[97] T. Hermann, “Taxonomy and Definitions for Sonification and Auditory Display,” presented at the ICAD 2008: The 14th International Conference on Auditory Display, Paris, 2008.
[98] T. Hermann, “definition | sonification.de,” *Sonification - A Definition*. https://sonification.de/son/definition/ (accessed Jun. 21, 2021).
[99] C. Scaletti, *Sonification ≠ Music*, vol. 1. Oxford University Press, 2018. doi: 10.1093/oxfordhb/9780190226992.013.9.
[100] L. Landy, *But Is It (Also) Music?* Routledge Handbooks Online, 2016. doi: 10.4324/9781315770567.ch1.
[101] M. Cobussen, “Introduction,” in *The Routledge companion to sounding art*, New York: Routledge, 2016.
[102] J. Edlund, “Musification and View,” *Musifier*. http://musifier.com/index.php/tech/musification-and-view (accessed Aug. 21, 2021).
[103] F. Grond and J. Berger, “Parameter Mapping Sonification,” in *The Sonification Handbook*, Logos Vertag, 2011, pp. 363–397.
[104] S. Gresham-Lancaster, “Relationships of sonification to music and sound art,” *AI Soc.*, vol. 27, no. 2, pp. 207–212, May 2012, doi: 10.1007/s00146-011-0337-3.
[105] A. D. Coop, “Sonification, Musification, and Synthesis of Absolute Program Music,” in *Proceedings of the 22nd International Conference on Auditory Display*, Canberra, Australia, Jul. 2016, pp. 177–183. doi: 10.21785/icad2016.030.
[106] G. Dubus and R. Bresin, “A Systematic Review of Mapping Strategies for the Sonification of Physical Quantities,” *PLoS ONE*, vol. 8, no. 12, p. e82491, Dec. 2013, doi: 10.1371/journal.pone.0082491.
[107] T. Tsuchiya, J. Freeman, and L. W. Lerner, “Data-to-Music: Real-time Data-agnostic Sonification with Musical Structure Models,” in *Proceedings of the 21st International Conference on Auditory Display*, Graz, 2015, pp. 244–251.
[108] J. G. Neuhoff, “Is Sonification Doomed to Fail?,” in *Proceedings of the 25th International Conference on Auditory Display (ICAD 2019)*, Newcastle upon Tyne, Jun. 2019, pp. 327–330. doi: 10.21785/icad2019.069.
[109] Y. Harris, “Presentness in Displaced Sound,” *Leonardo Music J.*, vol. 23, no. 1, pp. 13–14, 2013.
[110] N. Neumark, *Voicetracks: Attuning to Voice in Media and the Arts*. MIT Press, 2017.
[111] S. Connor, *The Matter of Air: Science and Art of the Ethereal*. London: Reaktion Books, Limited, 2010. Accessed: Jul. 05, 2021. [Online]. Available: http://ebookcentral.proquest.com/lib/vuw/detail.action?docID=692191
[112] J. G. Neuhoff, “Perception, Cognition and Action in Auditory Displays,” in *The Sonification Handbook*, Berlin: Logos Vertag, 2011, pp. 63–85.

[113] E. H. Margulis, *On repeat: how music plays the mind*. New York: Oxford University Press, 2014.
[114] V. Shklovsky, “Art as Technique,” in *Russina Formalist Criticism.*, L. T. Lemon and M. J. Reis, Eds. Lincoln: University of Nebraska Press, 1965, pp. 3–24.
[115] S. Graham, “The Sound of Data (a gentle introduction to sonification for historians),” *Program. Hist.*, Jun. 2016, Accessed: Jun. 23, 2021. [Online]. Available: https://programminghistorian.org/en/lessons/sonification
[116] C. Scaletti, "“Sound Synthesis Methods for Auditory Data Representation Auditory Display: Sonification, audification, and auditory interfaces, Gregory Kramer, ed., Santa Fe Institute Studies in the Science of Complexity, 1994.,” in *Auditory Display: Sonification, audification, and auditory interfaces*, G. Kramer, Ed. Santa Fe: Institute Studies in the Science of Complexity, 1994.
[117] G. Markowsky and School of Computing and Information Science, University of Maine, “The Sad History of Random Bits,” *J. Cyber Secur.*, vol. 3, no. 1, pp. 1–24, 2014, doi: 10.13052/jcsm2245-1439.311.
[118] D. J. Bennett, *Randomness*. Cambridge, Mass: Harvard University Press, 1998.
[119] P. L’Ecuyer, “History of uniform random number generation,” in *2017 Winter Simulation Conference (WSC)*, Las Vegas, NV, Dec. 2017, pp. 202–230. doi: 10.1109/WSC.2017.8247790.
[120] S. A. Terwijn, “The Mathematical Foundations of Randomness,” in *The Challenge of Chance: A Multidisciplinary Approach from Science and the Humanities*, 1st ed. 2016., K. Landsman and E. van Wolde, Eds. Cham: Springer International Publishing : Imprint: Springer, 2016, pp. 49–66. doi: 10.1007/978-3-319-26300-7.
[121] B. Hayes, “Computing Science: Randomness as a Resource,” *Am. Sci.*, vol. 89, no. 4, pp. 300–304, 2001.
[122] N. Montfort *et al.*, *10 PRINT CHR$(205.5+RND(1));: GOTO 10*. The MIT Press, MIT Press, 2012.
[123] A. Compagner, “Definitions of randomness,” *Am. J. Phys.*, vol. 59, pp. 700–705, Aug. 1991.
[124] M. G. Kendall and B. B. Smith, “Randomness and Random Sampling Numbers,” *J. R. Stat. Soc.*, vol. 101, no. 1, p. 147, 1938, doi: 10.2307/2980655.
[125] P. E. Ceruzzi, “Relay Calculators,” in *Computing Before Computers*, Ames, Iowa: Iowa State University Press, 1990, pp. 200–222.
[126] P. A. Laplante, Ed., *Comprehensive dictionary of electrical engineering*, 2nd ed. Boca Raton, FL: Taylor & Francis, 2005.
[127] P. E. Ceruzzi, “The Early Computers of Konrad Zuse, 1935 to 1945,” *IEEE Ann. Hist. Comput.*, vol. 3, no. 3, pp. 241–262, Jul. 1981, doi: 10.1109/MAHC.1981.10034.
[128] W. H. Ware, *RAND and the information evolution: a history in essays and vignettes*. Santa Monica, CA: Rand Corp, 2008.
[129] J. W. Tukey, “A Million Random Digits with 100,000 Normal Deviates by The Rand Corporation,” *J. Oper. Res. Soc. Am.*, vol. 3, no. 4, pp. 568–571, Nov. 1955.
[130] L. H. C. Tippett, *Random Sampling Numbers*. Cambridge, UK: Cambridge University Press, 1927.
[131] D. Chakrabarty and B. K. Sarmah, “Manual Method of Construction: Table of Random Two-Digit Numbers,” *Biom. Biostat. Int. J.*, vol. 5, no. 5, pp. 1–6, 2017.
[132] D. Chakrabarty, “Random Numbers Tables Due to Tippet, Fisher & Yates, Kendall & Smith and Rand Corporation: Comparison of Degree of Randomness by Run Test,” *J. Biostat. Biom. Appl.*, vol. 3, no. 1, pp. 103–108.
[133] F. Sandon, “1790. Random Sampling Numbers and the Schoolmaster,” *Math. Gaz.*, vol. 28, no. 282, pp. 216–218, Dec. 1944, doi: 10.2307/3609593.
[134] G. W. Brown, “History of RAND’s Random Digits - Summary,” Jun. 1949.
[135] “Monte Carlo method | mathematics | Britannica.” https://www.britannica.com/science/Monte-Carlo-method (accessed Apr. 11, 2022).
[136] H. Molderings, *Duchamp and the aesthetics of chance: art as experiment*. New York: Columbia University Press, 2010.
[137] J. Mac Low and A. Tardos, *Thing of Beauty: New and Selected Works*. Berkeley: University of California Press, 2008. Accessed: Nov. 20, 2020. [Online]. Available: http://ebookcentral.proquest.com/lib/vuw/detail.action?docID=2002084
[138] “An Account of Randomness in Literary Computing,” *@samplereality*, Jan. 08, 2013. https://www.samplereality.com/2013/01/08/an-account-of-randomness-in-literary-computing/ (accessed Sep. 22, 2020).
[139] A. Trenkamp, “The Concept of ‘Alea’ in Boulez’s ‘Constellation–Miroir,’” *Music Lett.*, vol. 57, no. 1, pp. 1–10, 1976, doi: 10.1093/ml/LVII.1.1.
[140] F. Leadon, “The Aleatoric Studio: Embracing Chance and Risk in First-Year Design,” *YOU STAND*, pp. 480–487.
[141] S. Luque, “The Stochastic Synthesis of Iannis Xenakis,” *Leonardo Music J.*, vol. 19, pp. 77–84, Dec. 2009, doi: 10.1162/lmj.2009.19.77.

[142] J. Pigott, "Across Fields: Sound, art and technology from an electromechanical perspective," *Organised Sound*, vol. 22, no. 2, pp. 276–285, Aug. 2017, doi: 10.1017/S1355771817000188.
[143] J. Cage, "Indeterminacy," in *Silence: Lectures and Writings*, Wesleyan University Press, 1961.
[144] J. Pritchett, *The Music of John Cage*. Cambridge, U.K. ; Cambridge University Press, 1993.
[145] M. P. Wright, "Zimoun," *EAR ROOM*, Jan. 01, 2011. https://earroom.wordpress.com/2011/01/01/zimoun/ (accessed Nov. 23, 2020).
[146] "LY Bi-power Relays," Dec. 2019. https://cdn.datasheetspdf.com/pdf-down/L/Y/2/LY2N-DC12_Omron.pdf (accessed Nov. 23, 2020).
[147] Rand Corporation, Ed., *A million random digits with 100,000 normal deviates*. Santa Monica, CA: Rand, 1955.
[148] N. K. Hayles, "Voices out of Bodies, Bodies out of Voices," in *Sound states: innovative poetics and acoustical technologies*, The University of North Carolina Press, 1997, pp. 74–96.
[149] H. Lefebvre, *Rhythmanalysis: Space Time and Everyday Life*, English Translation. London: Continuum, 2004.
[150] W. Ernst, *Chronopoetics: the temporal being and operativity of technological media*. London ; New York: Rowman & Littlefield International, 2016.
[151] R. Barthes, *The Responsibility of Forms: Critical Essays on Music, Art, and Representation*, English translation. New York: Hill and Wang, 1985.
[152] D. Lyon, *What is Rhythmanalysis?* Bloomsbury Academic, 2019. doi: 10.5040/9781350018310.
[153] G. Bachelard, *The Dialectics of Duration*, English translation. Manchester: Clinamen Press, 2000.
[154] J. Sterne, *The Audible Past: Cultural Origins of Sound Reproduction*. Durham: Duke University Press, 2003.
[155] J. Lacan, "Psychoanalysis and cybernetics, or on the nature of language," in *The Seminar of Jacques Lacan*, vol. 2, London ; New York: W.W. Norton & Company, 1988, pp. 294–308. Accessed: Dec. 02, 2020. [Online]. Available: https://static1.squarespace.com/static/5d52d51fc078720001362276/t/5e1a045351f223209a115b2a/1578763355724/19550622+Psychoanalysis+%26+Cybernetics+Jacques+Lacan.pdf
[156] M. Alhadeff-Jones, "Beyond space and time—Conceiving the rhythmic configurations of adult education through Lefebvre's rhythmanalysis," *Z. Für Weiterbildungsforschung*, vol. 42, no. 2, pp. 165–181, Aug. 2019, doi: 10.1007/s40955-019-0133-0.
[157] "Jeffrey Aronson: When I Use a Word . . . Anamnesis," *The BMJ*, Feb. 21, 2020. https://blogs.bmj.com/bmj/2020/02/21/jeffrey-aronson-when-i-use-a-word-anamnesis/ (accessed Dec. 15, 2020).
[158] H. Lefebvre, *Critique of Everyday Life*. London: Verso, 2014.
[159] "Timeline of social media," *Wikipedia*. Jun. 03, 2020. Accessed: Jun. 05, 2020. [Online]. Available: https://en.wikipedia.org/w/index.php?title=Timeline_of_social_media&oldid=960576229
[160] "Social media," *Wikipedia*. Jun. 04, 2020. Accessed: Jun. 05, 2020. [Online]. Available: https://en.wikipedia.org/w/index.php?title=Social_media&oldid=960732831
[161] L. Dahlberg, "Which Social Media? A Call for Contextualization," *Soc. Media Soc.*, vol. 1, no. 1, p. 205630511557814, Apr. 2015, doi: 10.1177/2056305115578142.
[162] R. Rymarczuk, "Same old story: On non-use and resistance to the telephone and social media," *Technol. Soc.*, vol. 45, pp. 40–47, May 2016, doi: 10.1016/j.techsoc.2016.02.003.
[163] J. A. Obar and S. Wildman, "Social media definition and the governance challenge: An introduction to the special issue," *Telecommun. Policy*, vol. 39, no. 9, pp. 745–750, Oct. 2015, doi: 10.1016/j.telpol.2015.07.014.
[164] Bollmer, Grant, *Inhuman Networks: Social media and the archaeology of connection*. New York: Bloomsbury Academic, 2016.
[165] Z. Papacharissi, "We Have Always Been Social," *Soc. Media Soc.*, vol. 1, no. 1, p. 205630511558118, Apr. 2015, doi: 10.1177/2056305115581185.
[166] Standish, Tom, *Writing on the Wall: Social Media - The First 2,000 Years*. New York: Bloomsbury, 2013.
[167] S. Ruzanka, "Sounder and Relay | Silvia Ruzanka." http://silviaruzanka.com/art/sounder-and-relay/ (accessed Sep. 07, 2020).
[168] D. Murthy, "Twitter: Microphone for the masses?," *Media Cult. Soc.*, vol. 33, no. 5, pp. 779–789, Jul. 2011, doi: 10.1177/0163443711404744.
[169] D. Murthy, "Contextualizing Twitter," in *Twitter: Social Communication in the Twitter Age*, Oxford: Polity, 2013.
[170] A. X. Mina, "An Xiao Studio: Morse Code Tweets." http://memestomovements.com/art/morsecodetweets.html (accessed Sep. 07, 2020).
[171] J. C. Tackett, "'I heard his silver call': Emily Dickinson and the Poetry of Telegraphic Acoustics," *Rev. Engl. Stud.*, vol. 71, no. 299, pp. 328–354, Apr. 2020, doi: 10.1093/res/hgz016.

[172] "Twihaiku? Micropoetry? The rise of Twitter poetry," *The Independent*, Jul. 16, 2013. http://www.independent.co.uk/arts-entertainment/books/features/twihaiku-micropoetry-the-rise-of-twitter-poetry-8711637.html (accessed Aug. 19, 2020).
[173] "Twitter4J - A Java library for the Twitter API." http://twitter4j.org/en/index.html (accessed Aug. 31, 2020).
[174] T. Smith, "WT8A Key Survey," *Morsum Magnificent. The Morse Magazine*, 2017 2006. http://www.n7cfo.com/tgph/Dwnlds/MM/MM.htm (accessed Sep. 21, 2021).
[175] F. E. D. Humy and L. W. Franklin, "Telegraph system," US2186895A, Jan. 09, 1940 Accessed: Sep. 21, 2021. [Online]. Available: https://patents.google.com/patent/US2186895/en
[176] "Recommendation M.1677-1 : International Morse code," *International Telecommunications Union*, 2009. https://www.itu.int/rec/R-REC-M.1677-1-200910-I/ (accessed Sep. 21, 2021).
[177] B. Winston, "Media Technology and Society - A History: From the Telegraph to the Internet," p. 389.
[178] D. M. Berry and M. Dieter, Eds., *Postdigital Aesthetics*. London: Palgrave Macmillan UK, 2015. doi: 10.1057/9781137437204.
[179] D. Kahn, "Earth Sound Earth Signal," p. 344.
[180] J. D. Hall, *Nineteenth-Century Verse and Technology*. Cham: Springer International Publishing, 2017. doi: 10.1007/978-3-319-53502-9.
[181] J. H. McCormack, "Domesticating Delphi: Emily Dickinson and the Electro-Magnetic Telegraph," *Am. Q.*, vol. 55, no. 4, pp. 569–601, 2003, doi: 10.1353/aq.2003.0035.
[182] "Cassandra Mohapp Rhythm in Morse.pdf."
[183] M. Wish, "A structural theory for the perception of Morse Code signals and related rhythmic patterns.," Center for Research on Language and Language Behavior, University of Michigan, Ann Arbor, Mich., 1967.
[184] L. Gitelman and G. B. Pingree, Eds., *New media, 1740-1915*. Cambridge, Mass: MIT Press, 2003.
[185] Q. Lin, "The Tyranny of Time," in *Brushing history against the grain: reading the Chinese new historical fiction (1986-1999)*, Hong Kong: University Press, 2005.
[186] C. Borck, "Blindness, Seeing, and Envisioning Prosthesis: The Optophone Between Science, Technology, and Art," in *Artists as Inventors Inventors as Artists*, Ostfildern, Germany: Hatje Cantz, 2008, pp. 109–129.
[187] C. Borck, "Sound Work and Visionary Prosthetics: Artistic Experiments in Raoul Hausmann," *Pap. Surrealism*, no. 4, pp. 18–21, 2005.
[188] E. E. Fournier d'Albe, *The Moon Element. An Introduction to the Wonders of Selenium*. New York: D. Appleton & Company, 1924.
[189] E. E. Fournier d'Albe, "The Type-Reading Optophone," *Nature*, vol. 94, no. 2340, p. 4, 1914.
[190] A. Neibisch, "Ether Machines: Raoul Hausmann's Optophonetic Media," in *Vibratory Modernism*, Basingstoke: Palgrave Macmillan, 2013, pp. 162–176.
[191] G. Lautenschlaeger, "Absences within and surrounding light-to-sound translations," *J. Sci. Technol. Arts*, pp. 3-13 Páginas, Sep. 2018, doi: 10.7559/CITARJ.V10I3.565.
[192] Unknown, "Making the Blind Hear Light," *Sci. Am. Suppl.*, p. 71, Aug. 1912.
[193] Unknown, "Hearing Print," *Sci. Am.*, p. 406, Nov. 1914.
[194] E. E. Fournier d'Albe, "On a Type-reading Optophone," pp. 373–375, 1914.
[195] A. Barr, W. Stroud, and E. E. Fournier d'Albe, "Optophone," US1350954A, Aug. 24, 1920 Accessed: Feb. 04, 2021. [Online]. Available: https://patents.google.com/patent/US1350954/en
[196] Unknown, "The Type-Reading Optophone," *Sci. Am. Mon.*, pp. 109–110, Oct. 1920.
[197] E. Cahen, "The Optophone," *Discovery*, vol. 2, no. 17, pp. 122–126, May 1921.
[198] M. Jameson, "The Optophone: Its Beginning and Development," presented at the Sixth Technical Conference on Reading Machines for the Blind, Washington, D.C., Jan. 1966.
[199] K. Beals, *Wireless Dada: Telegraphic Poetics in the Avant Garde*. Chicago: Northwest University Press, 2019.
[200] R. Greene, S. Cushman, C. Cavanagh, J. Ramazani, and P. Rouzer, *The Princeton Encyclopedia of Poetry and Poetics: Fourth Edition*. Princeton, UNITED STATES: Princeton University Press, 2012.
[201] "Futurism - Literature," *Encyclopedia Britannica*. https://www.britannica.com/art/Futurism (accessed Jul. 22, 2021).
[202] A. L. Latham, "Bruitism," in *The Oxford Companion to Music*, A. Latham, Ed. Oxford University Press, 2011. Accessed: Jul. 19, 2021. [Online]. Available: https://www.oxfordreference.com/view/10.1093/acref/9780199579037.001.0001/acref-9780199579037-e-998
[203] L. Russolo, "The Art of Noises: A Futurist Manifesto (1913)," in *Futurism*, L. Rainey, C. Poggi, and L. Wittman, Eds. Yale University Press, 2009, pp. 133–139. Accessed: Jul. 19, 2021. [Online]. Available: https://www.jstor.org/stable/j.ctt1nq4q3.22

[204] R. Huelsenbeck, *En Avant Dada: A History of Dadaism*, Trans. Ralph Manheim. Zurich: Verlag, 1920.
[205] M. Biro, *The Dada cyborg: visions of the new human in Weimar Berlin*. Minneapolis: University of Minnesota Press, 2009.
[206] A. Niebisch, *Media Parasites in the Early Avant-Garde*. New York: Palgrave Macmillan US, 2012. doi: 10.1057/9781137276865.
[207] A. Kramer, “Speaking Dada: The Politics of Language,” in *Dada and Beyond. Volume 1: Dada Discourses*, vol. 1, Amsterdam - New York: Rodopi, pp. 201–213.
[208] M. Biro, “Raoul Hausmann’s Revolutionary Media: Dada Performance, Photomontage and the Cyborg,” *Art Hist.*, vol. 30, no. 1, pp. 26–56, Apr. 2007, doi: 10.1111/j.1467-8365.2007.00531.x.
[209] G. Marcus, *Lipstick Traces. A Secret History of the Twentieth Century*, 3rd ed. London: Faber and Faber, 2011.
[210] J. Baillehache, “Chance Operations and Randomizers in Avant-garde and Electronic Poetry: Tying Media to Language,” *Textual Cult.*, vol. 8, no. 1, pp. 38–56, Mar. 2014, doi: 10.14434/TCv8i1.5049.
[211] A. Neibisch, “Dada Engineering,” *Modernism/modernity*, vol. 21, no. 1, pp. 169–177, 2014.
[212] B. Schneider, “On Hearing eyes and Seeing Ears: A Media Aesthetics of Relationships between Sound and Image,” in *Audiovisuology, a Reader.*, vol. 2, Koln: Verlag Walther Konig, 2015, pp. 608–633.
[213] J.-F. Bory, *Prolégomènes À Une Monographie De Raoul Hausmann*. Paris: L’Herne, 1972.
[214] M. Lista, “Raoul Husmann’s Optophone: ‘Universal Language’ and the Intermedia,” in *The Dada seminars*, Washington, DC: Center for Advanced Study in the Visual Arts, National Gallery of Art, in association with DAP/Distributed Art Publishers, 2005.
[215] M. Mills, “Optophones and Musical Print,” *Sounding Out!*, Jan. 05, 2015. https://soundstudiesblog.com/2015/01/05/optophones-and-musical-print/ (accessed Feb. 02, 2021).
[216] G. C. Smith and H. A. Mauch, “The Development of a Reading Machine for the Blind,” *Bull. Prosthet. Res.*, p. 31, 1968.
[217] R. M. Fish, “An Audio Display for the Blind,” *IEEE Trans. Biomed. Eng.*, vol. BME-23, no. 2, pp. 144–154, Mar. 1976, doi: 10.1109/TBME.1976.324576.
[218] M. Capp and P. Picton, “The optophone: an electronic blind aid,” *Eng. Sci. Educ. J.*, vol. 9, no. 3, pp. 137–143, Jun. 2000, doi: 10.1049/esej:20000306.
[219] J. Gage, “Signs of Disharmony: Newton’s Opticks and the Artists,” *Perspect. Sci.*, vol. 16, no. 4, pp. 360–377, 2008.
[220] D. Loughridge and T. Patteson, “Ocular Harpsichord :: Museum of Imaginary Musical Instruments,” *Museum of Imaginary Musical Instruments*, 2013. http://imaginaryinstruments.org/ocular-harpsichord/ (accessed May 23, 2021).
[221] B. Elder, *Harmony + dissent: film and avant-garde art movements in the early twentieth century*. Waterloo, Canada: Wilfrid Laurier University Press, 2010.
[222] J. Beck and T. Grajeda, *Lowering the Boom: Critical Studies in Film Sound*. University of Illinois Press, 2008.
[223] K. Schöning and M. E. Cory, “The Contours of Acoustic Art,” *Theatre J.*, vol. 43, no. 3, pp. 307–324, 1991, doi: 10.2307/3207586.
[224] J.-Y. Bosseur, “Mesostics,” *memento*, Aug. 22, 2016. http://www.diptyqueparis-memento.com/en/mesostics-2/ (accessed May 24, 2021).
[225] “The Lab Imaginary: Speculative Practices In Situ | transmediale.” https://archive.transmediale.de/content/the-lab-imaginary-speculative-practices-in-situ (accessed Jul. 22, 2021).
[226] T. Chan, M. Mills, and J. Sayers, “Optophonic Reading, Prototyping Optophones,” *Amodern*, Jan. 2018. https://amodern.net/article/optophonic-reading/ (accessed May 24, 2021).
[227] “Remaking Optophones: An Exercise in Maintenance Studies.” http://www.digitalrhetoriccollaborative.org/2016/03/14/remaking-optophones-an-exercise-in-maintenance-studies/ (accessed Jan. 12, 2021).
[228] P. Keene, “Optophones,” 2004 1999. http://www.peter-keene.com/Optophones-us.html (accessed May 24, 2021).
[229] J. Peradel, “Magic Frame: Turn Everything into a Touch Area.” https://hackaday.io/project/27155-magic-frame-turn-everything-into-a-touch-area (accessed Jul. 19, 2021).
[230] S. Connor, *Dumbstruck: a cultural history of ventriloquism*. Oxford ; New York: Oxford University Press, 2000.
[231] J. Baron, “Ventriloquizing Obama, or, the Ethics of Archival Ventriloquism,” in *Media Ventriloquism*, Oxford University Press, 2021, pp. 199–214. doi: 10.1093/oso/9780197563625.003.0011.
[232] S. Natale and G. Balbi, “Media and the Imaginary in History: The role of the fantastic in different stages of media change,” *Media Hist.*, vol. 20, no. 2, pp. 203–218, 2014, doi: 10.1080/13688804.2014.898904.

[233] E. Kluitenberg, “On the Archaeology of Imaginary Media,” in *Media archaeology. Approaches, Applications and Implicatiuons*, Berkeley: University of California Press, 2011, pp. 48–69.
[234] D. Daniels, “Artists as Inventors and Invention as Art: A Paradigm Shift from 1840 to 1900,” in *Artists as Inventors, Inventors as Artists*, Ostfildern, Germany: Hatje Cantz, 2008, pp. 18–53.
[235] D. Jones, *Dada 1916 in Theory: Practices of Critical Resistance*. Liverpool University Press, 2014. doi: 10.5949/liverpool/9781781380208.001.0001.
[236] J. J. McGann and L. Samuels, “Deformance and Interpretation,” in *Radiant textuality: literature after the World Wide Web*, New York: Palgrave, 2001, pp. 105–135.
[237] F. Dombois and G. Eckel, “Audification,” in *The Sonification Handbook*, T. Hermann, A. Hunt, and J. G. Neuhoff, Eds. Berlin: Logos Vertag, 2011, pp. 301–324.
[238] D. Worrall, “An Introduction to Data Sonification,” in *The Oxford Handbook of Computer Music*, R. T. Dean, Ed. Oxford University Press, 2011, pp. 1–23. doi: 10.1093/oxfordhb/9780199792030.013.0016.