Computer-Assisted Algorithmic Compositional Approaches:
The Role of AI in Music Creative Practices

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Abstract

Algorithm had rich precedents in music, and composers' relationships with algorithms have been witnessed since ancient times. With the advent of computers, music was forced to go beyond the boundaries of the traditional musical languages. The mid-1950s was a transitional period between traditional and innovative modes of thoughts in compositional practices. Music technology stimulated the growth of music while altering musical forms. During the second half of the 20th century, the positive results from the musical experiments have demonstrated the flexibility and generality of computer-assisted compositional methods. This study offers a deep view of a wide range of approaches for algorithmic compositions. In the modern landscape of algorithmic music, the various approaches of algorithmic composition have opened new directions in music, including the stochastic method, rule-structured technique and Artificial Intelligence (AI) -based systems. The computer, as an assistant of the human composer, was designed to execute rules, learn rules and create rules.

This study focuses on the musical evolution from the topics of musical patterns, algorithms, AI, computational creativity to collaborative intelligence, by examining composer's perspectives on what compositional technique they approach, and how they approach it. A number of musical works have demonstrated the power of human-AI interaction. Composers are seeking sophisticated, advanced and intelligent approaches to extend the potential of computer-assisted music. The implemented algorithm can represent composers' creative processes, and algorithmic composition is considered as a mode of creativity. From the current millennium, there is a growing trend for composers to embrace state-of-art technologies and to infuse AI languages into music creative practices to complement their musical minds.

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List of Abbreviations

AI	Artificial Intelligence
AIVA	Artificial Intelligence Virtual Artist
EMI	Experiments in Music Intelligence
MAGE	Music Algorithm Generation Engine
MIDI	Musical Instrument Digital Interface

Chapter 1. Introduction

1.1 Overview

Algorithmic composition is an automation of the process of composing music using algorithms (Maurer 1999). With the evolution of computational techniques, new methods of music production were extensively explored and music was produced experimentally through the aid of digital tools. An algorithmic approach to music goes back many centuries. From early examples throughout the history, basic algorithmic solutions were employed in the algorithmic-like processes. Dannenberg hints that the concepts of algorithms existed long before the advent of digital computing and programming languages (Dannenberg 2000, p.1). W. A. Mozart's *Musical Dice Game* (1792) is one of the earliest examples of algorithmic compositions. Trace back to the late eighteen century, the game was implemented in a re-combinatorial process, as such the method involves the combination of pre-composed phrases. The procedures of Mozart's music-generating techniques indicates the significance of early algorithmic composition. In the late 20th century, with the extensive use of computers, algorithms were applied on composing programs and compositionally-related tools. The concept of computer-assisted composition refers to the music production process when composers employ a series of rules. These rules are known as algorithms, with the term being used among composers, engineers and scientists (Cope 2000, p.3). In the field of computer music, the notion of algorithm becomes conceptual. Algorithm, as a distinctive, musical grammar, is used for the production of musical structures. Algorithms in music are utilized in various ways, such as sound synthesis, sampling and composing. With the development of theoretical and applied technologies, many composers and programmers explored the greatest possibility from music to mathematics, and far beyond. Music, math and patterns are closely linked to explain the rationale and logic behind the practices.

Roads points out that 1968 marks the beginning of modern research into artificial intelligence and music (Roads 1980, p.15). Forte argues that, the questions in music analysis would gradually become questions in the field of AI (Forte 1967). By using state-of-art algorithms, computers behave intelligently and creatively. As many higher level concepts emerged, such as interactive sound, artificial creativity and musical intelligence, they are far more complex than the classic algorithms and mathematical frameworks. However, since the onset of the digital transformation and revolution, some major critics had arisen. The emergence of AI has been a challenge in the music industry. Some believe the virtues of technology are over praised, and that AI is killing creativity. It was argued that at the terminus of technology, people will eventually go back to pen and paper. In terms of audience reception in algorithmic culture, it has been postulated that the initial purpose of composing music using computers is not aesthetically pleasing to its audience.

Although many concerns have not been addressed yet, the volume of AI-related discussions are growing. As Cope argues, algorithmic procedures already exist in the creative process, the computer is just a tool (Cope 2000, p.2). Caianiello suggests that the computer is an extension of creativity, and the difference of human and machine intelligence should be obscured (Caianiello 1984, p.30). As Roads points out, in every situation where the idea of musical intelligence is proposed, new possibilities and further directions become clear (Roads 1980, p.23). The discussion on the technological change and the role of computer music continues to expand, and provides a different understanding of human musical cognition and machine intelligence.

1.2 Goals and Motivation

The process of composing algorithmic composition involves the use of formal procedures. This study attempts to interpret what are the "formal procedures" and how do "algorithms or rules" work within a creative setting. The purpose of the study is to excavate algorithmic techniques from pre-computer age to post-digital age, and to explore how different algorithmic approaches are shaped by social discourse. This paper addresses the questions on how algorithms and technologies subvert the conventional means of how music is produced. The study then recognises the need to gather subjective reviews and critical reflections from experienced individuals, in order to receive a variety of responses of different musical approaches. In order to respond to the need, the study aims to gain insights into composers' point of views of computer-assisted composition and how much of the piece is effected by this. With the method of qualitative research, the aim can be achieved through contributions from expert composers. With the development of artificial intelligence, many composers implemented AI techniques to their music creative processes. The motivation of the research is to provide a broad understanding on algorithmic compositional practices and the application of AI techniques to computer music. The ultimate goals of the study is to understand the role of AI in contemporary music as well as the influence of AI techniques to modern human composers. Other aspects of AI techniques are the possible results of human-AI interaction and collaborative intelligence. The intersection of music, computational technology and AI is becoming a compelling area to explore. The study aims to combine multidisciplinary research (mainly focus on art, computer science, mathematics and music) and comprehensive investigations of music professions to provide a broad understanding on the relationship of algorithms, artificial intelligence and human.

1.3 Outline

This paper contains five chapters including an introduction, the background, methodology, findings and reflection, and a conclusion. Chapter 1 is the introduction to the paper, creates an overview of algorithmic composition from the pre-computer age to the digital age, and introduces research aims as well as the structure of the paper. Chapter 2 provides a historical viewpoint on the development of algorithmic practices in music, drawing from a selection of literature and sources. Further, chapter 3 examines the process of conducting the research and the implementation of the questionnaire. Chapter 4 presents the analysis and interpretation of the findings, accompanied by musical examples. Chapter 5 unites previously discussed findings and algorithmic compositional approaches, concludes the paper, and provides an outlook toward future research.

Chapter 2. Background: The Evolution of AI

2.1. Introduction

Drawing from a selection of literature and sources, this chapter offers a historical viewpoint on the development of algorithmic practice in music. The chapter is organised into five sections. The first section gives a brief introduction of the chapter, and the second section discusses the origin of algorithmically derived composition. The third section covers the topics from the background of computers to music technology, and the fourth section shows a modern landscape of algorithmic music, as well as the current trends and future possibilities of AI in music practices. The last section concludes the history of algorithmic composition in a nutshell.

2.2. Origins of Algorithmic Thinking

Algorithm, can be found across cultures in ancient era as early as 1200 BC, in Babylonian times. The term algorithm is derived from the older forms of Greek word “arithmos” and Arabic word “algorism”, which literally means a series of numbers (Cope 2000, p.2). It originates from a mathematical book called *Rules of Restoration and Reduction* in the ninth century. The word’s original meaning is linked to an algebraic system. In the late twelfth century, the rules of Hindu-Arabic numerals and the variants of algorism were translated into Latin, and the word began to spread into Europe. The form and meaning of the word algorithm evolved over millennia of time. The modern meaning of algorithm wasn't introduced until nineteenth century. The ancient definition of algorithm and its subsequent derivations represent a remarkable modernity in terms of the mathematical logic (Boyer 1951).

In the field of music, some aspects of music have long been involved with algorithmic segments. Algorithm had rich precedents in music, and musicians’ relationships with algorithms have been witnessed in the history of music. The origin of algorithmic thinking in music dated back to the beginning of the fifth century BC. Around 500 BC, Greek philosopher and mathematician Pythagoras found music has mathematical foundations, and the mathematical characters exist in basic musical concords (Riedweg 2008, p.2). He convinced that music is convertible into numbers by any forms, based on the discovery that the intervals in music originate with numbers. An octave (1:1), perfect fifth (3:2) and fourth (4:3) all have integer ratios (Crocker 1963, p.197). Pythagoras revealed the nature of music, without inventing sophisticated mathematics. While the “simplest mathematics” in musical intervals later expressed as arithmetic ratios. This numerical interpretation could be demonstrated on monochord, an ancient single-string instrument invented by Pythagoras.

The instrument consists of a string, a moveable bridge and a sound box. It explains how the natural interval relationship is linked with the length of the string vibrating and the pitch produced (Riedweg 2008, p.27). Monochord has become an early evidence of the evolving awareness on Pythagorean musicology. The ancient scientific method of measuring intervals and pitches was developing and evolving over the centuries. Monochord had been revived and used as an illustrating tool throughout the Middle Ages. In the nineteenth century, several modern divisions of the monochord had been proposed based on the old mechanism. As a progenitor of mathematics and music, Pythagoras's legendary discovery of the numerical relationship in music had a major impact on the modern shape of algorithmic composed music.

In the eighteenth century, *Musikalisches Würfelspiel (Musical Dice Game)* was an attempt of an algorithmically derived composition in the Classical Period. However, the notion of algorithm was not yet defined at that time. Since the dawn of music, musicians have been employing methods which are often considered as algorithmic in some sense. Algorithm was used as a broad term and Mozart's Musical Dice Game is one of the most often cited examples (Dawin 2010, p.2). The rule of the game is to use a dice to produce musically randomly in a re-combinatorial process, whereby the pre-composed phrases are combined at random. The process is based on a Markov (or Markoff) chain model, which is a mathematical system experiences transitions within two states (Dawin 2010, p.4). The result of composing and re-composing tends to be an infinity as long as the dice remains rolling. The probability of transitioning is a stochastic process. The principle of Markov chain is memorylessness, which means the transition probability depends solely on the current state (Srivastava 2014). The memory-less property enables the model to be analysed mathematically. The Markov chain is named after mathematician Andrey Markov and developed in the nineteenth century. Today the framework and its applications are widely used in algorithmic composition and machine learning intelligence, while in Mozart's era the blueprint of algorithmic composition practice remained unveiled over centuries. The method implemented in the musical dice game was a precedent on later explorations, although the specific terms were not defined at that time.

Besides Pythagoras and Mozart, Johann Sebastian Bach's approach to canonic composition is another precedent on algorithmic procedures for music generation. Bach embodies the genres of canon and fugue. Canon is a contrapuntal technique, it refers to the rule of continuous imitation among a composition (Collins 1995, p.93). The early definition of canon indicates the genre of the puzzle canon. In a composition the initial melody is devised first, then it transposed to the remaining parts of the piece. The time intervals in-between must be guessed enigmatically. In the puzzle canon, the entire composition is constructed in this way. Many of Bach's canons were composed in this style, they are considered as parts of a long tradition of contrapuntal approaches in the Baroque era (Collins 1999, p.27). During the performance, musicians interpret the original score and solve the musical riddles in canonic variations. The composition *The Musical Offering* (1747) is one of Bach's remarkable contributions in a fugal form. Another notable work is *The Art of Fugue* (1740), an unfinished piece written in the eighteenth century. Bach coded his name (B-flat, A, C, and H) and embedded in the music as a hidden motif (Simoni 2003). *The Art of Fugue* represents the apotheosis of musical procedures on the imitative counterpoint. During the course of a composition, the transposition and modulation processes are indispensable parts of algorithmic practices. For Bach and the other early eighteenth-century classical music composers, the rules applied to the canonic melodies are indeed the algorithm.

In the early 20th century, modern music reaches a turning point. According to Ashby, "music composition in analogy to science, has evolved to a process of problem solving" (Ashby 2001, p.585). The idea of scientific models and compositional techniques have offered solutions to the musical problems. Arnold Schoenberg was one of the advocates. In 1921, Schoenberg composed the first piece using twelve pitch classes. Later in 1923, he refined the method and devised a twelve-tone system, a compositional technique of serializing musical elements, such as pitches, rhythms, and dynamics. The regular use of notes, tones and series became influential on atonal music and serial music (Kostka 2016, p.198). Schoenberg's serialism is a method to integrate musical parameters into a particular series. It is a significant modern experiment of composing and it is connected with the basics of algorithmic composition. The twelve-tone method was exclusively used for many decades. One of Schoenberg's students Scott Bradley, an American composer, applied the twelve-tone technique for scoring animations and films. During the 1950s, Bradley practiced the technique in the musical scores of the classical Hollywood cartoon, *Tom and Jerry* (1940-1958) (Goldmark 2007, p.70). One example was in a scene from "Puttin' on the Dog" (1953), Bradley used twelve-tone scale for a disguised dog. The twelve-tone method was a prelude of aesthetic and intellectual transitions to modern music. The introduction of twelve-tone serialism has brought the musical composition into the discourse of intellectual history (Ashby 2001, p.586).

2.3. From Computers to Music Technology

In the history of music, the connection between music and mathematics predates musical computer science (Collins 2018, p.1). By the mid-20th century, with the development of technology and the advent of computers, music was forced to go beyond the boundaries of the traditional musical languages (Milstein 1992, p.62). Around the time of World War II, the decade was a transitional period between traditional and innovative modes in music. In 1948, “musique concrete”, literally means concrete music, was developed by French composer Pierre Schaeffer (Manning 2004, p.19). Musique concréte was an early form of electronic music. In the early 1950s, with the establishment of music studios in Cologne, the concept of “elektronische musik”, literally means electronic music, was created by German composer Herbert Eimert. Despite the debatable relationship between musique concréte and elektronische musik (Manning 2004, p.68), the concrete and synthetic techniques were combined by many avant-garde composers. They mixed instruments, voices, electronic sounds, and non-musical elements into their compositions (Maurer 1999).

The avant-garde, a term originated from French, referring to a group of vanguards or the practice of experimental treatments in terms of social reforms. The praxis of avant-garde challenged the traditional forms of literature, science as well as musical arts. The avant-gardists in music refer to tradition-breakers who practice new compositional strategies. During the post-World War II period, many radical compositions were produced, and music was heavily shaped by a variety of rules (Jakubowska 2011). Among a group of pioneers, American composer Henry Cowell and his pupil John Cage were profoundly influential in the mid-20th century. Henry Cowell is one of the earliest composers intended to explicitly explain the musical materials (Cowell and Godwin 1969, p.xvi). As a prolific composer, he composed over seven hundred musical works as well as many academic publications (Sitsky 2002, p.115). By the late-1910s, Henry Cowell wrote his first avant-garde piano piece, *The Tides of Manaunaun* (1917). Around that time, he became acquainted with many experimental musicians and modernists, including Arnold Schoenberg, who devised the twelve-tone method (Sitsky 2002, p.112). Cowell’s thoughts on radical compositional approaches were explained in his later published book *New Musical Resources* in 1930. He created a repertoire of his unconventional innovations and established a relation between the “theory of musical relativity” and his music (Cowell and Nicholls 1996, p.xi). By the end of 1931, Cowell designed the first electronic drum machine, “Rhythmicon”, with scientist Leon Theremin (Sitsky 2002, p.114). He composed several original compositions for the instrument, including *Ryhthmicana* (1931). *Ryhthmicana* was the first musical work in record that exploiting the fundamentals of the modern electronic technology (Smith 1973, p.145). Cowell was also known for his early efforts on the approach of indeterminacy, and the idea was further developed by John Cage. John Cage was another avant-garde composer of post-war avant-garde. His music was especially influenced by Henry Cowell’s avant-garde piano repertoire. *4’33’’* (1952) is an often cited example of avant-garde music. It is a silent piece consists of three movements, and it was premiered in 1952, with the title refering to the length of the performance, which is four minutes and thirty-three seconds. 4’33’’ is the epitome of Cage’s rejection of tradition (Sitsky 2002, p.xiii). Cage challenged conventional music by applying an inventive, unprecedented and contentious method. He believed that silence is an organized sound, and his musical work embraced silence as a musical gesture (Sitsky 2002, p.6). In 1951, Cage composed a solo piano piece, *Music of Changes* (1951) using I Ching charts. I Ching is ancient Chinese text used for divination. Cage used it as a tool and approached composing music by similarly using chance elements. Music of Changes is the first instrumental work that involves chance and mechanical procedure, and it is a remarkable piece using indeterminate compositional technique (Sitsky 2002, p.94). As a leading figure of the progressive avant-garde movement, John Cage redefined the limit of music understanding in a cultural context. However, the avant-garde music was deprecated as aggressively unattractive by some critics. Indeed, the mid-1950s was a transitional period between the old and new music forms. Composers invented various “calculating tools” to organise sound, from rule-based instrumental piece (The Tides of Manaunaun), the musical imitation on the silence of nature (4’33’’) to the change-controlled music (Music of Changes), creating radical compositional techniques and challenging musical tradition (Sitsky 2002, p.95). Furthermore, the development of technology has opened a new field of composing. The avant-gardists’ musical ideas and approaches are now place within a broader context of musical modernism (Cowell and Nicholls 1996, p.113).

As Manning asserts, the development of music in any period is subject to the technological progress which it parallels (Manning 2004, p.8). From both a technical and musical point of view, music technology stimulates the growth of music while altering musical forms. A major breakthrough of computer music occurred in the 1950s. Lejaren Hiller is an American composer and professor. He is a leading figure of experimental music and has created a number of pioneering works during the 20th century. In 1952, as ILLIAC I, the first series of supercomputers ILLIAC became operational, Hiller decided to compose a musical score with the assistance of a machine. In 1956, he composed a piece “Illiac Suite” in collaboration with Leonard Issacson using the computer ILLIAC I. Illiac Suite is the earliest composition generated with the aid of a computer (Higgins and Kahn 2012, p.150). In 1958, Hiller founded Experimental Music Studios, the first canonical electronic studio in America. In the late 1960s, HPSCHD was a subsequent work he created with John Cage. HPSCHD consisted of harpsichord solo and electronic sounds, it was a pioneering and ambitious piece built using computers. HPSCHD’s premiere performance, occured on May 1969, and brought computer-assisted composition into the public sphere for the first time (Manning 2004, p.201). Another computer program developed in the 1960s was MUSICOMP, one of the first computer systems for automated composition. It was created by Lejaren Hiller and Robert Baker, and it took many years to programme (Hiller and Baker 1964, p.62). Computer Cantata (1963) was a composition by MUSICOMP, it was comprised of electronic sounds, natural sounds and human voice (Higgins and Kahn 2012, p.149). The original purpose of creating Computer Cantata was to test the experimental logic and the potential combination of concrete and synthetic sounds. Hiller's compositions were dependent on digital methods, many of them were created in rule-based computational systems. During the following decade, Hiller, Cage and other composers continued to explore various techniques and styles, and many musical works were created. The compositions were based on a set of rules and procedures, following electronic and mechanical approaches. The digital revolution in music during the 20th century was considerably inspired by the invention of the computer. It has brought musicians and technology together into a field of computer music composition. During the second half of the 20th century, the positive results from the musical experiments demonstrated the flexibility and generality of computer-assisted compositional methods, and provided a possibility for the further development on a more sophisticated, advanced musical logic: algorithmic composition (Hiller and Baker 1964, p.62).

2.4. The Modern Landscape of Algorithmic Music and AI

2.4.1. The Stochastic Method

From the early efforts on formalism to algorithmic music, composers imposed maximal complexity in terms of the development of more advanced machine models. According to Schwanauer and Levitt, computer-assisted algorithmic composition is based on three approaches: random generation of note attributes, concise and powerful grammars, and intelligent mathematical models (Schwanauer and Levitt 1993, p385). The stochastics method, the rule-structured technique and the artificial intelligence system are current approaches to algorithmically generated music.

By the late-20th century, the well-defined compositional models were established with programming generative algorithms. Iannis Xenakis was a post-World War II algorithmic composer, he is known for his stochastic compositions during the 1960s. In his ground-breaking book *Formalized Music (1963)*, he asserts stochastics is the foundation for composing (Manning 2004, p.87). Stochastics is a term derived from mathematics. Xenakis furthered the basics of stochastics and applied this to his composing process. The computer was used as a tool to deduce a piece from data's structure using probability weightings. The creative decisions were determined by chance and the probabilistic factors. The concept of randomness has existed since early times, it can be found in Mozart's

Musical Dice Game and John Cage's chance-oriented music whereby his I Ching charts also implied the idea of random variables. By the late 1960s, Xenakis employed the stochastic method in both instrumental and electronic compositions. The stochastic approach was considered as one of the applications in algorithmic compositional environments. In terms of the relationship between human and machine, Xenakis believes the output of the machine is a set of computational materials which aids in composing music. In contrast, Lejaren Hiller, a composer who approaches a rule-based technique to his compositions, instead integrates the human contribution and computer generation process together (Maurer 1999). However Xenakis continued to explore the possibility of mathematical models as an integral part of the composing process itself. In 1966, Xenakis founded EMAMu, an institute of interdisciplinary research for music and other forms of arts (Manning 2004, p.87).

2.4.2. The Rule-Structured Technique

Another approach to algorithmic composition is a rule-structured technique. Early efforts on the use of rules include Bach's canon and fugue, Arnold Schoenberg's twelve-tone system and serialism. Lejaren Hiller is an example of modern composers who developing complex rule systems. As opposed to the stochastic method, the composing process in a rule-based system is not chance-oriented (Nierhaus 2009, p.239). The data is constructed in a formal, pre-decided procedure, and the musical grammar guides the structure of the composition. The specific musical patterns are unified as database or subroutines with the composer programming the rule into a computer system, such as Hiller's MUSICOMP. Another example is CHORAL, a system created by Kemal Ebcioglu. CHORAL used BSL (Backtracking Specification Language), a logical programming language to harmonize chorales of Bach's style (Schwanauer and Levitt 1993, p385). During the compositional process, Ebcioglu developed a rule-based method and divided the chorale into manageable units.

By formalizing and geometrizing the music, the different methods (stochastics and rule-structured) applied to the mentioned examples have broadened the conception of computer-assisted algorithmic composition (Xenakis 1963, p.ix). Inspired by the algorithmic methodology and rule structures, some algorithmic composers started to explore further possibilities of musical intelligence from a different perspective. They aimed to combine AI methods with musical applications. Applying AI to algorithmic composition is a unique method in music production and during the mid-20th century, electronic and computer music composers were seeking for a human-like response from the computer systems (Maurer 1999). The development of the intelligent, responsive system often associated with the applications of artificial intelligence in music production process. In 1957, Hiller and Issacson's composed Illiac Suite, the first composition using AI method. In 1960, Russian researcher Zaripov published the first paper about AI-assisted music (Zaripov 1960, p.479). In the late 1960s and early 1970s, many programs were developed using formal grammars augmented by heuristic techniques. At the beginning of the decade, the emergence of AI-related music theory was significantly notable. The theoretical foundations of artificial intelligence languages were established by that time period. In 1967, American musicologist Allen Forte concluded that musical analytical questions would become questions of AI (Schwanauer and Levitt 1993, p.3). The year 1968 marks the formal intersection of music and artificial intelligence. Shortly after Forte, two important papers were published that year. The first scholarly paper "Pattern in Music", was written by Herbert Simon and Richard Sumner (Roads 1980, p.15). They suggested that music composition is the process of pattern processing. Simon and Sumner's study draws a direct parallel of pattern induction and sequence extrapolation of the intelligence test (Rowe 2001, p.169). The second paper published in 1968 was Terry Winograd's "Linguistics and the Computer Analysis of Tonal Harmony". Winograd's theory was based on the model of systemic grammar. He implemented the method into a harmony-analysis system (Roads 1980, p.16). In both models, they established a paradigm for proposing musical formalism. Computers are designed to identify and learn musical patterns, they are well-equipped to be involved in the musical discourse (Rowe 2001, p.169).

2.4.3. AI-based systems

The fundamental of the stochastic and ruled-based techniques is similar to the third method, artificial intelligence. However in AI systems, computers have a greater capacity to create their own musical formulas (Maurer 1999). The intelligent systems are often associated with the process of machine learning. For both researchers and composers, the learning computer opened a new possibility in music creative process. David Cope is one of the practitioners of applying AI techniques to music. He is a leading figure on the advancement of artificially composed music. Begin in the early 1980s, Cope has been developing his expert system EMI (Experiments in Music Intelligence). Cope defined the function of an expert system is to incorporate artificial intelligent techniques to emulate a human expert (Cope 1987, p.30). EMI is a collection of computer programs for the simulation of musical styles (Cope 1999, p.79). It composes music by analysing the musical patterns through database and re-composing phrases in that style. Based on a pattern-matching process, EMI is programmed to re-assemble each component to a new piece (Cope 1999, p.79). Cope introduced the concept of recombinancy, and he believes it exists within every creative process (Cope 2018). He implemented the recombinancy technique using the association network. The association network is a database where the musical information is analysed and recombined, and a new composition is formed automatically using the given subroutines. In the following decade, Cope explained EMI's methodology in his 1991 published book *Computers and Musical Style (1991)* and its sequel *Experiments in Musical Intelligence (1996).* From 1981 to 2003, EMI's career produced a considerable amount of classical music compositions within two decades. Cope programmed augmented transition networks to produce music in the style of Bach, Chopin, Beethoven, Brahms, Stravinsky, Gershwin, Mahler, and many more. In the context of artificial intelligence, EMI is based on the framework of a musical Turing test (Nierhaus 2009, p.122). Some listeners couldn't distinguish EMI generated music from the authentic human-produced classical music. For example, EMI's simulated style of Bach is virtually identical with Bach's original works (Nierhaus 2009, p.124). In 2003, Cope began developing a new system "Emily Howell". As a result, the early 21st century marks the end of EMI's era. "From Darkness, Light" was Emily's first album released in 2009, including three preludes and fugues. Unlike EMI, Emily's music doesn't remain particular styles, it has the ability to generate new styles. Emily creates a computer model of musical creativity, and its output becomes unpredictable. The composing process integrates pattern-matching and recombinance in Cope's association network. From the late 20th century to the early 21st century, Cope have produced many pioneering compositions based on computer-assisted simulation of specific musical styles. He also explored new artificial intelligence languages to integrate with human minds (Cope 2018). After EMI and Emily, Cope further explored aspects of machine learning and algorithmic intelligence. He acknowledges the algorithmic nature of his musical works, and he believes that computer will continue to play a significant role in music production during the next millennium (Cope 1999, p.82).

Another AI method is genetic programming, a technique that the computer evolves to solve its own problem (Keats 2006, p.72). It seeks to imitate nature's evolution to generate programs artificially. Genetic programming is based on the principles of heuristic technique. It was developed by computer scientist John Koza and he patented the invention in 1988. Genetic programming is a paradigmatic algorithm that can apply to specific domains such as music generation. This technique has been applied to musical tasks in the areas of composing as well as improvising (Alpern 1995, p.12). GenJam is a model developed in a framework of genetic programming for bebop improvisations. Bebop is a modern style of jazz emerged in the 1940s, it often features fast tempos. GenJam was created by John Biles and he has been developing the program since 1993 (Biles 1994, p.131). The system operates based on learning and breeding, which includes the process of initialization, selection, reproduction, crossover, and others. An initial jazz melody is mapped in the population as the parent program, then the new melody is sent to the fitness function as the children output of the initial individual (Biles 1994, p.131). Biles explored beyond the relationship between music generation and machine learning. Machine learning algorithms are used as creative compositional tools, it is a ground-breaking approach from executing rules, learning rules to creating rules (Fiebrink and Caramiaux 2018, p.3). Genetic programming transcends the machine learning capabilities, it is a combination of genetic algorithms and artificial intelligence (Keats 2006, p.70).

From the musical intelligence systems to the genetic programming, the basics of two branches of AI methods are similar. The AI compositional techniques have been successfully applied in the field of music as music can be composed using digital algorithms in an iterative process. In the 1980s, Cope's EMI model successfully structured classical music. Cope's model is very similar to the structure of Markov chain (Nierhaus 2009, p.124). In the late 1980s, John Koza foresaw an inevitable growth of integrating music technology and intelligent systems. He could be viewed as a prophet of the underlying power of AI, ultimately believing that human beings will live in the age of creative machines. The different approaches (stochastics method, rule-structured technique and AI system) to algorithmic composition are distinctive in terms of the algorithmic means and output, however in addition to the three approaches mentioned above, there is trend of a hybrid approach to algorithmic compositions for automated music. "Music Algorithm Generation Engine (MAGE)" is an experimentation on such method. MAGE is a system that combines several AI methods, includes stochastic techniques and genetic algorithms to generate music piece (Crawford and Fox 2016, p.215). Besides the compositional approaches based on score, musical patterns and genres, some systems focus on sound synthesis and MIDI tools to generate musical materials (Maurer 1999). An example from recent years includes AIVA, the first virtual electronic composer created in 2016 (AIVA 2019). AIVA composes music for film soundtracks, games, commercials and many more fields. Another example is MuseNet, a system developed by OpenAI in 2019. By analysing a MIDI database, MuseNet is capable of composing multi-instrumental music in different styles. In April 2020, OpenAI introduced an advanced system Jukebox, which is designed to generate music cross genres in various modes (OpenAI 2020).

Since the 1950s, composers have employed single or combined methods to compose music with the assistance of different intelligent systems. However, as Forte hints, the interaction between music, mathematics and machines has been controversial (Forte 1967, p.32). Music technology has been a threat to earlier traditions. It is not easy to generalize the relationship between a computer's capabilities and human creativity. Indeed, how AI methods are compatible with human input is a question which has been of interest for a long time. Some musicians have given reluctant answers on the role of the computer and AI-oriented music, many finding it difficult to balance computer assistance and human input. Since the mid-20th century, from over five decades of numerous examples and experiments, composers' attempts weren't proved as great successes artistically and technologically, and the criticism persists. However the experiments are important in terms of the development of computational techniques. In a larger context, collaborative intelligence becomes a possibility between composer and computer. As Cope asserts, AI is not replacing the human, it is adhere to human (Cope 2018). In a modern landscape of algorithmic music, the various techniques and methods of algorithmic composition have opened new directions in music. Stochastic processing, rule-based systems and AI techniques are pioneering methods that expand the potential of computer-assisted music.

2.5. Conclusion

This chapter draws from the historical view on the development of algorithmic composition, from the early times, the information age to recent periods. To conclude, the use of random processes in music is significantly notable before the advent of computers. Algorithms and the human have had a long and deep relationship in the history of music. This association has been existing across cultures and across eras. From the 1950s to 1980s, composers attempted to encode musical knowledge and patterns into the algorithm itself. Algorithm is becoming an indispensable part in the composing process, it is a process of recombining musical DNA. The intelligent systems evolved from executing rules, learning rules to creating rules. An AI system can be based on a database of various compositional strategies. The stochastics method, rule-structured technique and AI system are three major approaches. The revolutionary approach to AI assisted music adds extra dimensions to algorithmic compositions.

During the recent decades, despite the controversy and critics, numerous computer systems and compositions demonstrated the power of human-AI interaction, with resultant musical works proving a positive response to collaborative intelligence. As Cope asserts, musical intelligence is an extension of the human's mind. From the current millennium, there is a growing trend for composers to embrace state-of-art technologies and to infuse AI languages into musical applications to achieve new results, and they are seeking for novel, sophisticated and intelligent responses from machines.

Chapter 3. Methodology

3.1. Introduction

This chapter presents the process of conducting the research and the implementation of the questionnaire. The chapter is organised into five sections. The first section creates an overview of the chapter, and the second section discusses the development of the proposed research method. The third section covers the topic of the recruitment of participants and sampling strategies, and the fourth section examines the collection and management of qualitative data. The last sections concludes the rationale of the applied research method and the measuring instrument.

3.2. Development and Approach of the Questionnaire

The paper aims to gain insights into composers' perspectives of computer-assisted compositions, and how much the musical pieces are impacted by technology. Due to the nature of the research, a questionnaire with qualitative dimension is considered appropriated. With a qualitative research methodology, it enables the researcher to gather data and professional judgments in a coherent way (Kouritzin et al., 2009, p.176). The approach of the inquiry is established on the immediate need for qualitative studies of expert composers. Since the selection of the research instrument is determined by the primary purpose and scope of the research, the discussion of sampling is essential. This paper aims at a specific population, and there is a strong focus on small-scaled sample groups. Considering the traditional distinction between quantitative and qualitative method is the sampling types: either probability or purposive samples in the survey, the research recognises the usefulness of purposive samples (Vogt et al., 2012, p.220).

At a practical level, the survey research is particularly appropriate to the investigation of various approaches of compositions and how music is produced in a contemporary context. In order to create the basic parameters of the proposed research tool, in the practice of the research, it is important to plan an effective method and follow three key procedures "concepts, reliability and validity". To increase the reliability of the research, the researcher needs to employ a valid method to define the concept (Vogt et al., 2012, p.319).

3.3. Participants

In order to gather idiosyncratic knowledge from sophisticated composers, a qualitative research instrument is implemented. It allows the researcher to gather viewpoints through a small group of musical professionals. By orchestrating the research framework, the survey investigates in-depth case studies of the chosen participants, which interprets the true value of the research (Nuhn et al., 2002). Seven composers were recommended by college staff as the possible participants, since the availability of participants is limited in the experienced individuals. They were contacted via email with an attached research outline and a brief introduction of the researcher. Three of them expressed their interests and accepted the initial invitation. They were: Hugh O'Neill, Judith Ring and Sebastian Adams (See Appendix i sample information table for details). Due to the non-sensitive topics and non-vulnerable populations involved in the subject matter, participants did not find themselves uncomfortable of the research topic and no ethical concern arose. Moreover, the research does not intend to focus on a deep analysis on gender differences. Instead, the recruitment focus on the suitability of participants based on musical knowledge, therefore the sampling is not dichotomized into gender groups. The small sample reflects a relatively healthy gender balance: two male and one female. In terms of the age considerations, all participants are mature and they are aged between 29 and 48. Since the participants come from different backgrounds and age groups, the diversity of sample profiles increases the representativeness of the qualitative data.

3.4. Method

The research was implemented by the means of questionnaire. Participants were recruited through email communications, and they were not required to present physically as a group. Each participant was communicated individually via email. Their contributions were based on the format of the questionnaire. The questionnaire was designed in a form which allows in-depth explorations of participants' inputs, with the expectation to maximize the sampling results. By employing qualitative research strategies, all questions were designed open-ended for a detailed evaluation of the answers (See Appendix iii for details). The advantages of the open-ended questions include the possibility to investigate the answers that the respondents give spontaneously (Denscombe 2008, p.360). Open-ended questions tend to produce an added diversity of responses compared with the close-ended form. In terms of the length of the answers, respondents are more likely to type long and detailed answers for the non-paper based questionnaire. Considering of various approaches on questionnaire structures, the research therefore is best suited to conduct non-paper based open-ended questions. The questionnaire consisted of ten questions. All questions were based on the topics of different compositional approaches in the context of contemporary music practice, which identified in the background chapter. Participants were informed that the questionnaire would take approximately thirty minutes to complete, and it may take longer depends on the answers. In terms of the format of the answers, any forms of inputs were encouraged, including written essay, musical score, recording, video material, sample of composition, and other musical examples. Participant information sheet, informed consent form and other written documents were provided electronically (See Appendix ii for details), as part of the practicing of social distancing guidance under COVID-19 circumstances.

The questionnaire was distributed by email, and each participant received identical questions. Considering of the busy schedules of participants, they were not required to respond the questions elaborately, however they were provided the opportunity to answer tailoring subsequent questions. After a week's time, the questionnaire results were emailed to the researcher as agreed. During the research conducting process, the researcher followed four basic procedures as mentioned by Rogelberg. First, no harm should come to a participant during the research. Second, the participants are aware of the potential consequences and the consent form should sent to them. Third, the participants understand they voluntarily agree to take part in the research. Fourth, the measures of accessing data should make sure the data is stored confidentially (Rogelberg 2004, p.180).

3.5. Data Collection

The answers from the questionnaire were received in the format of written email, and the data was already transcribed. Most of the data format was textual based, and the answers were organised into a docx document. Besides written responses, other forms of data, including musical examples and related information were assembled in a folder. All data collected from the questionnaire was stored in a Google Drive folder, and it was used for solo purpose of research analysis. Nobody outside the research will have access to the data, and the electronic data stored online will not be used for future studies without permission of participants.

Furthermore, considering the common limitations of qualitative method, the results from the questionnaire were carefully evaluated to make sure they were representative and generalizable. As Rogelberg asserts, comparing to a quantitative research, the qualitative research does not gather enough data from a selected population (Rogelberg 2004, p.175). Therefore the researcher intended to improve the adequacy of the sample by applying various strategies. The research aimed to focus on the richness and complexities of data in order to present a deep analysis of the findings.

3.6. Conclusion

This chapter presents the methodology behind the questionnaire design. The research applied a rigorous method to the practicing of data collection, selection, and evaluation. Survey research provided a legitimate approach into sampling strategies and data collection methods. The chapter has identified the need for an effective and efficient research instrument. The choice of qualitative research established a solid research base for the investigation of computer-assisted compositions, and the method guides the discussion of findings in the following chapter.

Chapter 4. Findings and Reflection

4.1. Introduction

This chapter presents the results and creates focus topics derived from the questionnaire. The chapter contains seven sections. The first section gives a brief overview of the chapter, and the second section examines various compositional approaches from three participants in a contemporary context. The third and the fourth section analyses two musical examples. The first piece is *Up to my f-holes* (2008), a cello and tape composition by Judith Ring. The second example is Sebastian Adams's *Turing Test: Text to Music #1* (2016), and this section discusses the development of a generative notation system and how it could produce generative music. The fifth section examines different compositional approaches of participants and future prospects of the human-AI interaction. The sixth section provides a critical reflection of the findings. This section addresses major concerns as well as some further thoughts from modern composers' point of view. The last section summarizes the chapter. It brings findings, critical reflections and future prospects of computer-assisted compositions together.

4.2. Algorithmic Practice in Contemporary Music

4.2.1. The Use of Music Software and Programming Languages

The results from the questionnaire emphasizes the lens of unique interpretations on composers' compositional approaches. The applied qualitative method reflects a degree of flexibility. With open-ended questions, participants were free to respond. Only a few responses were left "yes" or "no", and most responses were rich and explanatory. Results of the survey largely represent a clear need of software or hardware environments for three composers. A music system typically comprises of buttons, keys and sensors which allows the composer to manipulate.

All participants expressed they use music production software in the process of composing, and they installed the software either in their own laptops or in music studios. Max/MSP, Finale, and Sibelius are most used programs. Two of three participants are using at least one of them. All participants use more than two software to create and manage the audio content. They use a wide range of musical applications from commercial to free, including Logic Pro X, Cubase, SPEAR, FFmpeg, FMOD, Note Performer, Wwise, SuperCollider, Premiere Pro, Ableton, Reaper, Pro Tools, Csound, Opusmodus and Audacity. One of the participants O'Neill explained his choices on different software. O'Neill is a composer and improviser who is specialised in music theory and performance. He mainly uses Logic Pro X. He uses it as a way to organise ideas and hear the possibilities between found sound and musical texture. In Logic Pro X he tends not to use many effects except as a way to tidy recorded sound, compression, and equalization etc. O'Neill also uses MaxMSP to generate compositional material from recorded samples and as an input for instruments to achieve a particular texture or abstraction of the instrumental sound. Occasionally the composer uses Csound for the precision it offers. As for notation processes, O'Neill uses Finale, he found it to be the most precise program in terms of unusual notation. “You can be very exact in Finale, more so than in Sibelius”, he indicated. O'Neill tries out new tools and interactive music systems quite regularly. Recently, he has started using Opusmodus which offers a more complete and intuitive way to compose algorithmically. The overall responses demonstrated the variousness of composers’ choices on musical tools. Participants use digital tools directly or indirectly in composition processes. These tools include digital audio workstation, music notation software, composing software, audio editing software and synthesis software.

Besides music software, the findings also suggested that some participants use certain programming languages. One participant indicated she does not use programming language. Two participants expressed they use programming languages. Adams is a composer who is experienced in writing notated instrumental and experimental music. He responded in the questionnaire that the coding approaches he uses are basic JavaScript and Max MSP. He also uses the Bach externals in Max to generate notation systems. The other participant O'Neill, who uses programming languages expressed that Lua is used to write scripts for live instrumental processing. It serves as a front end for the control of Supercollider. Like JavaScript, Lua is a multi-paradigm programming language. Findings suggested for the participants who use programming languages, they often compose music with functional programming and have showed great interests in problem solving and object-oriented programming. In music software programming environments, two of three participants employ high-level coding directly in their music. All participants demonstrated a good understanding of programming concepts.

On the topic of how they utilize computer systems with or without embedding object-oriented programming, participants expressed that they use digital tools in certain aspects of the compositional process, depending on the individual program and musical genres. Ring explained her compositional approaches in Finale, Note Performer and Logic Pro X. She stated that Finale is used to hone the compositional material and sometimes writes directly onto the score in the program. She also uses the playback facility to hear back what she has done. “Playback engine is a new way of working for me”, as she stated. In recent times, Ring purchased Note Performer, which is an artificially intelligent instrumental sound library that can be loaded into Finale for playback. She stated the quality of the sound set is good and her playback “sounds much more real”. Note Performer is also compatible with Sibelius but Ring has not attempted to use it yet, she is happy to work in the Finale set. Ring uses Logic Pro X to layer samples of the instruments that she recorded with different musicians. “I would use Logic to blend different textures together to form a ‘tape part’ or fixed media element for my composition”, she noted. Similarly, O'Neill expressed his approach in Logic Pro X. When preparing mock-ups he uses Logic Pro X. Computer systems are prepared with a lot of detail as is necessary when inventing new playing techniques or abstracting extended techniques. O'Neill also uses MaxMSP more frequently when he is generating musical material. He has created patches that work with various types of sounds, a patch that works with percussive sounds, or one that works with single pitch sounds like (talking), and so on. He processes found sounds and recorded sounds to generate musical information, pitch sequences or rhythmic patterns. O'Neill also transforms sounds to be used directly in a composition. The last participant Adams explained his experience of using Max and Sibelius. He uses Bach externals in Max to create generative computer notation systems. By applying a complicated sets of adjustable weighted-but-randomised parameters, the system can produce music that could be sight-read in real-time. Adams often uses similar tools to generate streams of data from a concept. For example, a series of pitches and rhythms etc. Occasionally, he uses computers to aid with calculating numbers relating to structural or harmonic elements of a piece. In Sibelius, he often writes music straight into the program, using its playback functionality as part of the compositional process. He considers playback is a quick method for copying and adjusting already typed music. Adams concluded that “generally, I use the computer anywhere as it will make a task quicker or simpler. I rarely write pieces completely, or even mostly without the computer”. Similarly, O'Neill pointed out that “I would say…in nearly every part of the compositional process I would use computers as they have a few main advantages”. Computers simplify difficult tasks and they allow for the use of more complex ideas in the compositional process. Three participants expressed their opinions on the role of the computer in their compositional processes. To a large extent they interact with computer-based composition systems. They compose music using their own familiar software and the software is becoming an integral part of composers’ working environments.

4.2.2. Indeterminacy, Randomization and Recombination

When asked the question if they use specific instructions or algorithms to generate music, all participants expressed that they use specific algorithms as compositional tools. Ring stated that in Wwise, she can detail any algorithmic composition she intends to approach. Randomisation of pitch, volume, start time, finish time, spatial placement, and percentage can all be controlled by herself. Ring also writes melody generators in other programs and she uses them to generate bass lines in pop music, or solo lines. She often makes algorithmic composition tools in M4L for Ableton. This allows her to control randomness and to have a compositional system that she guides, rather than composes. She writes a lot of generative tools, which feed into Ableton mostly. This applies in a different way when using controllers. She explained, "for example, if I am controlling six parameters with a controller through physical movement, but I want to control twelve musical parameters, I will write a little process to include the six parameters and manipulate as sonically appropriate". It keeps the relationship of movement, data and sound, without needing a literal connection. Ring also described her experience on experimental composition. Within her more experimental music, she takes data from movement and voice data to influence other parameters. The idea behind it is that there is a harmonious relationship between different elements, even if that is sometimes a tenuous link. In O'Neill's answer, he described his algorithmic approach in the compositional process. Algorithmically he uses Max to extract information from recorded sound. "I will allow whatever sets of information dictate the flow of the composition", as he indicated. He will often record a particular gesture performed on an instrument and use the results as musical information. This is generally done as a pre-compositional process and will usually dictate the parameters of the piece. O'Neill also mentioned he continues to discover different algorithmic compositional approaches with new tools. He has recently started to use Opusmodus but cannot yet include it in his list of software as he has yet to write a piece with it. Opusmodus provides an innovative method of composing and analysing music. O'Neill's initial exploration of Opusmodus has proven that it is an integrated, self-contained software. The musical possibilities in using this software are very exciting. Likewise, Adams explained the general algorithmic approaches which involve the computer. He generally uses very simple algorithmic approaches, simply dealing with repeating or augmenting series, transcription of one parameter into another (for example, turning letters of a text into pitch values), and particularly by using weighted-randomness to control a property in general without specifying the specific property. "I like to approach problems by generalizing them and not by doing laborious work by hand, so I delegate as much as possible to the computer", he summarized. Results from this question reflected that all compositions from three participants are partially or fully generated from computer systems. All participants' experience of algorithmic approaches ranged from applying basic algorithms to complex computational techniques. The findings demonstrated that music activities are automated by software tools to varying degrees.

On the next question when participants were asked which part of the composition is controlled by the composer, they expressed their opinions in details about human elements in computer-aided algorithmic compositions. Ring believes that form is the most important thing for her to control. She creates a structure that she progresses through but often other processes control the shape within sections that she can respond to. In her performance work, the system aids her in the performance and composition. However in the studio based work, she sometimes is aiding the computer. The other participant O'Neill argued that there have been a few occasions when instructions have been given for the performer to improvise within certain parameters. This is aleatoric techniques and he is combining technology with earlier styles of aleatoricism. Aside from that he would control every part of the composition, and the entire score is controlled by the composer. Adams gave the similar answer that he believes he is the creator of the music instead of computers. The general response showed that, participants acknowledged the compositional process represents a large degree of automation. Some parts of music are controlled by the computer while some are controlled by the composer. Findings implied that in certain circumstances, computers play the role of the improvisational or performance of the music.

When asked the question if they use any indeterminate approaches that akin to processes of Cage, two of three participants answered they use indeterminate approaches much of the time, and one participant does not use the method. One participant explained he creates indeterminate scores in his improvisations based on random numbers on a modular synthesizer. The answers were expanded in the next question when they were asked what kind of randomization or recombination of musical elements they use. Ring expressed that, “this is different every time” and that she tries experimenting with many elements that are chosen by the ear, rather than by a rules-based process. It involves tweaking things all the time until she gets something she likes. It also involves taking something designed for another purpose and seeing how it fits or does not. “This helps me challenge my approach”, Ring added. In some cases, “something I write later on in a piece can end up sounding better at the beginning, or somewhere else with the structure”. The other two participant’s answers focused on the use of Max. O'Neill described the techniques he uses in detail. He creates patches in Max to generate musical material. “I would sometimes use the traditional elements such as retrograde inversion of that found in serialism.” He perceives a composition as an eco-system of sorts, in which each element has a connection to all other elements and to the composition as a whole. “Any composition is, for me, a recombination of initial elements used”, he concluded. When discussing the randomization of information, O'Neill responded he would use randomization in some of the techniques involving Max and in the generation of musical material. However any use of randomization is usually done within strict parameters and with an idea as to what the result might be. “I would tend to use this technique loosely, always picking and editing the final result”. Similarly, in Adams’s answer, he described his approach in Max. He developed a generative notation system using Bach externals in Max. In the computer system, all musical parameters except duration and instrumentation of the piece can be randomized, always with weights assigned to different values so that the result will be random in its specifics but pre-decided in a more general way. Overall, the whole sample of composers believe the algorithmic patterns exist in their compositions. Results suggested that composers encode musical patterns into the algorithm. The composing process is a process of recombining, or randomizing the musical elements. These contributions reiterate the concept in the background chapter that composers can apply algorithmic techniques in rule-based compositions. In David Cope’s computer systems, the composing process integrates pattern-matching and recombinance in the association network (Cope 2001, p.77). O'Neill’s approach on recombination is an interpretation of Cope’s method. Findings also demonstrated the stochastic foundation on the use of random parameters.

4.3. Up to my f-holes

When participants were asked to give musical examples of particular algorithmic techniques they have used, two of three participants presented relevant examples. The first participant Ring shared her composition *Up to my f-holes* (2008), see the score below (Figure 1).

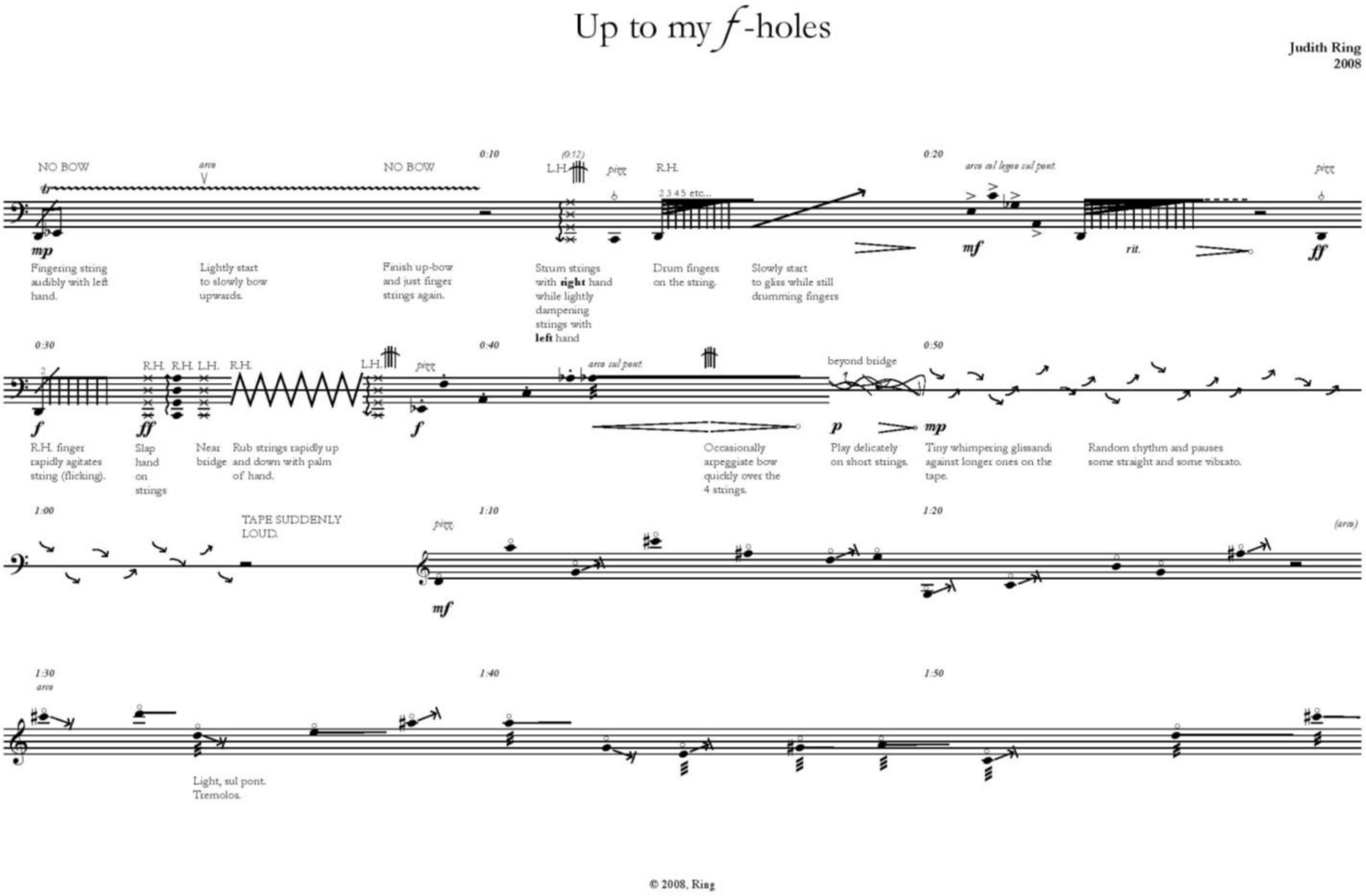

Figure 1: Score of *Up to my f-holes*, page one (Ring 2008)

Up to my f-holes is a track from Ring's debut album "What Was" produced by Ergodos records. It is an electro-acoustic and truly experimental piece for solo cello and tape (Daylight Music 2008). The performer is free to interpret the score in an individual manner by embellishing the timbre to blend or contrast with the tape part. Ring wrote it in 2008 for cellist Laura Moody for the tape part and it was performed by cellist Kate Ellis. "Each piece of mine is highly collaborative as I work closely with musicians to find out what their instruments can do", as Ring indicated (Ring 2008). She has also explored a wide range of instruments as well as different styles. "Each player offers something new to the mix, and each piece is unique to the player involved", she added. The duration of *Up to my f-holes* is six minutes and thirty seconds. There is a good balance and blend between two parts: cello and tape. "I assembled the tape part out of samples I recorded with cellist Laura Moody in London", as Ring described her process of composing. Recordings were made of the cellist exploring her instrument in imaginative ways, using extended techniques and additional sound generation. Ring recorded all the sounds Moody could make on her cello from normal notes to everything else they could think of. Then, Ring edited all the elements into single sound files and layered them in different ways in Logic Pro X. The resulting sounds were composed into a tape part that provides an exciting accompaniment to the energetic live part. The live part was written after the tape part to compliment it and it aimed to provide a more interesting live experience. The performer should become familiar with the tape part in order to interpret the score in a creative way, enhancing both parts in the process.

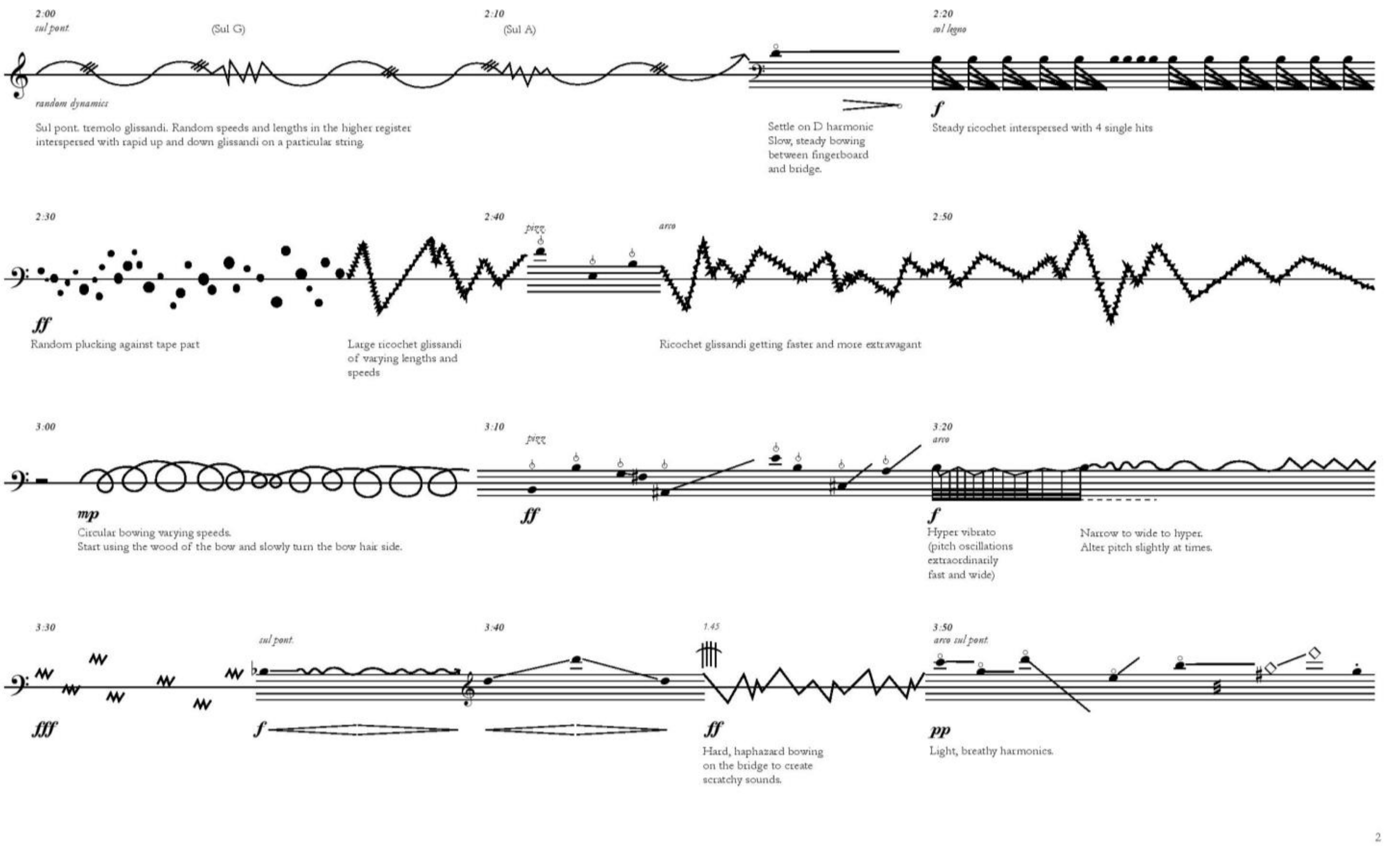

Figure 2: Score of *Up to my f-holes*, page two (Ring 2008)

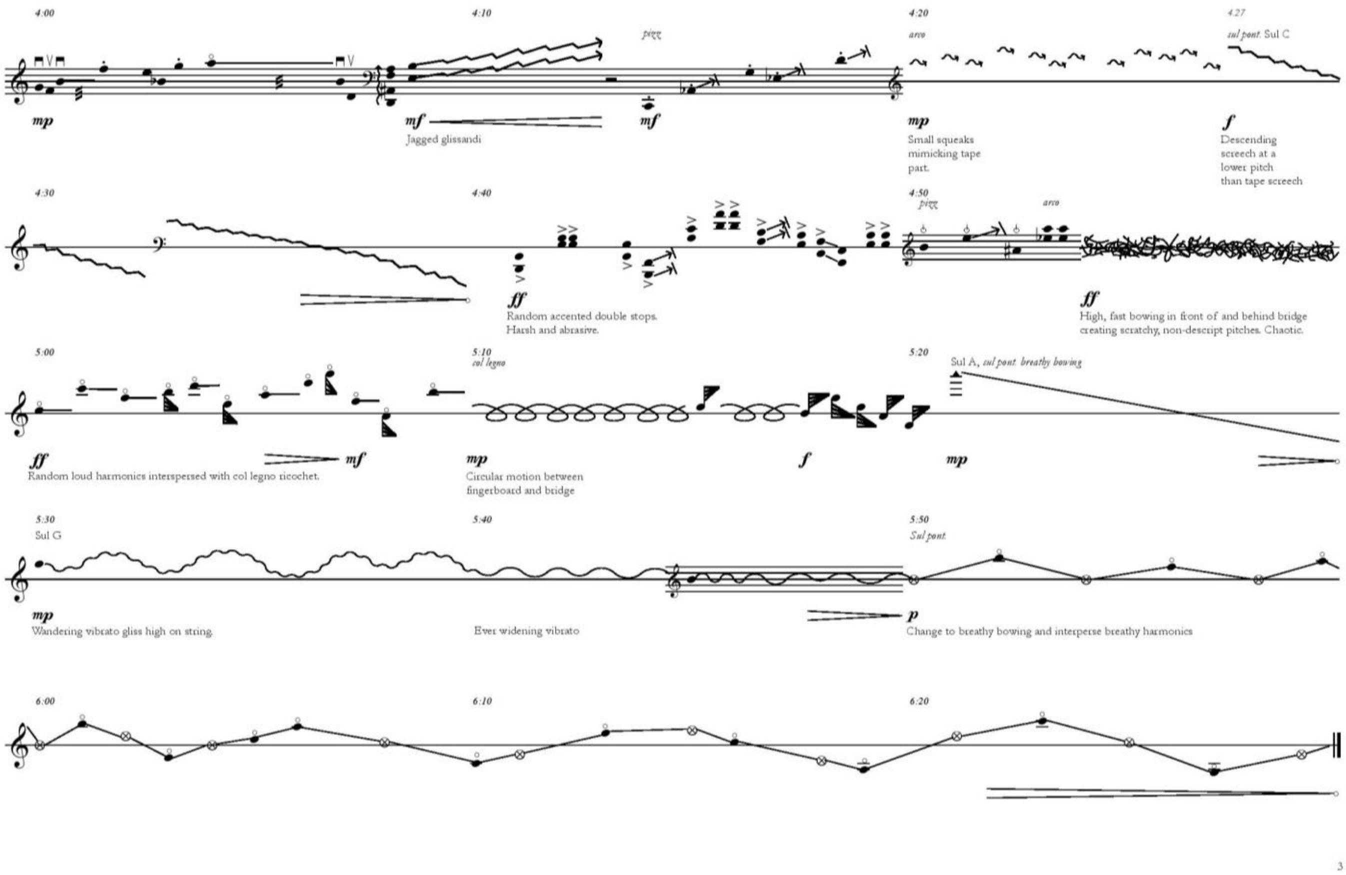

Figure 3: Score of *Up to my f-holes*, page three (Ring 2008)

As shown in the score (Figure 2), the distribution of notes was determined by randomized procedures. At 0:50 of the piece, the note reads as "random rhythm and pauses, some straight and some vibrato". At 2:00 in the glissandi part, the note reads as "random dynamics". The piece should be played in "random speeds and lengths in the higher register interspersed with rapid up and down glissandi on a particular string", and it lasts for twenty seconds. At 2:30, a short fortissimo follows with "random plucking against tape part". At around 4:40, harsh and abrasive random accented double stops are played, following a decrescendo of the descending screech (Figure 3). At 5:00, the phrase changes to "random loud harmonics interspersed with col legno ricochet". Throughout the piece, the performer may feel free to embellish the score if a particular colouring of a segment should come to mind. Ring concluded, "Every time it is played, it sounds slightly different as the score is mainly gestural". The whole processing of *Up to my f-holes* involves random choices. "My music stems from the electro-acoustic world and its core technique is based on the practices of musique concrète", as Ring indicated.

4.4. Turing Test: Text to Music #1

Besides Ring's *Up to my f-holes*, the other participant Adams also introduced his specialized algorithmic composition system. *Turing Test: Text to Music #1* (2016) is a generative notation system. It was developed in 2016, using Max 6 and the Bach externals. The system is developed based on text, improvisation and sight-reading, where a text could be converted to notation and used as a tool for improvising. A screenshot of the system demo video is displayed below (Figure 4).

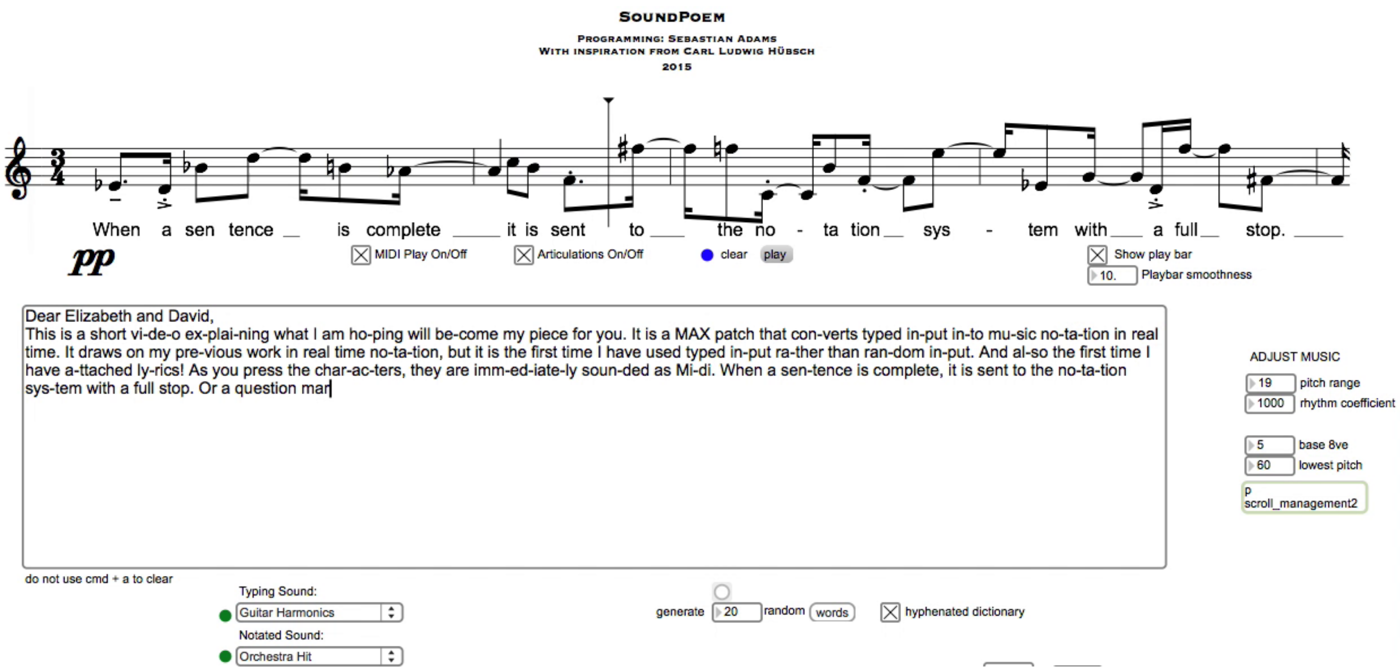

Figure 4: A screenshot of *Turing Test* system demo (Adams 2019)

"A fascinating aspect of real-time notated music is that it is a truly nascent field", as Adams explained the practical reasons for pursuing his invention, "the idea of live-generated notation sight-read in real-time is musically compelling". The interpretative faculties of a performer are seen in their least cultured form during the performance of a piece written in *Turing Test*. The performer of *Turing Test* has no time to think about the most musical way to approach a phrase, produces a very different interpretation to the one they would of the same music with a written score and a week to practice. The focus of *Turing Test* is left purely on the computer, with the composer providing no melodic material and not participating in the performance in any way. The system follows in the footsteps of the aleatoric, generative and algorithmic movements of musical composition. As Adams stated, "John Cage is my main touchstone in all manners indeterminate". His interest in Cage was sparked through performing works like "four" for string quartet, where there is an almost complete lack of determinacy and yet a very predictable end result. Cage's varying levels of indeterminacy all fascinate Adams and have informed on his own music.

Adams also described some technical details of the system. In the pitch generation process, creating pitch material is one of the vital steps. He decided to ask the computer to generate a starting pitch (the tonic, subdominant or dominant of the chosen "key"), and then generating the next pitch by adding or subtracting a random interval from the previous note. It is essentially one basic operation of arithmetic and yet altering the likelihood of different intervals radically altering the sound world of the resulting music. Adams then described the most interesting element of the patch, the memory system. "This is a collection of four memory banks and a series of transformers that alter pitch, rhythm, tempo and dynamics of the material stored in the memory", he explains. Each list of pitches are inputted into index files called "colls" and then asking for a random item from the coll whenever a new phrase is needed. The output from these colls then goes through the transformers before being sent back out into Bach. The output from the memory is then routed back into the memory as a new item, meaning that developments of phrases can then be developed further themselves. The fourth and final memory bank receives everything that happens, whereas the first three only receive information if they are selected. "Minimilate is my favourite transformer that I have built into *Turing Test*", Adams stated. Below is a screenshot of Minimilate's video demonstration (Figure 5).

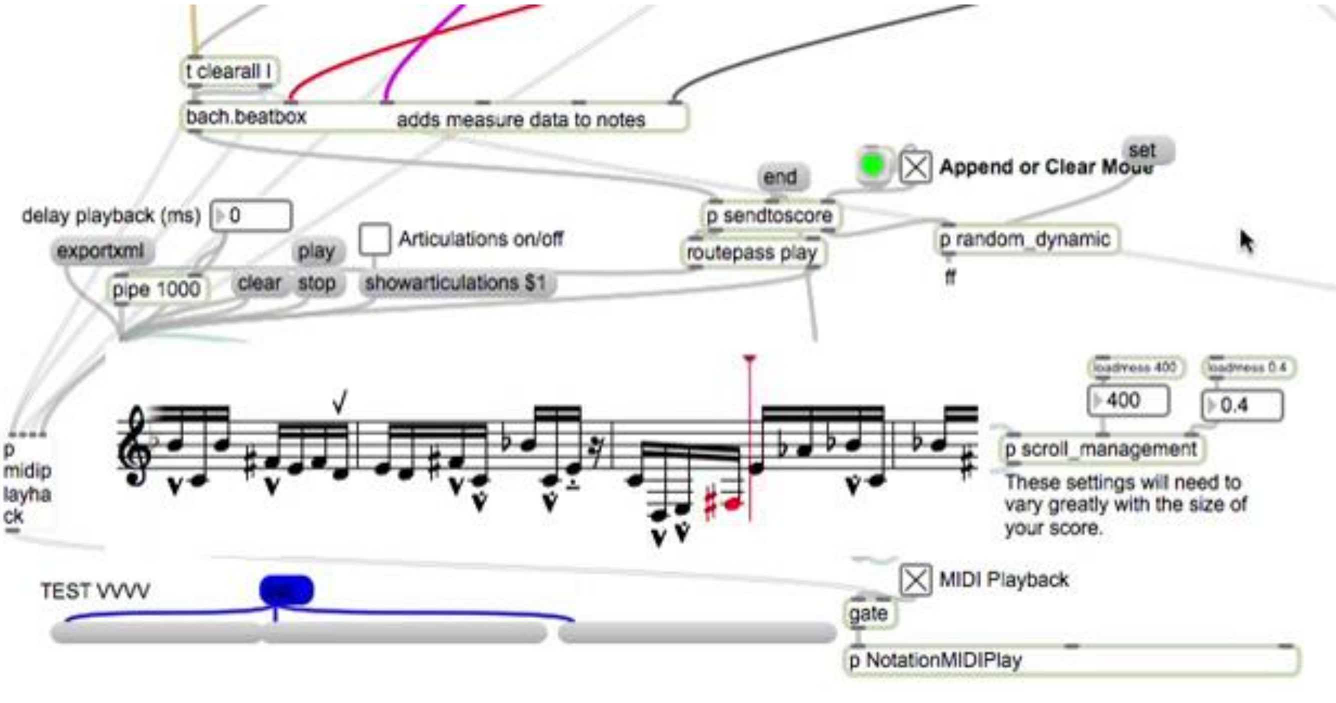

Figure 5: A screenshot of minimilate object demo (Adams 2019)

In Minimilate, the phrase remembered by the computer can be minimilated. It takes a list of numbers, copies N numbers from the list and then replaces N numbers elsewhere in the list with those copied. Adams gave an example of the method: [before: {4 6 5 9 7 **3 1 7** 2 8 2} after: {4 **3 1 7** 7 **3 1 7** 2 8 2}].

Turing Test: Text to Music #1 aims at forcing performers to sight-read in public. The image below shows flautist William Dowdall practices sight-reading in the Contemporary Music Centre's Salon series (Figure 6). The salon took place in Lutheran Hall, Dublin in 2016. It featured Adams's solo viola performance and Dowdall's solo flute performance (CMC 2016). In a live situation, the computer writes music during the concert, which then has to be sight-read by Dowdall. He could not be able to practice the piece in advance. As Adams himself remarked, "the extraordinary tension created by a musician sight-reading in the arena they normally reach only after careful preparation". The whole appeal of virtuoso music lies in the palpable demands and stress placed on a musician when they and their instrument are pushed to the very edges of their capabilities. The demands expected of a musician increase by expecting a player to sight-read in a concert setting thereby increasing the demands and tension without abandoning notation, and allowing for audible thematic development. Adams's approach showed a unique perspective of the implementation of sophisticated probabilistic models. The findings demonstrated that musical parameters can be randomized in an indeterminate approach with stochastic elements.

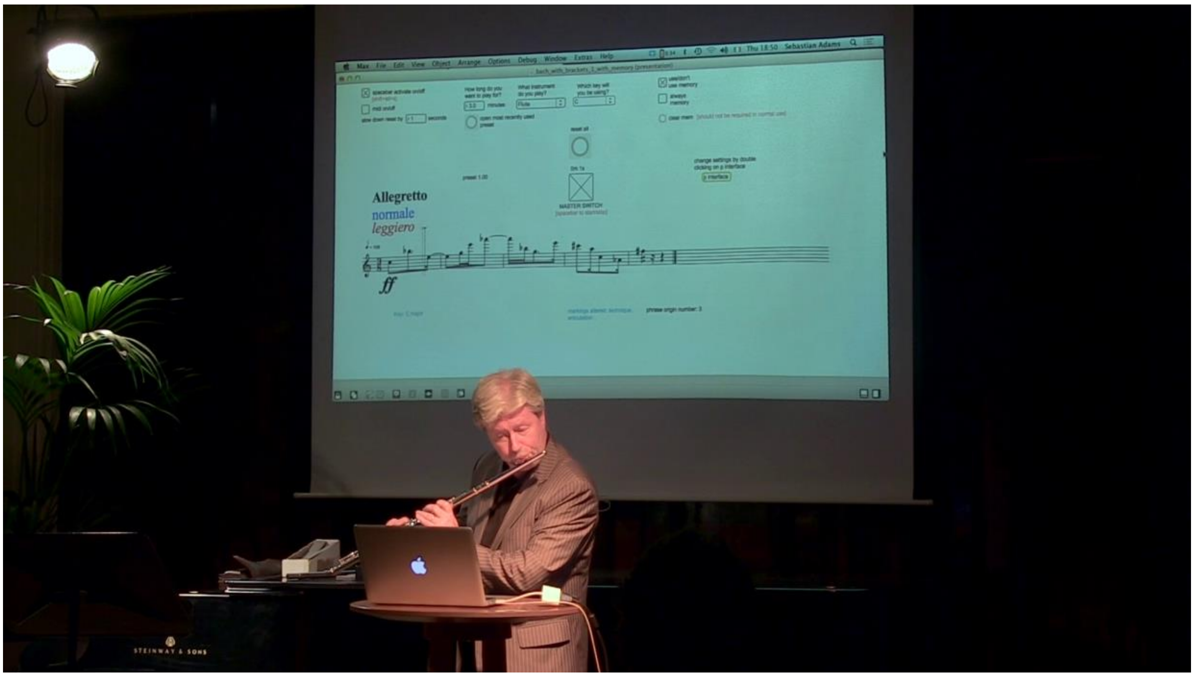

Figure 6: An image of William Dowdall's performance in Contemporary Music Centre's Salon 2016 (CMC 2016)

4.5. Future Prospects

Relating to the topic of further exploration of participants' music approaches, three participants responded that they would like to try new tools and approach differently on their music practices. O'Neill pointed out that, "I'm always looking for new ways to approach composition but much of my approach has developed for an initial interest in composing a particular way". O'Neill is always looking to extend the compositional technique but he is generally happy with the way he composes. New tools such as Opusmodus offers a composing continuum, this is less a new approach than a way to gather information, and access certain techniques all in a single place. O'Neill also commented that "new tools are always worth exploring but sometimes one can be easily distracted by technology". Adams expressed that after *Turing Test*, he has tried various approaches in his music practice, even creating a different application for *Turing Test* as an educational tool for training sight-reading. It is possible using the existing architecture of the patch, however the program would need to be tailored to produce much more conventional phrases before it could be truly useful as an education program. Adams also mentioned his enthusiasm for machine-learning system: "I would love to work with machine-learning, I tried but only very minimal, I have not figured out an appropriate musical context for this yet". Furthermore, the work of John Cage and David Cope all fascinate Adams. "Something which has recently intrigued me is the work of David Cope", Adams responded. He suspects that taking Cope's ideas on board will be incompatible with his current application and will require a fresh start, however, "Cope's work is something I hope to delve into deeply in the future", he indicated. From Ring's point of view, she mentioned her interests in touch screen technology. "I would love full touch screen capabilities on a massive screen for Logic Pro X and Finale", she expressed. Ring is happy with what she is working on at the moment, but it would be great to be able to move and input elements very precisely with a mixture of touch and trackpad. For example, to be able to zoom in close to a sample use a finger spread and then to alter the volume envelope of that sample but tapping and sliding fingers in different ways. It would also be great to be able to draw in the notes in Finale and have them automatically be typeset. "There was a windows based tablet being especially designed for that at one stage, I believe it had great potential", she added. Findings showed two of three participants prefer to use their own familiar software, and one expressed that new technology can be distracting. Nevertheless, the whole sample highlighted the possibility of further development of advanced computational approaches. Findings reflected that composers are slowly embracing computer-driven technology, although some participants have not yet shown a keen interest to the software which they are not familiar with.

When participants were asked their opinions on the future prospects of human-machine interaction, AI and collaborative intelligence, they answered the question from different aspects. Adams believe the work of many pioneers already demonstrates a future of the human-AI interaction, such as Jennifer Walshe, Holly Herndon and David Cope. “There will be many more exciting ways to use AI in music which have not been discovered yet”, as Adams stated. Likewise, Ring expressed her thoughts too. She responded it would be exciting to see more opportunities and more pushing of boundaries, and she imagines composition tools are just going to be more and more user-friendly and capable of extraordinary things. Expectedly, apart from the positive prospects mentioned above, findings also reflected the downsides and concerns. O'Neill responded there is no yes or no answer. He sees AI as having a place in certain types of music and at certain stages in the compositional process, as an aid to the composer or songwriter in the completion of certain tasks. However it is important to see the distinction between music that is written by composers and songwriters and that which is composed by an artificial intelligence. O'Neill believe it is a great trick but music speaks of the human condition, whether it is a love song or a complex exploration of sound. He indicated that “the day we relinquish control is the day we lose sight of the real function music serves: a wordless communication between people and a way that we can connect with the deepest parts of ourselves”. He would hate to think that he is listening to nothing more than an algorithm that reduces human experience to ones and zeros. Similarly, Adams expressed he believes in a more human-oriented approach. The composing process tends be a human-centred process incorporating algorithmic approaches that include collaboration with humans, rather than attempting to replace or outsell them. Adams also drew the concerns in terms of absolute music (instrumental music, classical music etc) and functional music (video game music, film soundtrack etc). “There will be a danger of shortcuts being taken with AI being used to generate unique but formulaic background music as a way to avoid spending money on a composer, particularly in functional music”, Adams pointed out. For absolute music, there is a challenge for AI to generate true harmony. It is likely that there will be truly “creative” AI which produce work of note, but that the pressures of the market will cause a major use of AI in music to be as a creator of bland, cheap (but original) stock music. The response showed that participants believe computer is becoming the universal tool and the development of computational algorithms and AI is inevitable. Despite the concerns raised, findings suggested that composers acknowledge the power of human-AI interaction, and they are maintaining an open mind on collaborative human and AI intelligence.

4.6. Reflection

Findings above illustrated that composers tend to use the musical software which can supplement and complement their musical minds. They are seeking for a virtual workstation to develop their ideas and organise pre-compositional materials. With the aid of specialized programs, composers can adapt to a fast-paced environment in the radical-changed music industry. The music industry in the age of digital transformation faces new challenges. The shift from handwriting scores to composing on screen is a revolutionary change. Today's composers go beyond the traditional format of music production, and digital tools form an essential part of the modern musical environment (Kiddle 2020, p.1). Laptop and studio composers are able to harness the powerful software to implement the musical concepts. They can fully engage with technological capabilities and greatly benefit from the practical applications.

Results from questionnaire recorded that the most used compositional tools are Max/MSP, Finale, and Sibelius. Logic Pro X and Opusmodus are popular choices for some composers. Findings suggested that composers often use more than two software with different focuses in terms of functionality. They tend to use the software which do not heavily overlap with the musical functions. In computer systems, having the programmatic and mathematical control over a piece are important for composers. Musical software makes comprehensive compositional workflows possible with built-in sound libraries, notation editors, and more. With the minds of computational thinking and problem solving, composers are able to manipulate music just like writing code. Multi-paradigm programming languages are popular among composers. Survey findings implied that compositional approaches are vary depending on software and coding environments. For example, playback engines, artificial intelligence sound library, and patch generation are compelling features. Composers can work on compositional systems to control the parameters and algorithms. Furthermore, findings demonstrated that composers believe that ultimately the creator of the music is the human. A human composer adds the individual touch to a software or a program. In a computer system where a human composer makes compositional decisions, intervenes and builds algorithmic models, then the human legitimately claims to be the composer, or the designer of any music or music generating systems developed. Findings also reflected that an important limitation of an intelligent system is the generation of a real harmonic language, such as chordal progressions, modulation and proper counterpoint. In indeterminate scores the musical information is randomized and left by chance, but the result is not unpredictable. Human intervention is a compositional technique in automatic systems.

The survey also demonstrated that the compositional process is a human-centred process, despite the extensive use of digital tools and intelligent systems. “Composing has become a multi-faceted process and takes ideas about structure and content from many disciplines” (Opusmodus 2020, p.40). Musical materials can be transformed, restructured and extended with the assistance of the computer. In composing processes, composers tend to work on screens, and finish a piece in one single environment. However much of the work is still done by the human. Computer systems do not provide the composing continuum, and the human approach is still dominant in the whole process.

Furthermore, two musical examples illustrated the use of specific musical patterns and the algorithmic techniques. The first example visualised how notes were assembled by chance and determined by randomized procedures. The gestural score allows the performer to interpret the piece in a creative way. The music performer is producing the music content as well. The second example discussed how to handle probabilistic models and apply indeterminate technique to composition. The memory system created easily audible developments of thematic material, and scores could be read for improvising and sight reading. The musical examples demonstrated the application of compositional strategies in algorithmic compositions in a contemporary context. Modern composers continue to explore new approaches on their music practices. Many of them are looking to extend the compositional technique by using new software and applying AI techniques. Findings implied positive prospects on the further development of collaborative intelligence. The combination of human and AI will guide a new direction of music generation. Creative AI is in its infancy. The results of the questionnaire showed an enormous possibility that humans will go beyond the present musical limits.

4.7. Conclusion

This chapter presents the analysis and interpretation of the findings, which are based on the qualitative data collected from the questionnaire. The answers of the questionnaire were carefully reviewed from different perspectives. In combination with the literature discussed in the background chapter, there is significant grounding to assume the findings of this research demonstrated the hypothetical relationship of the human and computer. The findings of the research revealed a growing trend and focus on human-AI interaction in music creative practices.

Chapter 5. Conclusion

5.1. Summary

Algorithmic compositional techniques have been extensively explored throughout history. Stepping into the information age, the rapid shift in the traditional music genre to the common use of computational technology become the driving forces of digital music evolution. The paper provides a comprehensive view of algorithmic music and different approaches that have been used for algorithmic composition. Many old models and frameworks from earlier musical traditions have been widely used in today's algorithmic compositional procedures. For example, Markov chain models can be found in the process of Mozart's Musical Dice Game. David Cope's musical intelligence system is very similar with the structure of the Markov chain, which was developed in the 1980s. Similarly, Bach's approach to canonic composition, and Arnold Schoenberg's twelve-tone method were notable precedents of algorithmic practices. From the early efforts on formalism to algorithmic music, composers imposed maximal complexity in terms of the development of more advanced machine models. By the late-20th century, the well-defined compositional models were established. The stochastic method, rule-structured technique and AI-based system are three major approaches of algorithmic composition. In addition to the major approaches, genetic programming (a branch of AI method) and the hybrid approach (combine several techniques) are recent approaches.

Drawing from the literature and composer's personal perspectives, the paper offers a broad understanding on the role of AI in music creative practices in the contemporary context. *Up to my f-holes* and *Turing Test: Text to Music #1* are two musical examples representing the implementation of formalized procedures. The paper also offers the critical view of computer-assisted composition and its future prospects. Gaining profound insights into composers' point of views of algorithmic approaches, O'Neill, Ring and Adams highlighted the algorithmic nature of their music. Findings showed the use of computer and musical software accelerating the development of new musical forms.

In the modern landscape of algorithmic music and AI, the composing process integrates randomization and recombination of information, indeterminate approaches, and more techniques with minimal human intervention. Results of the survey largely represented composers' clear needs of digital tools. Each participant uses more than two software to create and manage the audio content. On the subject of ownership, many of the technical decisions indirectly involve compositional decisions. Composers integrate different manners of compositional approaches with the computer automatically producing the output. Despite the processing, the response of the survey showed that participants believe music is more human-oriented. As Cope argues, musical intelligence is an extension of the human mind. In the relationship between machines and musicians, one should never replace the other. The survey findings also suggested a positive future outlook of truly creative and original AI which could add to the spontaneity and subjectivity of music. The combination of human and AI subverted the traditional means of how music is produced. Furthermore, the increased capabilities of computers and algorithms continue to play an important part in the musical discourse. For further exploration, there is a great opportunity to experiment multi-dimensional approaches to music creative processes.

5.2. Contributions

The paper contributes in the field of computer-assisted composition by providing a deep understanding of the complexities of algorithmic techniques. The multidisciplinary nature of algorithmic composition brings together many intersecting fields of artificial intelligence, arts and mathematics. The questionnaire results presented the idea that the computational techniques have altered the working environment for composers permanently. The findings of the paper could inspire programmers and software developers to design software products more attuned to composers and their creative needs. Composers' practical experience allows programmers to rethink the framework of existing systems. The participants' invaluable input to the study offered profound insights of the composer user experience. One of the participants Ring implied, that in the future the development of musical tools, the user-friendly interface and touch screen technology could provide new focus on music technology development. This could provide composers a space whereby they are able to work in an immersed and embodied environment, such as the use of touch screens. Human-machine interfaces will make the interaction between the composer and computer more streamlined and integrated. It will also allow the composer to interact with the music performer or music interpreter.

Furthermore, the paper also contributes to the practical and theoretical aspects of algorithmic music. In the composing process, the need for AI languages in musical applications is increasing. The paper provides solutions on how to process AI-related musical problems. The intersection of music and technology brings a different perspective to music composition. Findings demonstrated that music generation should not be dependent on human effort alone. Many musicians benefit from the employment of intelligent instruments and programs. During the experimental process, composers discover new methods on music practices and achieve more than expected.

Moreover, by analysing music theory and the knowledge from multiple disciplines, the paper provides a scientific way to help the composer think algorithmically. Understanding and learning algorithmic techniques is becoming an essential need for composers to access and engage with compositional tools, and this paper explicitly responds to that need. In the larger context of the modern digital landscape, the paper stimulates composers to adapt the algorithmic techniques in order to further their individual compositional developments.

5.3. Limitations and Further Research

Considering to the limitation of the paper, the sample size is relatively small. Due to the scope of the research, the small-scaled sample group has inherent limitations. Participants could not contribute a musical database of various styles and genres. The analysis of musical genres is not the central focus of the study, but algorithmic compositions generally cover all styles of music. For example, electroacoustic music, contemporary classical music, jazz, interactive game music, dance music and experimental music, they all belong to the domain of contemporary music activity.

Overall, the research experience was a rewarding practice, and such experiences helped the researcher establish good research habits. Further investigation could focus on the exploration of compositional approaches of different musical genres. The qualitative research would be conducted on a larger scale to fill the gap of in-depth study in this field. The future study could also explore the collaboration between composers, and how they work together in order to discover the musical potential of different musical instruments.

Appendices

i. Sample Information Table

Composer	Age (years)	Organisation	Specialism	Experience (years)
Hugh O'Neill	48	Founder of Spitroast Records, a recording studio	Improvisation, recording engineering, trumpet performance	25
Judith Ring	44	Co-founder of Strike the Air, an events company	Experimental Irish music, electroacoustic music	20
Sebastian Adams	29	Director of Kirkos, an experimental contemporary music ensemble	Instrumental and experimental music, viola performance	10

ii. Participant Information Sheet

Study title:

Computer assisted algorithmic compositional approaches: The role of AI in music creative practices

Researcher Name: Mingmei Hao

Research Supervisor Name: Dr Natasa Paulberg

You are being invited to take part in a research study to be carried out in the School of Computer Science and Statistics at Trinity College Dublin (TCD).

Before you decide whether or not you wish to take part, you should read the information provided below carefully. Take time to ask questions – don't feel rushed and don't feel under pressure to make a quick decision.

You should clearly understand the risks and benefits of taking part in this study so that you can make a decision that is right for you. This process is known as 'Informed Consent'. Your participation is entirely voluntary, and you can withdraw at any time or refuse to answer any question without any consequences of any kind. You can change your mind about taking part in the study any time you like. Even if the study has started, you can still opt out.

Why is this study being done?

The study aims to gain insights into composers' perspectives of machine assisted composition and how much of the piece is effective by this. The purpose of this study is to gather subjective reviews and critical reflections from experienced individuals, in order to achieve a variety of responses from different musical approaches. This paper addresses the questions on how algorithms and technologies subvert the conventional means of how music is produced. Human-AI interaction embodies the current trends on what a digital area looks like.

By exploring the possible result of collaborative intelligence, the intersection of music and technology becomes a significant area for researchers. The incentive on organising the study is to provide a broad understanding on the role of AI in compositional processes. By building a bridge between computer algorithms and musical compositions, it would make an empirical and theoretical contribution towards the understanding of machine assisted music.

Who is organising and funding this study?

As the researcher, I am conducting the research for the purposes of obtaining an academic qualification. No funding is available for this study.

Why am I being asked to take part?

You have been chosen to participant due to your experience in this area (music), as the researcher believes your contributions would be invaluable considering your expertise and any prior experience. You are one of 3 that have been invited to take part.

How will the study be carried out?

The study will be carried out by survey, as you will need to fill in a questionnaire and email back to the researcher. You can find the questionnaire below. If you wish to do face-to-face questionnaire and to make oral comments, then you are very welcome to make further contributions to the study.

You are expected to have access to the Internet, via mobile phone or computer. Once you finished the questions you can send back to the researcher.

What will happen to me if I agree to take part?

Your contributions would be in the form of a questionnaire document, which consisting of a series of questions (9-15 questions, no more than 15), and some general questions. You are expected to take 30 minutes to complete the questionnaire, but it will depend on your answers.

You will start with warm-up questions which are simple to answer, such as age and specialism. The questionnaire is mostly based on open-ended questions, you are very encouraged to answer the questions in details and make extra comments. Subjective responses to the questions are also encouraged. You can skip a question if you do not wish to answer, and you do not have to discuss the topics you do not wish to. However the researcher would be grateful if all questions are responded to. All answers are kept private and confidential.

What are the benefits?

Whilst there are no immediate benefits for participants, it is hoped that this study will contribute to a gap in in-depth analysis to the nature of machine assisted music in a contemporary context.

It would assist the researcher close the gap in minority representation on computer generated musical tools, allowing for greater generalizability on the applied music approaches based on research findings. The probable benefits to be derived from the research would be learning benefits for participants' further development. Participating in research should be a positive experience, it would offer them a new point of view on an academic and deeper understanding of such creative process.

What are the risks?

Due to the non-sensitive topics and non-vulnerable populations the subject matter, participants will be less likely to find themselves uncomfortable during the process. The method will be based on questionnaire, participants may feel the loss of privacy. The questions may evoke personal viewpoints or experience that participants may not wish to reflect on their answers. In order to minimize the risk of it, the researcher should conduct the questions carefully and only reference personal viewpoints that is absolutely essential to the research activity.

The researcher will communicate to participants that personal opinions will be a part of the survey, however they could choose to give less subjective response to the questions. Participants are free to omit any question. No information will be withheld from them on the entire research.

Will it cost me anything to take part?

The cost to take part in the research is virtually zero, the participants are expected to have access to the Internet.

Is the study confidential?

Any information and data collected for the research will be kept confidential.
If any participants do not hope to be identifiable in any publication or record, their names will be in either initials or short. For example, Kelly Murphy will be abbreviated as KM.

The data generated from questionnaire will be stored online, it will be used for the sole purpose of analysis. No data will be sent or shared. The dissertation supervisor and the researcher will have access to the data, and nobody outside the research will have access to the data. Any information or samples will not be used in future research studies without permission of participants.

The data will be retained for 2 months until the end of the study. The data will be destroyed after, and all electronic data will be deleted permanently in the end of the study.

Any conflicts of interest?

Conflicts of interest is considered of the research. There is no potential conflicts of interest. Personal or commercial relationship is not involved. No contradictory interests exist within individuals or institutions.

Where can I get further information?

If you have any further questions about the study, do not hesitate to ask me.
If you need any further information now or at any time in the future, please contact:

Mingmei Hao
haom@tcd.ie
086 8850570

Dr Natasa Paulberg
patersn@tcd.ie

Thank you for taking the time to read the sheet and consider to participate.

iii. Sample of Questions

1. What programs/software do you use?
2. What coding approaches to you use? (if any)
3. In your music production process, is there any aspect of the compositional process utilizes computer operated systems?
4. What algorithmic approaches do you use? Which ones involve the computer?
5. What part of the score is controlled by you, the composer? (human element)
6. What sort of randomization/recombination of information/musical elements do you use?
7. Do you use any indeterminate approaches?
8. Would you like to approach differently on your music practice? (if you haven't yet) Machine-assisted, AI-assisted etc?
9. Do you see a positive future of collaborative intelligence (human and AI) in music industry?
10. Can you give examples of your work that use algorithms/AI/non-human tools etc and describe your process?

References

Alpern, A. (1995). Techniques for Algorithmic Composition of Music. Available at: https://www.semanticscholar.org/paper/Techniques-for-Algorithmic-Composition-of-Music-Alpern/0c239a5c8a407088e5e01b2749dc75a83317b94b [Accessed 22 Mar. 2020].

Ashby, A. (2001). Schoenberg, Boulez, and Twelve-Tone Composition as "Ideal Type". *Journal of the American Musicological Society*, 2001, vol. 54, no. 3, pp. 585–625.

AIVA. (2019). I am AI - AI Composed Music by AIVA. Available at: https://www.youtube.com/watch?v=Emidxpkyk6o [Accessed 12 Apr. 2020].

Adams, S. (2019). Sebastian Adams's website. Available at: https://www.sebastianadams.net/ [Accessed 25 Apr. 2020].

Biles, J. (1994).GenJam: A Genetic Algorithm for Generating Jazz Solos. *International Computer Music Conference*, 1994, pp. 131-137.

Boyer, C. B. (1951). The Foremost Textbook of Modern Times. *The American Mathematical Monthly*, 1951, vol. 58, no. 4, pp. 223. Available at: http://mathshistory.st-andrews.ac.uk/Extras/Boyer_Foremost_Text.html [Accessed 15 Feb. 2020].

Cowell, H., and Nicholls, D. (1996). *New Musical Resources*. New York: Cambridge University Press, 1996.

Cowell, H., and Godwin, J. (1969). *New Musical resources: With a preface and notes by Joscelyn Godwin.* Something Else Press, Inc., 1969.

CMC. (2016). Contemporary Music Centre's Salon. Available at: https://www.cmc.ie/events/2016/may/contemporary-music-centre-salon-series-2016-sebastian-adams [Accessed 29 Apr. 2020].

Cope, D. (2018). Portfolio website for David Cope. *Artsites.ca.* Available at: http://artsites.ucsc.edu/faculty/cope/music.htm [Accessed 15 Feb. 2020].

Cope, D. (1996). *Experiments in Musical Intelligence.* Vol. 12 Computer Music and Digital Audio Series. Madison, WI: A-R Editions, 1996.

Cope, D. (2000). *The Algorithmic Composer.* Wisconsin: A-R Editions, Inc., 2000.

Cope, D. (2001). *Virtual Music: Computer Synthesis of Musical Style*. Cambridge: MIT Press, 2001.

Collins, N. (2018). Origins of Algorithmic Thinking in Music. In *The Oxford Handbook of Algorithmic Music*. Oxford University Press, 2018.

Caianiello, E. R. (1984). *Cybernetic Systems.* London: Research Studies Press.

Crocker, R. (1963). Pythagorean Mathematics and Music. *The Journal of Aesthetics and Art Criticism*, 1963, vol. 22, no. 2, pp. 189–198.

Collins, D. (1995). Musical Terminology in the Canonic Works of Bach: An Historical Context. *Bach*, 1995, vol. 26, no. 1/2, pp. 91–101.

Collins, D. (1999). Bach and Approaches to Canonic Composition in Early Eighteenth-Century Theoretical and Chamber Music Sources. *Bach,* 1999, vol. 30, no. 2, pp. 27–48.

Crawford, R., and Fox, R. (2016). *Artificial Intelligence Perspectives in Intelligent Systems*. Brno: Springer, 2016.

Denscombe, M. (2008). The Length of Responses to Open-Ended Questions: A Comparison of Online and Paper Questionnaires in Terms of a Mode Effect. *Social Science Computer Review*, 2008, vol. 26, no. 3, pp. 359–368.

Daylight Music. (2008). Kate Ellis - Up to my f-holes (Judith Ring). Available at: https://www.youtube.com/watch?v=d6r6WlX1Ejg [Accessed 15 Apr. 2020].

Dawin, J. R. (2010). Markov Chain Analysis of Musical Dice Game. *ResearchGate.* Available at: https://www.researchgate.net/publication/45913718_Markov_Chain_Analysis_of_Musical_Dice_Games [Accessed 16 Feb. 2020].

Dean. R. T. and McLean, A. (2018). *The Oxford Handbook of Algorithmic Music*. New York: Oxford University Press, 2018.

Dannenberg, R.B. (2000). Artificial Intelligence, Machine Learning, and Music Understanding. *Computer Music,* 2000. Available at: https://www.semanticscholar.org/paper/Artificial-Intelligence-%2C-Machine-Learning-%2C-and-Dannenberg/9618ecdd92c85f2813dc83e3470405fb27552bc8 [Accessed 9 Apr. 2020].

Fiebrink, R., and Caramiaux, B. (2018). The Machine Learning Algorithm as Creative Musical Tool. *Oxford Handbook of Algorithmic Music*. Oxford University Press, 2018. Available at: https://www-oxfordhandbooks-com.elib.tcd.ie/view/10.1093/oxfordhb/9780190226992.001.0001/oxfordhb-9780190226992-e-23 [Accessed 25 Mar. 2020].

Forte, A. (1967). Computer-Implemented Analysis of Musical Structure. In *Computer Applications in Music*, West Virginia University, Morgantown, 1967.

Goldmark, D. (2007). Tunes for 'Toons: Music and the Hollywood Cartoon. London: University of California Press, 2007.

Higgins, H., and Kahn, D. (2012). *Mainframe Experimentalism: Early Computing and the Foundations of the Digital Arts*. London: University of California, 2012.

Hiller, L., and Baker, R. (1964). Computer Cantata: A Study in Compositional Method. *Perspectives of New Music,* 1964, vol. 3, no. 1, pp. 62–90.

Jakubowska, J. H. (2011). Music perception of avant garde: Musical structure and time. *ResearchGate.* Available at: https://www.researchgate.net/publication/228953564_Music_perception_of_avant_garde_Musical_structure_and_time [Accessed 5 Mar. 2020].

jMusic. (2020). Music composition in Java. Available at: https://explodingart.com/jmusic/ReferencesLinks.html [Accessed 1 Apr. 2020].

Kostka, S. (2016). *Materials and Techniques of Post Tonal Music.* New York: Routledge, 2016.

Koza, J. (1992). *Genetic Programming: On the Programming of Computers by Means of Natural Selection*. Cambridge: MIT Press, 1992.

Keats, J. (2006). John Koza Has Built an Invention Machine. *Popular Science*, 2006, vol. 268, no. 5, pp. 66–92.

Kouritzin, S. G., Piquemal, N. and Norman, R. (2009). *Qualitative Research: Challenging the Orthodoxies in Standard Academic Discourse(s).* New York: Routledge, 2009.

Kiddle, G. (2020). *Learning Music Theory with Logic, Max, and Finale.* New York: Routledge, 2020.

Loy, G. (2006). *Musimathics, Volume 1: The Mathematical Foundations of Music.* Cambridge: The MIT Press, 2006.

Manning, P. (2004). *Electronic and Computer Music.* New York: Oxford University Press, 2004.

Milstein, S. (1992). Schoenberg's Serial Odyssey. *Music & Letters*, 1992, vol. 73, no. 1, pp. 62–74.

McBride, J. L. (2019). Advance Recordings: Innovative Label for American Twentieth-Century Avant-Garde Music, *ARSC Journal*, 2019, vol. 50, no. 1, pp. 1–43.

Maurer, J. (1999). Interactive Electronics in Computer Music and Chris Chafe's "Push-Pull" composition. *Stanford University.* Available at: https://ccrma.stanford.edu/~blackrse/interactive_electronics.html [Accessed 9 Jan. 2020].

Maurer, J. (1999). A Brief History of Algorithmic Composition. *Stanford University.* Available at: https://ccrma.stanford.edu/~blackrse/algorithm.html [Accessed 9 Jan. 2020].

Nierhaus, G. (2009). *Algorithmic Composition: Paradigms of Automated Music Generation*. Mörlenbach: Springer Science & Business Media, 2009.

Nuhn, R., Eaglestone, B., and Ford, N. (2002).A Qualitative Analysis of Composers at Work. *ResearchGate.* Available at: https://www.researchgate.net/publication/228609098_A_Qualitative_Analysis_of_Composers_at_Work [Accessed 9 Apr. 2020].

OpenAI. (2020). OpenAI site. Available at: https://openai.com/ [Accessed 28 Mar. 2020].

Opusmodus. (2020). Opusmodus quick guide. Available at: https://opusmodus.com/media/pdf/Quick%20Guide.pdf [Accessed 19 Apr. 2020].

Rowe, R. (2001). *Machine Musicianship*. London: MIT Press, 2001.

Ring, J. (2008). Judith Ring's website. Available at: http://www.judithring.com/about/ [Accessed 15 Apr. 2020].

Rogelberg, S. G. (2004). *Handbook of Research Methods in Industrial and Organizational Psychology*. Oxford: Blackwell Publishing, 2004.

Riedweg, C. (2008). *Pythagoras: His Life, Teaching, and Influence.* New York: Cornell University Press, 2008.

Roads, C. (1980). Artificial Intelligence and Music. *Computer Music Journal*, 1980, vol. 4, no. 2, pp. 13–25. Available at: https://www.jstor.org/stable/3680079 [Accessed 2 Mar. 2020].

Smith, L. (1973). Henry Cowell's Rhythmicana. *Anuario Interamericano De Investigacion Musical,* 1973, vol. 9, pp. 134–147.

Sitsky, L. (2002). *Music of the Twentieth-century Avant-garde: A Biocritical Sourcebook.* Westport: Greenwood Press, 2002.

Schwanauer, S., and Levitt, D. (1993). *Machine Models of Music.* London: MIT Press, 1993.

Schwartz, E., and Godfrey, D. (1993), *Music Since 1945: Issues, Materials, and Literature.* New York: Schirmer Books, 1993.

Simoni, M. (2003). Algorithmic composition: A gentle introduction to music composition using LISP and common music. *ResearchGate.* Available at: https://www.researchgate.net/publication/303911920_Algorithmic_composition_A_gentle_introduction_to_music_composition_using_LISP_and_common_music [Accessed 10 Feb. 2020].

Srivastava, T. (2014). Introduction to Markov chain. *Analytics Vidhya.* Available at: https://www.analyticsvidhya.com/blog/2014/07/markov-chain-simplified/ [Accessed 5 Mar. 2020].

Vogt, W. P., Gardner, D. C., and Haeffele, L, M. (2012). *When to Use What Research Design*. New York: Guilford Press, 2012.

Winograd, T. (1968). Linguistics and the Computer Analysis of Tonal Harmony. *Journal of Music Theory*, 1968, vol. 12, pp. 2-49.

Xenakis, I. (1992). *Formalized Music: Thought and Mathematics in Composition.* Stuyvesant: Pendragon Press, 1992.

Zaripov, R. (1960). An Algorithmic Description of a Process of Musical Composition. *Soviet Physics Doklady,* 1960, vol. 5, pp. 479-482.