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Aesthetic Implications Of Using The Computer Medium In Music

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AESTHETIC IMPLICATIONS OF USING THE COMPUTER MEDIUM IN MUSIC

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In this thesis, I reflect on the relationship between the materiality of computers and computer music. Marshall McLuhan and Friedrich Kittler had a fundamental role in unraveling how media shape discourse and influence their conveyed message and history. These were important discoveries that built the foundation for the field of Media Studies. Throughout this thesis, I will revisit reflections of researchers who contributed to this field and point out how the medium molds computer music's history and aesthetics. After reviewing the role of the materiality of computers, I will indicate some aesthetically compelling directions of computer music, which consider features of the medium's materiality rather than hiding them as if they were illegitimate.

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by

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INTRODUCTION

The relationship between medium and message is a subject that has intrigued scholars in the field of media studies. Researchers of this field were responsible for unravelling innate features of numerous media, from traditional – handwriting and traditional musical score, for instance – to recent ones – typewriter, phonograph, tape, and computer – and how they are related to the media's product. The approach to this relationship led to questioning the aesthetic implications from the use of a certain medium. At last, every medium has its own possibilities and limits, which offer constraints to artists during the creative process. Consequently, it is paramount to insist on investigating the media and be conscious of how these media mold the final artistic product.

When narrowing the object of study to digital media the connection to its message becomes even more mystified because of, among others, the possibility of converting data to almost any channel – image, sound, video. The extensive experimentation with computers has definitely prompted more questions about this topic and expanded the boundaries of artistic possibilities. Nonetheless the materiality of computers, although unique, impose their own limits as any other medium. Hence, in this thesis I will focus on the aesthetic implications of using the computer medium in music. Arguing that computers establish limitations, I point out how these limitations influence and, possibly, help our music expression and how the materiality of these machines generate glitches, which are interesting zones for artistic ideas.

The German theorist and philosopher Friedrich Kittler plays a central role in the field of media studies. He started from Marshall McLuhan's motto "the medium is the message", and Walter Benjamin's "historicity of perception" to develop a series of reflections regarding how media shapes discourse. In his investigation of incipient technologies of the 19th century, Kittler explains how the phonograph changed musical paradigms. Unlike traditional music notation, which can only store the writing itself representing musical notes, Edison's invention made it possible to capture, store and reproduce sound. So, music was not only musical notes anymore, but it also became frequencies and noises[1]. This medium opened the door for sound manipulation, particularly TAM (Time Axis Manipulation). As Rehding states, Kittler left a wide production, which approaches several other media and their history, and influenced numerous scholars who intend to broaden our understanding of mediation.[2] Conversely, Magnusson argues that software such as SuperCollider, CSound, Pure Data, and Max/MSP impose their particular constraints that are necessary for creative engaging in musical composition. While there are programming environments that grant users more freedom, some creators choose to work with more restrictive software to avoid creative paralysis and to have their musical expression's potential increased.[3]

On the other hand, Olson, discussing how synthesizers are able to produce sounds based on data that inform diverse parameters – such as, frequency, intensity, growth, duration, decay, portamento, timbre, vibrato and variation, tends to perceive digital media as an ideal medium, which is able to surpass all laws of physicality[4]. He expounds that synthesizers do not have any inherent physical limitation, so they can produce sounds without unwanted noises un-realizable by acoustic instruments. On the contrary to this idealist statement and a immaterial understand of

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[1] Friedrich A. Kittler, *Gramophone, Film, Typewriter* (Stanford: Stanford University Press, 1999), 24
[2] Alexander Rehding, "Discrete/Continuous: Music and Media Theory after Kittler," Journal of the American Musicological Society 70, no. 1 (2017): 222–3.
[3] Thor Magnusson, "Designing Constraints: Composing and Performing with Digital Musical Systems," Computer Music Journal 34, no. 4 (Winter 2010): 62-66.
[4] Olson, Harry F. and Belar Herbert. "Electronic Music Synthesizer." The Journal of the Acoustical Society of America 27 (1955): 595.

computers, Arild Fetveit explains how computer glitches reveal the materiality of the computer and questions the supposed perfection of the digital medium.[5] Furthermore, Howe discusses the limitations that musicians face while performing with synthesizers.[6] Even though Howe admits that the synthesizers broadens the range of musical possibilities in comparison to acoustic instruments, he points out that these possibilities are not unlimited. For example, he states that keyboard devices can produce more timbral variety than acoustic keyboard instruments, but their capacity of producing glissandi is fairly limitative – some glissandi can be produced, but glissandi of individual notes in their own pace and in different directions are not possible. Besides imposing performance restrictions, the materiality of the machine is also responsible for glitches, which are often used for artistic purposes, according to Cascone.[7]

Even though some of Olson's conclusions about the flexibility of the digital medium are accurate, he does not mention that this medium imposes its own constraints. Also, his premise that "bow scratching and the rushing of wind instruments and clatters in plucked string instruments" are undesirable sounds is not necessarily true, since these sounds are consequences of the materiality of acoustic instruments and not only add a natural quality to their sound, but also may be used in expressive ways.[8] In fact artist, such as, Brian Eno recognize the expressivity of the medium noise as they can be a starting point for emotional engagement.[9] Therefore, my investigation is directed towards how innate features of computers, such as their

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5 Arild Fetveit, "Medium-Specific Noise," in Liv Hausken ed. Thinking Media Aesthetics (Berlin: Internationaler Verlag der Wissenschaften, 2013), pp. 211.

6 Hubert S. Jr. Howe, "Compositional Limitations of Electronic Music Synthesizers," Perspectives of New Music 10, no. 2 (Spring - Summer 1972): 120-129.

7 Kim Cascone, "The Aesthetics of Failure Post-Digital Tendencies in Contemporary Computer Music," Computer Music Journal 24, no. 4 (Winter 2000): 12-18

8 Olson, Harry F. and Belar Herbert. "Electronic Music Synthesizer." The Journal of the Acoustical Society of America 27 (1955): 595.

9 More Dark Than Shark, "The Revenge of the Intuitive" (accessed 12 May 2022) <https://www.moredarkthanshark.org/eno_int_wired-jan99.html>

dissociative discrete operating system, inform the musical thinking and expression and, consequently, shape the musical product. While most scholarship makes disseminates important information about technical aspects of computer music to explore and broaden the possibilities of the digital medium, I will focus on the constraints of this medium as a remarkable feature to inform our creative process. These limitations not only may help our musical expression, but, when imposing restrictions, generate glitches. These failures represent a resistance force of this medium, but it can also be artistically explored and create a particular aesthetic.

In the first chapter of the thesis, I will focus on a historical overview of media studies, and I will present scholarly contributions on media that are used to produce music (musical score, phonograph, and computer). After exploring this information, I will consider the computer medium in more detail the second chapter. In Chapter III, I will explore music that was created using computer under a historical and technical perspective. In Chapter IV, I will examine the Human-computer Interaction and how this plays a determining role during musical creation and performance. Finally, I will discuss in Chapter V the aesthetic implications that are imposed to music by using computer in its creation process.

CHAPTER I

MEDIA STUDIES

Introduction

In this chapter I present a historical and theoretical overview of media studies. I start by mentioning the main contributions of Marshall McLuhan and Walter Benjamin and how they influenced an important researcher and philosopher of this field, Friedrich A. Kittler. Then, I explain how Kittler was inspired by the discourse and the analysis made by Michel Foucault, but also thought that his approach had limitations as he only regarded analog media. After pointing out the foundations of the thought of Kittler, I approach his theory and legacy in more detail. Finally, I prompt some reflections about two musical media, the musical score and the phonograph.

Historical Overview

Early Stage of Media Studies

The Canadian philosopher Marshall McLuhan first explained his motto "the medium is the message" in his book *Understanding Media: The Extensions of Man*, which was published in 1964. According to McLuhan, "the social and personal consequences of any medium – which is defined as an extension of ourselves – result from the new scale that is introduced into our affairs by each extension of ourselves, or by any new technology." [10] In the second chapter McLuhan presents two distinctive classifications for media – hot media and cool media. While hot media

[10] Walter Benjamin, "The Work of Art in the Age of Its Technological Reproducibility," *Grey Room* 39 (Spring 2010): 23.

“extends one single sense in "high definition”” and “do not leave much to be filled by the audience,” cool media is in “low definition” and leaves a lot to be filled by the audience. Some examples of hot media include radio, movies, and some examples of cool media include telephone, TV, cartoon[11].

Another researcher who made expressive contributions to media studies was the German-Jewish philosopher Walter Benjamin. His approach takes into consideration the mutability of diverse mediations, and how they configure our experience. Within the scope of mutability of our perception, Benjamin introduces in the concept of “historicity of perception”, that is, the idea that our “mode of perception” changes throughout history.[12] Therefore, he focuses on understanding the transformation over the historical periods of our perception, which is always mediated in a technical manner. He approaches the historicity of perception from two different angles: He researches the changes of the sensory experience caused by *Apparate* and also “these changes in the technical and material culture of the 19th century.” [13]

In his writings, the terms *Apparat* and *Medium* play an important role. While *Apparat* is used to refer to “technical artifacts” that confer organization to the realm of perception, *Medium* refers to the environment in which the sensory experience happens.[14] Within the frame of *Aparrat*, Benjamin differentiates the “perceptual apparatus” – that is, our human “apparatus of perception” – and “all the forms of auxiliary apparatuses,” which are the machines humanity created to intensify our senses.[15]

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[11]Marshall McLuhan, *Understanding Media : The Extensions of Man*. (Cambridge: MIT Press, 1994), 30-31.
[12]Antonio Somaini, “Walter Benjamin’s Media Theory: The Medium and the Apparat,” *Grey Room 62* (Winter 2016): 7.
[13] Ibid, 10.
[14] Ibid, 7.
[15] Ibid, 11.

The German theorist Friedrich A. Kittler bears the insights of McLuhan – "Media is the message" – and Benjamin – "historicity of perception" and "reproducibility of art" – in writing his own theory of Media highly influenced by French post-structuralism. The core of Kittler's second period works laid on discourse analysis, which was also a central subject in the work of the French post-structuralist philosopher Michel Foucault. One of Foucault's assets to history was to concentrate on the conditions of a given historical period and society that make possible the emergence of certain events and discourses, instead of doing an exegesis. In his self-classified archaeological work, the French philosopher was particularly interested in "the limits and the forms of expressibility," "the limits and forms of conservation," "the limits and the forms of memory such as it appears in the different discursive formations," "the limits and the forms of reactivation," and "the limits and the forms of appropriation."[16] Therefore, the study of discourse taking into consideration exterior dimensions leads to following outcomes: treating a discourse as a monument, seeking to comprehend "the condition of existence" of certain discourses and relate the discourse to its external environment instead of the particular subject who may have proposed it.[17]

Even though Kittler recognizes the importance of analyzing discourse as established by Foucault, the German philosopher criticized its narrow focus on written discourse. Kittler goes even further and states that Foucault's research was not capable of covering much of what happened after the mid-1800's, so he proposes that archaeologists of his time should acknowledge technological media that can store, transmit and calculate data. According to him, the monopoly of writing (alphabetic storage) faded out with the advent of data-processing methods.[18] As a

[16] Michel Foucault and Anthony M. Nazzaro, "History, Discourse and Discontinuity." *Salmagundi* 20 (Summer-Fall 1972): 233-5.
[17] Foucault and Nazzaro, "History, Discourse and Discontinuity," 233-5.
[18] Kittler, *Discourse Networks 1800/1900* (Stanford: Stanford University Press, 1990): 369-70.

consequence, Kittler was responsible for shifting the focus from textual archives to technical media in discourse analysis.

What are Media Studies?

Objects of Study

Whereas the main interest of Media studies evidently resides on Media, the field can be approached in numerous ways. McLuhan values the importance of the impact that media has on society, while Benjamin – as the researcher who proposed the historicity of perception – aims to explain how media change our perception. Kittler, who departs from Foucault's interest in analyzing discourse, researches how media shapes discourse.

These three approaches share the highlighting of the media itself, rather than studying the media's content alone. Besides focusing on media and on how their inner structure works to engender a product, media studies examines the numerous impacts of media. In the matter of this discipline, the content is always understood because of a specific medium. After all, due to how the media shapes the environment and imposes restrictions, the content's condition remains as a sequel of the media. To better understand what is at the center of media studies, I cite McLuhan's statement "the impact of the content is incidental comparing to the impact of the media itself."[19]

Studied Media

All concepts of media can be the object of Media studies. For instance, Benjamin highly engaged his research on understanding photography and film, while McLuhan, who had a broad

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[19] NotPercy203, "Marshall McLuhan - The Medium Is The Message [1977] (Media Savant)," *YouTube* video, 8:45. January 2, 2016. https://youtu.be/UoCrx0scCkM

understanding of what media is, approaches among other motorcar, games, telegraph, typewriter, telephone, phonograph, movies, radio and television in his book *Understanding Media*. In comparison to the Canadian philosopher, Kittler has a stricter notion of media. However, this more exclusive definition did not prevent him from investigating several media – such as the phonograph, tape, film, typewriter, and computer.

The Media Archaeology Lab, founded by professor Lori Emerson and supported by the University of Colorado at Boulder, maintains a vast archive of media from the past, including hardware (computers systems, computer devices, game systems, e-books, typewriters, lie detectors, cellphones, phones, and teletype), software (floppy disks, cartridge, CD-ROM, cassettes, DVD-ROM, punched cards and VHS), and audio-visual devices (televisions, cameras, cd-players, cassette recorders, Walkman, stereoscope, projectors, slide viewers).[20] The Media Archaeology Lab gathers all these material with the intention of conducting research using functioning media from the past.[21] In essence, any media, regardless of content, can be object of investigation of media studies.

Friedrich Kittler's Perspective

Media According to Kittler

The question "What is Media?" cannot be followed with a simple answer. This concept varies from author to author and even within the bibliographical production of a researcher, we may find more than one definition or different ways of using it – such as in Benjamin's writing.

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[20] Media Archaeology Lab, "Collection," (accessed 12 May 2022) <https://www.mediaarchaeologylab.com/collection>

[21] Media Archaeology Lab, "About," (accessed 12 May 2022) <https://www.mediaarchaeologylab.com/about>

In 1985, Kittler presents an objective definition: media are technologies that are able to "select, store, and process relevant data."[22] Due to the limiting properties that emerge from the materiality of Media, all discourses are consequence of historically existing Media technology.[23] As Kittler had a historical narrative based on the technical media, he presents a divergence point with McLuhan in his understanding of media. The German philosopher understands that "Men are extensions of Media", rather than "Media are extensions of Man."[24]

History of Media

Technical media, such as photographic camera, phonograph and film, only started being popularized from the end of the nineteenth century into the first half of the twentieth century. Therefore, until then, most of the information circulated through the analog written medium, i.e., in books. Kittler differentiates the discourse generated by these two types of media. He classifies the discourse resultant from the analog media as the "Discourse Network 1800", which is characterized by the monopoly of books, the only medium that could store serial data.[25] Differently from technical media that could store audio and image, writing was only able to store writing itself. Therefore, in order for the alphabetical signs to be fully comprehended, instead of only read, their meaning must be imagined by gaining figural qualities.[26] On the other hand, Discourse Network 1900 broke the written monopoly with the emergency of technical media, which can store data, with any sort of logical filter. Finally, media did not rely on the figure of the interpreter who translates the reality into writing passing through his logic filter. Technical media stores data without using "the code of a workday language," in fact, it utilizes physical

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[22] Kittler, *Discourse Networks 1800/1900,* 369.
[23] Ibid, 369-71.
[24] Jordan Carroll, "Introduction to Friedrich Kittler" YouTube video, 12:12. December 16, 2015. https://youtu.be/UoCrx0scCkM
[25] Kittler, *Discourse Networks 1800/1900,* 116.
[26] Ibid, 86.

processes that are faster than our perception and can only be formulated thanks to the code of modern mathematics.[27]

In the twenty-first century, there was a rapid growth of the use of digital media, which are nowadays our main source of communication. According to Kittler, digital media work similar to an alphabet, but using numbers. Instead of using continuous functions, digital media translates them into discrete data, by scanning them in equidistant points (similar to film recording that preserved a series of pictures taken at equidistant intervals of time). In digital media, using binary system is an essential condition that makes their operation possible. Alan Turing inaugurated the principle of digital media with his universal discrete machine, which will be later discussed, and its principal can still be seen nowadays in the modern computers.[28]

Media Studies after Kittler

Cultural Techniques and Media Archeology

Two main branches s of Media studies were born from the Kittlerian tradition: "Cultural techniques" and "Media Archeology." Researchers from the German Media Theory – such as, Sybille Krämer and Bernhard Siegert – explore "cultural techniques" to broaden the understanding of operations that underlies mediality. Meanwhile, Media Archaeology researchers – such as, Wolfgang Ernst and Jussi Parikka – address epistemologies based on the medium. It is also characteristic of researchers from this field to analyze media history under less Eurocentric optics comparing cultural techniques' ones. In summary, the Media Archeology field tends to focus more

[27] Friedrich A Kittler, "The History of Communication Media," *ZERO - the Art of Being Everywhere (1993*): 73-4.
[28] Ibid, 77.

on epistemologies regarding media, while the Cultural Techniques field's main target are the practices.[29]

As mentioned by Siegert, Cultural Techniques accentuates the operation that antecede media. In other words, there are human practices that anticipate the conception of a medium – for instance, the musical notation system was created after a singing practice was already established. Therefore, the focus of researchers from this field resides in investigations regarding these human practices. Nonetheless, Cultural Techniques moves away from the substantive method of the Kittlerian approach: this new branch, instead of initiating its investigations with media, – starts with human practices and techniques that engender a medium.[30]

Media Archaeology's pioneers articulated contributions made by Foucault, Benjamin and Kittler in a new branch, which has been developing itself since the 1990's. This new branch focuses on studying past media (with an emphasis on unremembered and underrepresented ones), in order to understand the present and the future[31]. On the other hand, this field does not focus only on the technicity of the past media, but it also aims to comprehend how these are related to history and media culture. Therefore, Parikka defines Media Archaeology as "a conceptual and practical exercise in carving out the aesthetic, cultural, and political singularities of media."[32]

Notwithstanding there are similarities between Media Archaeology and Cultural Techniques, their differentiation lies on their relationship to signs and signals. As argued by Siegert, Media Archaeologists aim to analyze signals, rather than signs. That is to say, these

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[29] Rehding, "Discrete/Continuous: Music and Media Theory after Kittler," 224-5.
[30] Bernard Dionysius Geoghegan, "After Kittler: On the Cultural Techniques of Recent German Media Theory," *Theory, Culture & Society* 30, no. 6 (2013): 69- 70.
[31] Jussi Parikka, *What is Media Archaeology* (Cambridge: Polity Press, 2012): 2.
[32] Internet Archieve, "CTheory Interview: Archaeologies of Media" (accessed 12 May 2022) <https://web.archive.org/web/20160418164618/http://www.ctheory.net/articles.aspx?id=631>

researchers intend to investigate how a signal is processed in a determined medium. On the other hand, researchers from the Cultural Techniques field are focused on understanding the technical and engineering features of the medium as techniques.[33]

New Concepts of Media

Some of these researchers propose new definitions of media. For instance, Siegert considers that "media appears as code-generating or code-destroying interfaces between cultural orders and a real that cannot be symbolized."[34] Siegfried Zielinski, on the contrary, states "Media are spaces of action for constructed attempts to connect what is separated."[35] Finally, the Media Archaeologist Wolfgang Ernst defines "*media* as electronic media that store, compute, and transmit data independently".[36] He disregards pre-modern communication devices, because they necessarily imply the presence and action of humans.[37]

Media and Music

Musical Score

The search for visually represented notes arises from the necessity of establishing a liturgical repertoire of melodies, possibly started in the eighth century in the medieval West.[38] A method for representing musical notes visually was proposed by Guido d'Arezzo in the late ninth century

[33] Jussi Parikka, "Afterword: Cultural Techniques and Media Studies," *Theory, Culture & Society* 30, no. 6 (2013): 154.
[34] Bernhard, "Cultural Techniques: Or the End of the Intellectual Postwar Era in German Media Theory," 62.
[35] Siegfried Zielinski, *Deep Time of the Media Toward an Archaeology of Hearing and Seeing by Technical Means* (Cambridge, MA: Massachusetts Institute of Technology, 2006), 7.
[36] Ann Marie Rasmussen and Markus Stock, "Introduction: Medieval Media," Seminar*: A Journal of Germanic Studies* 52, no. 2 (May 2016): 100.
[37] Ibid, 100
[38] Karol Berger, "The Guidonian Hand," in Mary Carruthers and Jan M. Ziolkowski ed. *The Medieval Craft of Memory: An Anthology of Texts* (University of Pennsylvania Press, 2002), pp.71.

– the Guidonian “hand.” This method proposes that every musical note is related to twenty different “places” (loca), which are parts of the hand. Another possibility of representing notes at this time was provided by the “scale” (scala), which, more similar to the modern musical score, differed the notes in a series of places that were arranged on the lines or on the spaces between them[39]. Due to their success in representing distinguished musical notes, these two methods of transcribing notes established themselves as paramount tools for memorization[40].

The creation of a method for translating music into writing legitimized music as a field of studies and gave it scientific status, since the sound could be fixed.[41] Even though scores are currently seen as an ontological document that defines a composition (by the fixation of pitches and rhythm), this medium contains limitations, which can manipulate the musical material after being translated to the notation system[42].

The musical score, like writing, was a European approach to time storing, which operated similarly to Lacan’s symbolic order (related to language, where signs are translated to a signified).[43] Like the process of translating speech into writing, the notation system controls the vast sound data to fit it into a system of twelve chromatic notes.[44] This discrete Western notation system disregards the sound of the rest of the world and was called into question with the advent of the phonograph – which remains in Lacan’s real order (state of nature).[45]

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[39] Karol Berger, The Guidonian Hand,” 76.
[40] Ibid, 77-8.
[41] Marija Maglov, “Musicology in the Context of Media – Media in the Context of Musicology,” in Tijana Popović Mladjenović, Ana Stefanović and Radoš Mitrović ed *Contextuality of Musicology: What, How, Why and Because* (University of Arts in Belgrade, 2020), pp. 284.
[42] Ibid, 288-289.
[43] Kittler, *Gramophone, Film and Typewriter*, 4.
[44] Ibid, 3.
[45] Ibid, 24.

Phonograph

In 1887, Thomas Edison created a machine that was able to capture, conserve, and reproduce soundwaves with fidelity to its original sound source. The nineteenth-century environment in which Edison was operating, was strongly influenced by an objectivistic ideal. In this environment, there were demands for machines that could conserve and duplicate information. Some machines contemporary to the phonograph were informed by these demands – for instance, the mimeograph (1876) and the, also invented by Edison, motion-picture camera (1888).[46] While Edison was working to improve Alexander Graham Bell's telephone, he created a device able to capture sound-waves – until there, considered fugitives – and store them permanently. Then, this sound could be reproduced to maintain its original features without the need of presence of the original sound source. Also, this sound could be multiplied indefinitely and be preserved with no need for the existence of the original source.[47] Because of this possibility of conserving sounds that were previously thought as "fugitive," this invention was a remarkable asset to history. Henceforth, a machine could have stored sounds of the present and they would have never been lost.[48]

In 1888, the phonograph was manufactured with a motor that revolved the cylinder without noise interference and at a uniform speed. Like with the previous equipment, the new cylinder made of wax, was recorded sound with indentations from the soundwaves. The diagram was the piece responsible for receiving the soundwaves and indenting them on the wax, by pressing a small point against it. After having recorded the sound, a delicate needle was able to

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[46] Lisa Gitelman, *Scripts, Grooves, and Writing Machines Representing Technology in the Edison Era*, (Stanford, CA: Stanford Press, 1999), 2.
[47] Thomas A. Edison, "The Phonograph and Its Future," *The North American Review* 126, no. 262 (May – Jun., 1878): 530.
[48] Gitelman, *Scripts, Grooves, and Writing Machines Representing Technology in the Edison Era*, 22.

reproduce these vibrations previously recorded in indentations and a tube amplified the sound to our ears.[49]

The impact of the introduction of this equipment in music, whose reproduction became the main purpose in the following century, is especially exceptional. Because of the possibility of storing noise and intervals that were foreigners to the Western music tradition, the phonograph switched the musical paradigms from notational to sonic. Besides capturing sound, the machine could play it back without any language or logical filter, thus conserving the authenticity of the performances.

As Kittler accurately analyses, the scripted grooves in the cylinder were nothing more than recording of vibrations.[50] Unlike the human brain, the machine does not pass the sound information into any conscious apparatus, therefore it can accurately capture sound. [51] Intervals and chords are concepts from Western music theory, which can only be conceived throughout a logical procedure. The intervallic relation is based on ratios, which the phonograph is not able to conceive. Because of that, music did not have to pass through the bias of the Eurocentric-musical notation to be conserved and many non-Western practices that utilized intervals smaller than a semitone could be accurately stored.

As Mark Katz points out, the phonograph had a greater impact in composition only several years later to its inventions, because most of the living composers did not have the opportunity to have their works recorded immediately after their composition.[52] Nonetheless, composers were

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[49] Thomas A. Edison, "The Perfected Phonograph," *The North American Review* 146, no. 379 (Jun., 1888): 642-645.
[50] Kittler, *Gramophone, Film and Typewriter*, 24.
[51] Ibid, 32.
[52] Mark Katz, "The Phonograph Effect: The Influence of Recording on Listener," PhD diss. (University of Michigan, 1999), 193-197.

influenced by phonographs in several ways. Features that promoted great changes were its portability and its ability to conserve sound.

In the late nineteenth-century, few important performers had the chance to make recordings with the phonograph. The sound machine was in an incipient state when Brahms became one of the first composers to have a direct contact with it. On October 30, 1889, Brahms heard through the phonograph recordings of an aria sung by Lili Lehman, a piano piece and a spoken recording. Later in the same sequence of events, his own work *Sapphische Ode* was interpreted by Rosa Papier and Franz Joseph I and this performance was recorded. On December 2 of the same year, in an event at Dr. Fellinger's house, Brahms recorded a section of the compositions *Libelle* by Strauss and his own arrangement of his *Hungarian Dance No. 1*.[53] Unfortunately, the cylinder was played several times, and the wearing severely decreased the quality of the audio. In 1935, in an attempt to preserve the characteristics of the performance Fritz Bose copied the audio of the cylinder to a long-playing disc, but damage had already been done.

This recording was thought not to be useful for musicological purposes, but in 1994 Berger and Nichols were able to capture musical data from it by applying "orthogonal trigonometric and wavelet-based analysis techniques."[54] Of their analysis of Brahms performance, I considered to be compelling the recognition of improvised parts. They mention that these improvised segments are from two different natures: "prominent melodic insertion within the phrase structures of the original scores, and alteration of phrase structure in order to

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53 Standford, "Brahms at the Piano" (Last accessed October 29, 2021) <https://www.cylinder.de/deeplink_resource_brahms.html>

54 Jonathan Berger and Charles Nichols, "Brahms at the Piano: An Analysis of Data from Brahms Cylinder," *Leonardo Music Journal* 4 (1994): 26.

facilitate closure at a nonterminal point of the piece."[55] The last kind of improvisation can be seen in measures 71-72 of the transcribed performance, indicating that Brahms applied augmentation of the duration figures to reinforce a conclusion by accentuating the last chord.[56] I argue that this anticipated ending had to be arranged to fit the composition in the time limit of the cylinder. The cylinder at the time of the recording could record around two minutes of sound, which was not enough for storing the whole composition.[57] This was one of the first times that the phonograph influenced compositional choices.

Stravinsky had an ambiguous relationship with the phonograph. Even though the Russian composer was amazed by the possibility of recording his own compositions, he was also concerned with issues that this machine could prompt. He was afraid that the easy accessibility of music could make listeners oversaturated and unable to discern quality compositions from the others.[58] Nevertheless, he was fascinated by the objectivity of the phonograph recordings and he believed that through it he would be able to preserve his compositional intentions by making recordings of himself performing his work. Differently from musical scores, recordings were able to capture sounds in the most detailed way leaving much less freedom for interpretation.[59] On the other hand, recording of his works may serve the opposite purpose. After 1929, Pierre Monteux's performance of *The Rite of Spring* was considered to be the main source of inspiration for interpretations of this work. Stravinsky was not pleased with this trend and published an article stating that the recording of himself conducting this piece by Columbia was

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[55] Berger and Nichols, "Brahms at the Piano: An Analysis of Data from Brahms Cylinder," 28-9.
[56] Ibid, 29.
[57] 45 Record Adapters, "13) All About The Records" (Last accessed November 22, 2021) <http://45recordadapters.com/10-record-types/ >
[58] Igor Stravinsky and Robert Craft, *Retrospectives and Conclusions* (New York: Alfred A. Knopf), 105.
[59] Katz, *The Phonograph Effect: The Influence of Recording on Listener*, 219-220.

the real model that should be used as a departure point for new performances.[60] Although he worked intensively on this idea that recordings should be a complement to the traditional score, not even his own performances were definitive, since within his own performances there are variations. For example, in his recording of the B section (rehearsal mark 149-161) of *The Rite of Spring* from 1929 he chooses a tempo for 120bpm, while in 1940 he increases the tempo of the recording to 145bpm and decreases back to 135bpm in his recording from 1960.[61]

The phonograph was also responsible for informing some of Stravinsky's compositions. There is some speculation about how some recordings of American popular music and of Spanish folk music would have influenced the composer to write the *Madrid*, *Española* and the *Pasodoble* from *L'Histoire du soldat*, *Ragtime for Eleven Instruments* and the *Piano Rag Music*.[62] Yet, Stravinsky saw the time limitation of phonograph recordsas a challenge, and he had this in mind while composing some of his works. A clear example is the *Sénénade en LA pour Piano*, in which the maximum length of the phonograph record was a predetermined limitation and reflected on the length of the composition itself.[63] At the same time, he disregarded this limitation as a factor for some of his other compositions. Even though Robert Fink found time marks on Stravinsky's copy of *The Rite of Spring* 1922 conductor score indicating time lengths up to 3'50" – the maximum capacity of the phonograph recording at that time – the composer decided to ignore this idea when recording the *Danse Sacrale*. After all, this

[60] Piero Weiss and Richard Taruskin eds. *Music in the Western World: A History in Documents* (Belmont, CA: Thomson and Schirmer, 2008), 392-4.
[61] Weiss and Taruskin eds. *Music in the Western World: A History in Documents*, 226.
[62] Ibid, 128.
[63] Stravinsky, *An Autobiography* (New York: W. W. Norton, 1962), 123-4.

would have increased the tempo to unfeasible 160 beats per minute. Therefore, he decided to record this episode on two different sides of the disc.[64]

All in all, Stravinsky's opinions about the phonograph were not always stable. He saw it as an astonishing tool for composers, but at the same time he feared the dangers that this machine could bring. Certainly, he benefited himself from recordings of folk music and, possibly, introduced ideas associated with the phonograph into his compositions. Regarding his own recordings, he believed that conserving his own performances would have served as a didactical source for the interpretation of his compositions. Although he left an extensive archive of recording of his own works, throughout the times these were not always selected as models for new interpretations. Furthermore, the phonograph had time limitations, which were sometimes considered by the composer as a structural factor for his works, but totally ignored in some others.

Another expressive implication of the phonograph was its use as a musical instrument. On June 18, 1930, a concert took place in Germany, with performances of three pieces for phonograph. Among the composers were Paul Hindemith, who presented two *Trickaufnahmen*, and Ernst Toch, who presented *Gesprochene Musik*. For *Trickaufnahmen*, Hindemith utilized three 78 rpm single-sided discs, one contained a melody with variation sung over one minute and the other two were identical – both contained xylophone and string instruments sounds. Due to the lack of information about Hindemith's procedure to compose this work, we can only speculate that, because of the technological restrictions of the time, the composer probably recorded two distinguished discs with viola sound and one with xylophone sounds. In the end of

[64] Katz, The Phonograph Effect: The Influence of Recording on Listener, 229.

the process, he probably played all the discs simultaneously with different playback speeds – resulting in a lower string instrument sound and a higher string instrument sound – and recorded a final version with these reproduced sounds.[65] Toch's composition was divided into three movements: the first two do not have a title and the last was named *Fuge aus der Geographie*. This last movement became Toch's most famous work and nowadays is performed without a phonograph – as a spoken choir piece, in which there is no indication of sung pitch. Since the discs utilized for this piece did not survive, it is not clear how this piece sounded.[66] However, Toch elucidates that he was trying to explore the extended functions of the phonograph, by searching its characteristic ways to operate. He analyzed its new possibilities and, using a recording of a spoken chamber choir, used techniques – such as, increasing tempo and pitch.[67]

Hindemith and Toch were not the only composers to experiment with phonographs in the first half of the twentieth century. The German composer Stefan Wolpe, inspired by the idea of simultaneities, organized in 1920 a Dada performance with phonographs. He had at his disposal eight phonographs, which could playback recordings at different speeds. He mentions that he was able to play Beethoven's Fifth Symphony simultaneously at several speeds, but he does not explain the specificities of this performance he organized when he was only 18 years old.[68]

Beyond all these experiments, much theory was written about the possibility of phonographic music. There was a lot of expectation that by scripting grooves directly in the disc, composers would stop depending on performers and, more important, would be able to produce new sounds

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[65] Mark Katz, "Hindemith, Toch and Grammophonmusik," *Journal of Musicological Research* 20 no. 2 (2001): 162-163.
[66] Ibid, 164.
[67] Ernst Toch, "Uber meine Kantate 'Das Wasser' und meine Grammophonmusik," *Melos* 9 (May-June 1930): 221-22.
[68] Austin Clarkson, Lecture on Dada by Stefan Wolpe, *The Musical Quarterly* 72, no. 2 (1986): 209-210.

– Hans Heinz Stuckenschmidt and Dorothy Swainson wrote about this possibility in 1927 and 1931, respectively. Stuckenschmidt, in particular, envisioned that it would be possible to do these micro-scripts with the help of a microscope and composers would be able to explore timbres, pitches and dynamics with high accuracy. Hansjörg Dammert imagined that the phonograph could be used as an instrument in live performance, accompanied with acoustic instruments. Also, Raymond Lyon believed pre-recorded noises could be used as sound materials to create musical landscapes.[69] However, before the vanishing of these discussions on the music journals in the 1930's, most likely little or nothing of these ideas was put into practice. On the other hand, it is possible to see many of these ideas resurfacing in different ways years later. The idea of scripting grooves into a disc to generate new timbres has some similarities with synthesizers created only in the 1960's. Hansjorg's concert for phonograph and acoustic instruments is similar to musical manifestations created in the second half of the twentieth century. Finally, Lyon's musical landscape resembles Pierre's Schaeffer's *musique concrète,* which used tape instead of phonographs.

Conclusion

Keeping these media studies theories in mind, I analyze the influence of the computer medium in our musical discourse. Like musical scores and the phonograph, computers offer possibilities and limitations due to their materiality. Hence, their role goes beyond the role of a mere tool, as they inform our musical practice. By examining computer music with this materialistic approach, I question common practices of the composer's community and formulate reflections about them.

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[69] Katz, "Hindemith, Toch and Grammophonmusik," 169-171.

Furthermore, this approach will help me stipulate interesting paths for computer music that explore the potentialities of the medium and places its materiality in the foreground.

CHAPTER II

COMPUTER MEDIUM

Introduction

In this chapter, I consider how the computer's materiality enables this medium to perform specific tasks and how they can be applied to music. First, I introduce the computer's elements and how they as a whole operates. Then, I explain how some computer's tasks, which are resultant of the medium's materiality, can be implemented into music. Not only computers are able to produce sound, both by playing back recorded or by generating synthesized sounds, but also they can perform equations that may help composers create coherence throughout their work. Finally, I will explore how some of the advancements in Artificial Intelligence may result in a reevaluation of the compositional practices.

Materiality of the Machine

How is it Built?

Computers are built with a large amount of two sorts of elements – switches and connectors. Being able to combine several signals into a single signal, switches are elements that allow us to steer the direction of the signal.[70] Complementing the function of the switches, connectors – which are wires – are responsible for transporting a signal from a switch to another. They can be divided into branches, which allow a signal to be carried from a single output to many inputs. Registers – capable of storing information – are elements that can be made with the elements

[70] W. Daniel Hills, *The Pattern on the Stone: The Simple Ideas That Make Computers Work* (New York: Basic Books, 1999), 24.

previously presented.[71] CPU – standing for central processing unit – performs calculations and manipulates blocks of bits. This unit can be divided into three parts: ALU – arithmetic logic unit, several RAMs – Random Access Memory – that stores variable data and a ROM – Read-Only Memory – that store commands and computing constants.[72]

How Do Computers Work?

Boolean Algebra

George Boole (1815 – 1864) was an English mathematician and a philosopher, who was responsible for the creation of *Boolean algebra*. When attempting to translate human logic into mathematical equations, he developed a language capable of "manipulating logical statements and determining if they are true or not" – the Boolean algebra. However, it was the American mathematician and engineer Claude E. Shannon (1916 – 2001) who applied Boole's thoughts to computer science with his master thesis "A Symbolic Analysis of Relay and Switching Circuits" for the Massachusetts Institute of Technology in 1940. In this work, Shannon pointed out the possibility of building electrical circuits that were analogous to the Boolean algebra expressions. Therefore, he built circuits, in which open or closed correspond to the variables false and true of Booleans algebra; circuits with active connections represent a true variable, while circuits in which the connection was broken was a false variable. This discovery, together with the *information theory* – theory that defines *bit* – constitute the most remarkable contributions that the American engineer made to computer science, building the pillars for its development.

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[71] W. Daniel Hills, The Pattern on the Stone: The Simple Ideas That Make Computers Work, 25.
[72] Kittler, *Gramophone, Film, Typewriter*, 243-4.

The switches can also be organized in series or in parallel, which will correspond to the "logic block" operations *And* and *Or*, respectively. While *And* implies that both switches need to be closed to establish a working circuit, *Or* needs only one of the switches to be closed or both to establish a working circuit. Differently from Shannon's experiments, nowadays computers use switches called transistors, nevertheless the basic foundations of switches organized in parallel or in series to produce the corresponding functions *Or* and *And* remain the same.

A Discrete Approach: Bits

Bits are the small unity of data that can be stored by a computer. They can be translated into two possibilities *1* or *0*, which form a binary signal. Computers use bits to produce any kind of content: colors, sound etc. The functional abstraction of defining data into *1* or *0* helps us to work with this information disregarding particular attributes of it. Thus, it is possible to apply functions to these building blocks repeatedly without mattering the details of what is inside it. This sort of procedure makes it possible to execute complex systems in simple ways. When organizing it into a hierarchical system of functional abstractions, it becomes an efficient tool to understand complex systems, since it allows the machine to work on a minimal aspect of the problem, instead of the complexity of the system itself. Together with the binary system, the idea of Universal Build Blocks implies that it is feasible to build anything with these blocks without the addition of external blocks. In conclusion, it is possible to generate any kind of data using a machine that operate with the properties previously regarded.

Universal Computers

As explains W. Daniel Hills, Universal Computers – a computer that is capable of simulating any computing system – was first mentioned by Alan Turing in 1937. He explained that mathematical operations could be performed by not only by humans what followed a set of rules of reading and writing data on a scroll but also by fine-state machines. In particular, *Turing Machines* is a fine-state machine with a long tape attached, which is analogous to the modern computer. This invention would interpret symbols on a tape and solve computable problems. Thus, problems would be solved by moving back and forth on this tape to interpret and write symbols that contained the solution on the tape. Taking into consideration *Universal Computer*'s Theory, it is possible to conclude that all these machines can only perform the same tasks and the only difference between them is their speed and memory size. In conclusion there is any machine nowadays that are able to perform beyond *Universal Computers*. For instance, a three-state computer – rather than a two-state computer that utilizes a binary system – cannot perform more tasks than the modern universal computers – since they can simulate any kind of ternary operation by using more than only one bit (for instance *00* can be used for *yes*, *11* for *no* and *01* for *a third option*). In a similar direction, an analog computer that could comport an infinite extension of values also is not able to perform better than our modern digital machines. Although analog computers can represent a continuous range of voltage between *0* and *1*, in the end this does not mean an improvement on the way it works. This feature allows signals that are random creating a considerable amount of noise. This noise always exists in electric circuits, and they can be a result of interference or a random disposition of molecules inside a wire. Since noise is always existent, there are a limited number of distinctions that are relevant, and they can be represent by 2-bits digital signals.[73]

Hills goes further and states that with the development of quantum computers, it is unpredictable exactly what kind of outcome can prompt from these new machines and if they

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[73] W. Daniel Hills, *The Pattern on the Stone: The Simple Ideas That Make Computers Work*, 63-6.

would be able to overcome the current Universal Computer. Despite the quantum world being discrete as a computer, it works with counterintuitive effects; for instance, in quantum mechanics one thing can be in more than one place at the same time, something which is impossible in our macro-scaled world. There is some expectation that computers could benefit from quantum effects and more powerful machines will be built. Since a quantum computer would be able to store superpositions of numerable 1's and 0's per bit – rather than only one element – it would be able to consider perhaps infinite number of possibilities at once, thus creating more powerful machines in comparison to our current computers, and it could perform tasks that are unfeasible to computers nowadays. On the other hand, Hills points out that there is no scientific evidence that our brain takes advantage of quantum mechanics to operate and, as the computer operates similarly to a human brain, the future effects of these machines can only be speculated.[74] Even if we leverage quantum mechanics to operate and our current computers are not capable of operating like our brains, universal computers play a paramount role in the way we think and we make music. In the following sections, I discuss how computers shape the history and the aesthetics of computer music and our creative thoughts.

Computer Possibilities in Music

Converting Sound Waves into Bits

As Thomas Edison's Phonograph, the computer is also capable of storing sound data through the same principle of measuring the pressure of the soundwave in the air. However, instead of utilizing a mechanical device, which in this case is a needle that engraves grooves to the wax

[74] W. Daniel Hills, *The Pattern on the Stone: The Simple Ideas That Make Computers Work*, 71-4.

cylinder –, computers digitize audio through a series of electric signals. The microphone is responsible for converting the acoustic sound waves into voltage that will later be input to the computer during the digitization process. In this process, the concept of storing sound data through its amplitude remains the same.[75] The use of voltage allows the computer to digitize the analog audio signal, which happens during the encoder stage. Digitizing audio eases the process of storing, processing, transmitting, and reproducing the audio data. To reproduce the stored audio, the coded audio needs to be converted back to analogue signal in the decoder phase. The common goal of coding sound is to achieve high quality, without demanding a lot of data.

Pulse code modulation (PCM) is the most disseminated way to code audio. It samples the audio signal into blocks at regular intervals whose amplitudes are quantized into finite codes. These codes are representations of the signal amplitude. Even though no loss is acquired during the PCM, it is the quantization stage that confers some loss to the final product. When the audio data is to be played back, computers decode it and interpole these segmented samples in to create an acoustic signal.[76] CDs established the standard for high quality digital audio for several years, while utilizing PCM. The most common value for the sample rate of a recording – that means, the number of samples that would be recorded per second – was 44.1 kHz, therefore a sample of audio would be taken every 0.023ms. This value is suitable for music recording since it makes it possible to conserve frequencies up to 22.05kHz. Differently from its predecessor – the vinyl, which could handle only frequencies up to 10kHz, the CD covers all the range of frequencies that humans can hear, since we can perceive frequencies up to 20kHz. If the sample rate is responsible for preserving the frequencies and the continuous sound, it is the bit rate that gives

[75] Marina Bosi and Richard E. Goldberg, *Introduction to Digital Audio Coding and Standards* (New York: Springer Science+Business Media, 2003), 3.
[76] Ibid, 6.

precision to the audio sample. An audio recording that used a bit rate of 16 will translate an audio sample into 16 bits, therefore this sample will be represented by 2^{16} discrete levels, covering amplitude ranges over 90 dB.[77] This transduction of original amplitude values into finite codes takes place in the quantization stage.[78] This stage finally converts the analog signal into digital data that can be stored, processed, and decoded by the computer.

Certainly, computers are able to transduce acoustic sounds into codes accurately preserving their features. One of the main interests of computer music lies on how this sound can be processed. The materiality of the vinyl did not allow much more sound transformation than changing the playback speed, possible through Times Axis Manipulation. Yet, the computer enables several options of processing, which together with sound synthesis are the pillars of computer music. Composers of computer music play the role of adventurous researchers of sounds that challenge the intuitiveness of the gesture-sound relation (one gesture, results in one sound paradigm). They operate the machine to produce sounds that pass through abstract equations made accurately in unhuman speeds, so the listener is presented with an aesthetic result which is created in an apparently mysterious manner. I argue that what stimulated composers to explore it even further is the ease of sound processing brought by computers. As computers perform these operations through codes, not only a similar result to sound transformation with vinyl and magnetic tapes was possible, but also several new possibilities were discovered. Furthermore, the challenges of physically manipulating tapes and vinyls were not an issue anymore, because computers perform all these operations abstractly. Digital media

[77] Marina Bosi and Richard E. Goldberg, *Introduction to Digital Audio Coding and Standards*, 7.
[78] Ibid, 20.

opened new possibilities to their user, which shaped our practices and our creative engagement, as I will further discuss in Chapter 4.

Synthesizing Sound

Besides encoding analog acoustic signals and playing them back later, computers can generate sounds electronically from coded data. Synthesizers will follow the attributed frequency, intensity, waveform, and time information designed by humans accurately. Due to the lack of compromising with the physicality of performing an acoustic instrument, synthesizers can produce sounds that cannot be played by standard instruments.[79]

Since the advent of analogue synthesizers, subtractive and additive synthesis have been used as a tool to create new timbers. In subtractive synthesis, a complex waveform is used as raw material and components are filtered from it in order to achieve a more polished waveform, many times white noise and sawtooth wave used in this synthesis, due to their complex and harmonically rich content. In additive synthesis, in contrast, simple waveforms – most of the times sine tones – are utilized to generate more complex waveforms as blocks of the simple raw material is superposed.[80] Synthesized sounds – but also recorded sounds – can pass through Amplitude Modulation (AM) synthesis, which is performed by modulating the amplitude of a signal with a modulation signal.[81] Another commonly used processing is the Frequency Modulation (FM) synthesis, which is achieved by modulating the carrier frequency of a waveform with another waveform (modulator).[82] As I will discuss in Chapter 3, these experiments of FM synthesis in electronic music were started by John Chowing in 1967.

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[79] Olson, Harry F. and Belar Herbert. "Electronic Music Synthesizer," 595.
[80] Nick Collins, *Introduction to Computer Music* (Padstow: John Wiley & Sons Ltd, 2010), 164.
[81] Collins, *Introduction to Computer Music*, 123.
[82] Collins, *Introduction to Computer Music*, 166.

Granular Synthesis consists of splitting an audio input – which can be a pre-recorded sound or a synthesized sound, like a sine tine – into samples that normally last 10-100ms. These samples may be processed and are later rearranged in different order creating a different structure of sound.[83]

As previously presented, synthesizing sound is a practice of electronically creating sounds that are not produced by an acoustic means. This becomes an interesting practice since the parameters of sound can be individually manipulated. Therefore, composers are able to create sounds that do not rely on the physical gesture and manipulate the gesture values through algorithms. This example together with the ease of sound processing granted by computers show how the use of codes changed the paradigms of music after the shift from analog media to digital media. Now, the physical involvement of composers or musicians with the raw media in electroacoustic music is not required anymore. By typing letters and clicking with a cursor, composers make computers perform tasks that rely on abstract operations, made possible by the computer's system. Hence, the use of computer medium has a fundamental role on how we compose music.

Algorithmic Music

Gerhard Nierhaus first defines algorithmic composition as "composition, by means of formalizable methods."[84] He presents a historical overview of composition that fit into this definition, starting with Guido d'Arezzo in the eleventh century, who formalized "solfeggio," which further contributed to the advent of music notation. His innovation is considered algorithmic method because of the intent conversion of text into melody. This tradition of

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[83] Ibid, 169.
[84] Gerhard Nierhaus, *Algorithmic Composition* (Vienna: Springer-Verlag, 2009), 1.

algorithm music did not stop with Guido d'Arezzo, though. Several European compositions relied on the use of this approach, including Bach's *The Art of Fugue* and Schönberg's twelve tone music, as both practices relied on a set of rules that would need to be respected at first. While Bach's practice mainly followed the rules of counterpoint, Schönberg's twelve tone music was more restrictive because it was built upon tone row that generated all the melodic-harmonic material of a composition. This practice was taken even beyond with contemporary composers like Xenakis, who used a variety of systems to compose.[85] Some of Xenakis's compositions where algorithm methods were employed include *Pithoprakta*, and *Achorripsis*, with the use of theory of gases; *Syrmos*, *Analogique A*, and *Analogique B*, with the use of Markov chains; and *Duel*, and *Stratégie*, with the use of the game theory. [86] After historically regarding algorithmic music, the author prompts three possible definitions for algorithmic music: "(1) A set of mathematical instructions that must be followed in a fixed order, and that, especially if given to a computer, will help to calculate an answer to a mathematical problem. (2) A systematic procedure that produces – in a finite number of steps – the answer to a question or the solution of a problem. (3) [...] (especially computing) a set of rules that must be followed when solving a particular problem."[87]

Due to the possibility of instantly performing large amounts of calculations computers became a suitable medium for the composition of algorithmic music. I claim that one of the most interesting features of algorithmic music remains the same as the algorithmic practices of d'Arezzo, Bach, and Schönberg, which is a high degree of coherence. As the values are products of a specific system, the parts validate themselves as being part of a whole system. In other

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[85] Ibid, 1.
[86] Peter Hoffmann, "Xenakis, Iannis." *Grove Music Online, Oxford Music Onlin*e <accessed May 12, 2022>
[87] Nierhaus, *Algorithmic Composition*, 2.

words, all the parts are interrelated because they come from the same equation or system. This feature is rarely achieved when the composer chooses to use a purely intuitive approach. I will regard some possible approaches – Markov chains and Logistic Equation – which represent an expressive but small portion of possible applications of algorithms in music.

Markov Chains are systems of probabilities that consider in which situation a particular event took place. Events rely on information from preceding events, which are used as the base for a matrix containing probabilities.[88] The relation of *accessibility* is established if e_b, can be followed by the event e_a. Moreover, if events are mutually accessible a *communication relation* is established, which. can come in three diverse forms: *reflected*, *symmetric* and *transitive*. The *reflected* form is defined if one particular event can be followed by itself. The *symmetrical* form takes place if distinguished events can be followed in both directions. Finally, the *transitive* form happens if there is a chain of communicable events. For instance, if e_a communicates with e_b, e_b communicates with e_c and e_a communicates with e_c, creating a group of even that communicated among themselves, a *transitive communication relation* is built. Furthermore, if an event will certainly happen again, it is named *recurrent*, but if it is possible that it will not happen again, it is named *transient*. To form a Markov Chain, it is necessary that there is minimum a *recurrent* event, so it is not possible to form it only with *transient* events. In fact, if a Markov Chain contains both types of events – *recurrent* and *transient* – when this process leaves the *transient* events, it will not be possible to return to them. In contrast, when it enters the *recurrent* events it cannot leave anymore – therefore a closed set is formed. This happens because *transient* events can only communicate with transient events and the same is applicable for *recurrent* events. The

[88] Kevin Jones. "Compositional Applications of Stochastic Processes," *Computer Music Journal* 5, no. 2 (Summer 1981):46.

only option to go from a *transient* event to a *recurrent* event is if the *transient* event is accessible to the *recurrent* event – the reverse direction is not feasible.[89]

In music, it is possible to build a Matrix of probabilities from a pre-composed piece of music. Composers can choose what are going to be the *events* that they are going to consider, but the most common approach is to use "notes," "musical figure," or "chords" as *events*. After selected, the possibility of an event b being followed by an event a must be analyzed.

Image 1: Transcription of the first part of the melody of *Chega de Saudade* by Tom Jobim

If we take as an example the first part of the melody of *Chega de Saudade* by Tom Jobim, we will find the following matrix:

[89] Kevin Jones. "Compositional Applications of Stochastic Processes," 47.

	F5	E5	D5	C#5	C5	B4	Bb4	A4
F5		0.57					0.14	0.28
E5	0.125	0.125	0.5		0.125	0.125		
D5	0.25	0.125	0.125	0.125	0.25			0.125
C#5	0.25	0.25					0.5	
C5	0.5	0.5						
B4			1					
Bb4	0.5			0.5				
A4	0.33		0.33			0.33		

Table 1: Matrix of probabilities constructed from the first section of the melody of *Chega de Saudade*

This matrix considers every time that F5 was followed by E5, Bb4, and A4 individually. Then, this same process was repeated for each note of the melody. After building this matrix, the computer generates a new melody based on these probabilities. Therefore, the new melody keeps the structural framework of the referenced melody, but without repeating it. There is coherence in the way that the melody is referenced since the rules of the system are strictly followed. Nevertheless, new results will almost always differ, because Markov Chains work with a system of probabilities and there are multiple possibilities of an event following the other.

Another mathematics application in music are Chaotic systems, which are the ones that belong to the domain of non-linear dynamic system – that is to say, system where the output does not change proportionally according to its input.[90] Verhulst's logistic equation can be classified

[90] Nierhaus, *Algorithmic Composition*, 131.

as a Chaotic system. Verhulst, attempted to create a mathematical equation that could represent the growth of a certain population in time taking into consideration limiting factors (for instance, the availability of food). This resulted in the following equation: $X_{n+1} = rx_n(1 - x_n)$, where x determines population size (depending on n, which represents time now and the next generation when followed by $+1$) and r is a constant constituted intrinsically by the growth rate of the particular population. The limiting factor is represented by 1.[91] When the population is small the limiting factor $(1 - x_n)$ tends to 1 resulting in almost exponential growth, but if the population is already large the limiting factor $(1 - x_n)$ is going to be near 0, so the population starts decreasing. The *Feigenbaum diagram* shows the results of this equation being the constant r the x axis and the population the y axis[92].

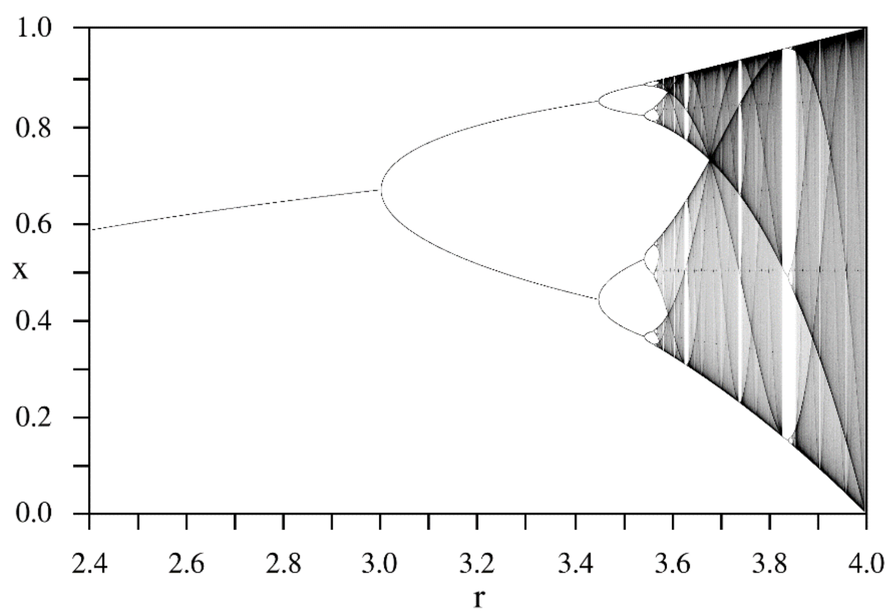

Image 2: The *Feigenbaum diagram*

[91] Ibid, 132.
[92] Ibid, 133.

As can be seen in the *Feigenbaum diagram,* when r = 3.0, x bifurcates into two different values. Bifurcations occur a few more times until the appearance of a chaotic region between r = 3.5 and r = 3.6. These values, translated into musical parameters, sounds like they were randomly generated, even though these results are fully deterministic. The blog Algorithmic Composer's author developed a Max/MSP and Pure Data patch that utilizes this equation to generate sounds live.[93] Although there is an apparent randomness of the resulting values inside the chaotic region, coherence is preserved as the use of the Verhulst's logistic equation is maintained throughout the generation of sound.

As previously approached, these two procedures produce values that are coherent among themselves, which I argue to be an important quality that composers should search for and can be easily accomplished through algorithmic procedures. Defined by the composer, these values can be used in numerous parameters of music opening infinite possibilities of results. Different from fully intuitive methods, computer algorithmic music comprehends a high degree of coherence, because of the interrelation of the parts – every single part is a fraction of a whole system that generates deterministic values. Therefore, I maintain that computers are a great tool for composers who value coherence in their music and wish to use systems that control compositional decisions, which create the idea of a coherent whole.

Artificial Intelligence

Artificial Intelligence in music covers a broad range of disciplines that aim to automatize the compositional procedure.[94] Some of this AI approaches include State space, context-related

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93 Algorithmic Composer, "Chaos in Max and PureData" (accessed 12 May 2022) <http://www.algorithmiccomposer.com/2011/08/chaos-in-max-and-puredata.html>
94 Nierhaus, *Algorithmic Composition*, 225.

variants of knowledge representation, reasoning, production systems and rule-based procedures, machine learning, and language processing.[95] One of the main projects related to the use of AI to generate music was developed by the American composer and researcher David Cope. Starting his project Experiments in Musical Intelligence (EMI) in 1981, he first attempted to develop a program that could compose according to the style of classical composers through coding stylistic rules. Even tough results that accurately followed the rules of counterpoint and harmony were achieved, most of them did not show any artistic interest, according to Cope. He had in mind that music followed a set of rules that made it possible for it to replicate itself and if these rules were correctly interpreted this could be a tool to create new works that were faithful to the style of an analyzed composer. Therefore, he revised the program following his recombinancy – which allowed the software to be more successful in its task. The performance of this software can be divided into three steps: (1) deconstruction (analyze and separate into parts), (2) signatures (commonality - retain that which signifies style), (3) compatibility (recombinancy - recombine into new works).[96]

As Artificial Intelligence is further developed, it contributes to music in more ways. The first is the possibility of instantly composing musical pieces and ideas. It not only can produce whole compositions independently, but it also can help composers develop their own musical ideas and it can work as an infinite source of musical materials to be developed by a human composer. The second way that AI can be beneficial to music is in the realm of analysis. As the computer is used to analyze pre-existing works, it can help us understand what makes the style of a certain composer unique and what are the kinds of signatures that every composer utilizes.

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[95] Nierhaus, *Algorithmic Composition*, 230.
[96] David Cope, "Experiments in Musical Intelligence" (accessed 12 May 2022) <http://artsites.ucsc.edu/faculty/cope/experiments.htm>

Finally, and more important, I believe that the advancement of AI in music will make it necessary to reevaluate the role of the composer. After AI is sufficiently developed, so anyone can generate composition in the style of consecrated composers, will it be sufficient for a composer to replicate established forms? I argue that this will lead composers' practices towards innovation, rather than the reproduction of established paradigms. Maybe the works of composers will be more similar to a researcher of sound who – experiments with sounds aiming to discover new musical possibilities without leaving aesthetics aside.

Conclusion

As the way computers are constructed shapes the way they operate, it will also have impacts on the possibilities of using them for music and becoming even more interesting tools for composers. I sustain that the potential of using computers for music purposes goes beyond the already rich possibilities of playing back pre-recorded sound and synthesizing new ones. Composers can also use computers as a tool to compose highly cohesive pieces that rely on a deterministic system. Moreover, the advancement of AI will allow anyone to instantly generate composition in the style of established composers and this will lead musical creators to reconsider their role in music.

CHAPTER III

COMPUTER MUSIC

Introduction

In this chapter, I focus on how the materiality of computers and the technological advances directly interfere with our artistic practices. I start by presenting some predecessors of computer music that utilized analog media, instead of digital media, and how they were influenced by their media. Then, I present a historical overview of the MUSICn software and how it relied on the capacity of computers from their time. After approaching the creative use of computers in music and presenting some of the practices that exist nowadays, I present some of the software that musicians currently utilize to compose their music.

Historical Overview

Predecessors of Computer Music

In 1944, while experimenting with a wire recorder (which was a predecessor of the well-known tape recorder) at the Cairo radio station, El-Dabd composed the earliest known tape composition, *The Expression of Zaar*. The work consists of a recording of the traditional exorcism ritual called *zaar*, in which echoes, reverberations, and distortions were later added during the manipulation process. In 1944, this work received a première at the Cairo gallery and was then released as a "wire recorder piece".[97] The final product of this experiment is a 20–25-minute composition recorded onto a tape.

In Europe, based on the background of Hindemith and Toch's *Grammophonemusik* and other machine music, the French radio engineer Pierre Schaeffer and the composer Pierre Henry founded the *musique concrète* – a musical expression based on recording, instrumental and natural sounds and electronic signals.[98] The multidisciplinary theorist Abraham Moles's ideas became an important starting point to the practices of *musique concrète*. Moles considers *l'objet sonore* as sounds that are independent from human perception and that music is a sequence of *objets sonores*. For him, not only traditional sounds could be explored by experimental music, but also sounds that were outside this domain. He divided the sound object into three dimensions – time, frequency, and amplitude – this last one could be divided further into more components – attack, sustain, and decay.[99] The technological reproduction of sound was the ideal environment for what became the focal point of Schaffer: the reduced listening.[100] This approach considers that the sound should be listed taking into consideration its most elementary components and disassociating them from cause and meaning.[101] Schaeffer composed in 1948 *Études de bruits*, the first work of *musique concrète* including a series of the five studies "Étude aux chemins de fer", "Étude aux tourniquets", "Étude au piano I and II" and "Étude aux casseroles." Differently from Hindemith and Toch, Schaeffer had the advantage of having access to more equipment: a disc-cutting lathe, four turntables, four-channel mixer, microphones, audio filters, a reverberation

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[97] The New York Times, "Halim El-Dabh, Composer of Martha Graham Ballets, Dies at 96" (accessed 12 May 2022) <https://www.nytimes.com/2017/09/08/arts/music/halim-el-dabh-dies.html#:~:text=Halim%20El%2DDabh%2C%20an%20Egyptian,He%20was%2096.>
[98] Thomas Holmes, *Electronic and Experimental Music Pioneers in Technology and Composition* (New York: Routledge, 2008), 45.
[99] Ibid, 45.
[100] Ibid, 46.
[101] Michel Chion, *Audio-Vision* (New York: Columbia University Press, 1994), 29.

chamber, a portable recording unit and diverse sound effects.[102] After much editing work and creating lock grooves (which are endless loops), he re-recorded his piece onto a final disc master. These Studies are of extreme importance to electronic music because they were the first experience of composition directly made with the recording medium, they used non-traditional sounds, they were reproducible, and they did not require humans to be performed. This musical manifestation did not rely on a mental abstraction, it dealt with the sound material itself – finally, the structured did not impose the material features.

Schaeffer's *musique concrète* was only able to emerge due to the materiality of tape. Besides its most apparent feature of recoding audio and accurately reproducing it later, the magnetic tape allowed multitracking and overdubbing, so it was easier to mix recordings that took place in different times and/or different places. This is one of the major differences with the use of the phonograph, which made it difficult to mix different performances in a single recording. Because of that, recording standard practices shifted from the documentation of a single performance to the mix of different recording. However, the most innovative characteristic of the magnetic tapes was that manipulating them by cutting them in different ways had an impact on sound. Different manipulation techniques allowed composers the reordering of recorded sounds, backwards playing, looping, and exploiting several shapes of fade in and fade out. All these techniques that are still in vogue, were a direct result of the use of the magnetic tape medium to record, create and reproduce music. Therefore, *musique concrète* and any other music that used magnetic tapes was shaped by its medium. I argue that these experiments were

[102] Holmes, *Electronic and Experimental Music Pioneers in Technology and Composition*, 49-50.

aesthetically interesting, because they opened the doors to new techniques in music and deeply explored the materiality of magnetic tapes.

After the success of his Studies, Schaeffer founded together with Jacques Poullin and Pierre Henry and with funds provided by the RTF the *Groupe de Recherches Musicales* (GRM). A lot of expressive works were developed in this studio. In 1949-50, Henry and Schaeffer composed *Symphonie pour un homme seul* – which used exclusively phonograph machines; This composition was mainly based on the use of human sounds and non-human sounds. Later in similar partnership, the same composers recorded *Voile d'Orphée*, which is known as a concrete opera. This composition uses traditional arias in a *musique concrète* manner. Distortion and electronic tones are played in addition to sounds performed by a live orchestra.[103]

Hebert Eimert presented a diverse approach in Germany. In collaboration with Werner Meyer-Eppler, a German physicist who was interested in the development of the technology in electronic music, Eimert organized lectures regarding the paths of *elektronische Musik*. This resulted in the creation of the *Nordwestdeutscher Rundfunk* in 1951 – later split into *Westdeutscher Rundfunk* and *Norddeutscher Rundfunk.* Under the direction of Eimert, who rejected Schaeffer's approach of working with recorded acoustic sounds, this studio focused on experimenting with serial techniques. In the beginning, the composers in this studio mostly relied on equipment that could generate tones and filters – such as the Monochord and the Melochord. With the arrival of the engineer Fritz Enkel, new possibilities were extended to the studio in Cologne: audio oscillators for generating sine and sawtooth waveforms, a variable-speed tape recorder, a four-track tape recorder, audio filters, including band-pass filters, a ring modulator

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[103]Holmes, *Electronic and Experimental Music Pioneers in Technology and Composition*, 51-52.

and a white noise generator. Based on a score written that described precisely the sound generated by serial rules, the composition required the engineering devices to follow precise rules to result in an accurate replication of it. Even though the serial approach dominated the studio on its early stage, after some time the French and the German aesthetics started being combined in new compositions. Some examples of this blend are visible in Eimert and Beyer's *Klang im unbegrenzten Raum* (1952) – whose sound spatial movement, reverb and fuzzy tones approach it to an acoustic sound experience – and in Eimert's *Klangstudie I* (1952), which constantly uses repetition. Other important composers worked in the studio in Cologne, including, Henri Pousseur, Györgi Ligeti, Mauricio Kagel, and Karlheinz Stockhausen.[104]

The antagonism of aesthetics between the studio of Paris and the studio of Cologne was established because of the use of distinct media. While *musique concrète* relied on the use of magnetic tapes, early *elektronische Musik* composers used only synthesizers. Instead of cutting and attaching magnetic tapes, the German practice worked with synthesizers, which give the composers the possibility of manipulating musical parameters in a detailed way. Therefore, the approach of determining these parameters in a detailed way seems almost inevitable, as the *elektronische Musik* composers did by employing serial techniques. Both *musique concrète* and *elektronische Musik* developed techniques and took aesthetical paths in accordance with the medium they were utilizing, As I will discuss in chapter 4, this does not happen without a reason. In fact, media has a fundamental role in our creativity because it also informs our creative thoughts.

[104] Holmes, *Electronic and Experimental Music Pioneers in Technology and Composition*, 56-61.

Stockhausen started his contact with electroacoustic music with some hours of supervised studio time at the GRM in 1952, but it was after 1953 that he joined the studio in Cologne and composed his most remarkable works. Previously only having composed a monophonic composition in France entitled *Étude*, he presented two of his pieces in a tape music concert organized by the Cologne Studio in 1954: the compositions were *Studie I* (1953) and *Studie II* (1954). In *Studie I,* Stockhausen generated edited and shaped sounds from a mathematically based tonal and timbral analysis; He went further in *Studie II* and using the same ideas he added experiments with attack and decay; Finally, between 1955 and 1956, Stockhausen composed his most important contribution to electroacoustic music – *Gesang der Jünglinge*. In this composition his intentions were towards fusing the pre-recorded sound of a youth choir with an electronic version that maintained the same tones and timbres. This work demarks a change of trend – the Paris and Cologne exclusive aesthetics were replaced by a wide stylistic period for electroacoustic music.[105] In my opinion, the use of the antagonistic media is what make this composition revolutionary and what demarks a turning point in electroacoustic music. The aesthetic friction between synthesizers and the magnetic tape are apparent, and their interaction play a fundamental role in this composition. Stockhausen explores particularities of these two media, which are not veiled as sound of voice of young people and sound of synthesizers are clear and easily distinguishable. On the other hand, he also manipulates features that are mutual to these two media, such as the possibility of reproducing tones. Throughout this composition Stockhausen extensively used unisons between synths and the young's choir, which connect these two-antagonist media aesthetics. Lastly, in *Gesang der Jünglinge* two hitherto antagonist approaches coexist with colliding and conciliating forces. In the end, conciliation prevailed over

[105] Holmes, *Electronic and Experimental Music Pioneers in Technology and Composition*, 62-66.

the conflict between these two aesthetics and Stockhausen trailed the path that electroacoustic music would take in the following years.

After *Gesang der Jünglinge*, a composition that relied on the spatial projection of sound, he resumed his experiments on *Kontakte* (1958). In this composition, he pursued the effect of spinning around sounds at diverse speeds and he accomplished that by placing a speaker on a platform that could be manually rotated while it was playing the sound of four tapes captured by four different microphones. In 1963, Stockhausen became the director of the Cologne studio and remained at this position until 1977.[106]

A third pole of electroacoustic music that is less regarded than the previous two is the *Radio Audizioni Italiane*'s *Studio di Fonologia Musicale* in Milan directed by Luciano Berio and Bruno Maderna. Founding the studio in 1955, both composers agreed not to follow the guidelines from the *musique concrète* – purely work with acoustic recorded sounds – or the *elektronische Musik* – based in serialism. Berio created the tendency "text-sound composition," which is electronic music that utilizes pre-recorded vocal sounds. Berio's compositions with vocal sounds include *Thema-Omaggio a Joyce* (1958) and *Visage* (1961). *Thema-Omaggio a Joyce* uses sounds recorded on tape by mezzo-soprano Cathy Berberian reading the beginning passage of chapter 11 of *Ulysses* by James Joyce in three different languages (English, Italian and French). This work is marked by the clear speech transitioning to a non-intelligible rhythmic sound material, which were achieved by editing, copying, changing the speed and processing the raw tape material[107]. *Visage* also uses as material a recording of Berberian – this time saying the Italian word *parole*, which means words, and other vocalization, crying, laughing, and other

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[106] Holmes, *Electronic and Experimental Music Pioneers in Technology and Composition*, 67-8.
[107] Ibid, 69-74.

sounds[108]. These two pieces also reaffirm the influence of the medium on the composition process, as it uses techniques particular to magnetic tape manipulation. Recording of the voices are manipulated to have the speed changed and to perform loops. Another feature that connects this composition to other that utilize the same medium is multitracking.

Berio composed other works during his direction of *Studio di Fonologia Musicale*; however, did not use voices as raw sound source, they are *Différences* (1958–60), which combined the live performance of flute, clarinet viola, cello and harp with pre-recorded sounds, and *Momenti* (1960) – which used 92 continually moving frequencies. Other composers also participated in the history of this important center for electroacoustic music, including Luigi Nono and John Cage. Both contributed in their own way to the artistic production made inside this institution, but what their approaches had in common was that they moved away from traditional practices.

Early Stage of Computer Music and the MUSICn Software

The development of Computer Music cannot be dissociated from the history of technological innovations. In fact, it was the improvement and vast dissemination of computers that permitted the conception of this music genre. The spreading of the computers in the late 1960s, which was allowed by the successful attempt of building cheaper and more compact machines, eased the access of them to creative researchers, who previously had available only Mainframe Machines.[109]

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[108] Holmes, *Electronic and Experimental Music Pioneers in Technology and Composition*, 71
[109] Peter Manning, *Electronic and Computer Music*, 181-182.

In the 1950s, in the Bell Telephone Laboratories' researchers were focused on synthesizing sound in order to transmit a digital form of telephone conversations; thus, transforming the analog signals produced by a sound into a series of digits that were to be transmitted and transformed back into sound at the end of the line. Researchers realized that, due to a not wide frequency bandwidth and the complexity of converting the analog signal to digital, the conventional telephone was a simpler technology that could be further improved.[110]

Later, Max Mathews, a researcher from the Bell Telephone Laboratories, started his enterprise to synthesize sounds based on the mathematical concepts that inform waveforms. During his experiments, he developed the programs MUSIC I and MUSIC II, which could perform basic tasks, the first could only produce a single triangle-wave synthetized sound and the second was able to produce four synthesized sounds independent and simultaneously manipulated from a collection of sixteen possible waveforms. After this innovative outcomes, other versions of MUSICn were developed. MUSIC III was created by Joan Miller in 1960 and allowed more possibilities of synthesis and processing and, the next version, MUSIC IV was developed by Mathews with the assistance of Miller in 1962. At this point, researchers from other groups became interested in the projected, so Princeton made substantial improvements in the last version of this software and renamed it to MUSIC IV B; these improvements were made to ease the using of this software to composers instead of scientists.[111]

With the launch of System 360 series by IBM in the middle of the 1960's and its new low-level programming requirements, Princeton and Bell changed their approach to the MUSICn software and started writing the series of software in FORTRAN, which allowed laboratories that

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[110] Manning, *Electronic and Computer Music*, 187.
[111] Ibid, 187-8.

did not own IBM machines to use their software. As a result of this new approach, Princeton launched the version MUSIC IV BF in 1966-7. Mathews also created a version fully written in FORTRAN in 1968, MUSIC V. The lack of refinements (especially regarding filters) in the last version by Matthews, led Barry Vercoe to create MUSIC 360, a version for the IBM machines that took advantage of the low-level programming possibilities with more complex features.[112]

In 1970, Mathews started working for the Massachusetts Institute of Technology (MIT) and created the version MUSIC 11, which was developed for Digital Equipment Corporation's PDP 11. Due to its higher efficiency regarding processing and memory space, this version was responsible for broadening the community of users. After that, new devices were developed – such as, interactive graphics and traditional music keyboards – to ease the use of the software. As the C programming language was starting to have paramount importance in the performance in the MUSICn software, Richard Moore, who was associated with University of California, San Diego, expanded MUSIC V into a new version and called it CMUSIC. In 1986, in a similar direction, MUSIC 11 was converted into a C version at MIT – then, CSOUND was born. CSOUND was in public domain from its release date, which stimulated its rapid spread and insisting popularity for music composition and research[113].

As the medium materiality did not allow the possibility of experimenting with these machines, composers were led to sustain a didactic approach. Result of this framework are the compositions *Variations in Timbre and Attack* (1961) and *Five Against Seven – Random Canon* (1961) by John Pierce, *Noise Study* (1961) and *Five Stochastic Studies* (1962) by James Tenney, *Bicycle Built for Two* (1962) by Matthews – all of them presented a highly influence of

[112] Manning, *Electronic and Computer Music*, 188-9.
[113] Ibid, 189.

mathematical procedures to compose music.[114] At this point, the processing power of computers would not allow a meaningful real-time interaction between humans and machines, which discouraged composers to experiment with them. The restrictions imposed by the limited technological advancement and the materiality of the medium of that time led composers to didactic method rather than experimentation.

In the late 1960s John Chowning started experiments with Frequency Modulation. He noticed that when modulating a carrier frequency by a modulation frequency higher than the first one, a non-traditional acoustic event would take place: the frequency would be deviated to a negative value mathematically. Nonetheless, as humans cannot perceive negative frequencies, these frequencies would be perceived as positive, but with an inverted phase. Chowning's ideas, whose timbral features he deeply explored in his *Sabelithe* (1971) and *Turenas* (1972), became later widely used by music composers.[115]

These early developments of computer music, represent a foreshadow of a more significant shift to digital media that would take place in the next few years. Computers, unlike analog media, work with binary data and because of their operating, new creation paradigms emerged. The physical engagement of the composer with the raw medium is not necessary anymore, instead of that, they operate machines through a series of codes that are linked to sound in an abstract way, which would allow faster processing in the future. After switching the standard medium to computers, an unforeseen demand for faster processing and larger memory started to be a central issue for electroacoustic music.

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[114] Manning, *Electronic and Computer Music*, 192-193.
[115] Ibid, 193-5.

Creative Use of Computers in Music

After the creation of MUSICn software, composers started to search for new sounds and new manners to express themselves artistically and began writing innovative electroacoustic music. French composer Jean Claude Risset was interested in timbre and the use of acoustic sound together with synthesized sounds. The MUSICn software enabled the analysis of capture sound, which could be further used in a process of resynthesis. The possibility of processing signals digitally helped composers to integrate sounds from acoustic sources with synthetic sounds. His work in the Bell Telephone Laboratories stimulated these sort of programming activities. Also, at Stanford University, James Moorer was doing a similar work, which was implemented in his composition *Perfect Days* (1975). In this work, he uses an innovative technique called cross-synthesis, which takes place when a parameter is influenced by the spectral characteristic of a sound. In the realm of synthesizing vocal sounds, Charles Dodge's *Speech Songs* (1973), builds a strict structure in which the text's phonemes produced by a synthetic voice are related to a permutation which results in a sectionalized form. Milton Babbitt remarkably played a part in the practice of computer-generated music with his works *Changes* (1969), *Earth's Magnetic Field* (1970), *Extensions for Trumpet and Tape* (1973), and *In Celebration* (1975).[116]

These real-time processing techniques were only possible thanks to the technological development with faster processing and larger memory capacities. From then on, a real-time interaction between the performer and computers was possible, and created a more complex interchange between the two. These new possibilities of engagement with the computer and live processing would shape the history of computer music, as it strengthened live electronic music.

[116] Manning, *Electronic and Computer Music*, 198-200.

This is an example of how the history of computer music and technological developments are interrelated and it corroborates the Kittlerian idea that discourse is a product of the "historically existing Media technology."[117] In summary, the contribution of Babbitt, Dodges, Riset, and Moorer are just examples of the boiling environment of Computer Music after the creation of the MUSICn software. Their importance goes beyond the aesthetic shaping of computer music, but contributed also to the diffusion of the genre and the influence on the compositional process.[118]

Computer Music Nowadays

The conception of microprocessors and reduction of their cost made possible a wider production of Computer Music – also outside academia. Computer Music is broadening its activities beyond festiva ls and academic conferences and reaching larger audiences. Currently, there is a vast amount of programming languages and environments that allows musicians to convey expressive musical ideas – such as Music-N (CSound), Patcher languages (Pure Data and Max/MSP), SuperCollider 3, Sonic Pi, etc.[119] This last one has shown itself successful for computer science and music teaching. It is expected that with the wider reach of algorithmic music, human creative and computation will undergo structural transformations.[120]

The audience of electronic music has been extended to groups of people outside academia. Among the prolific composers of Computer Music are Autechre, the English Leafcutter John, the Viennese label Mego and collective Farmers Manual (FM), the Danish composer Goodiepal, and Mark Fell. Autechre and Leafcutter John uses dance music as a

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117 Kittler, *Discourse Networks 1800/1900*, 369-71.
118 Manning, *Electronic and Computer Music*, 201.
119 Alex McLean and Roger T. Dean, "Musical Algorithms as Tools, Languages and Partners: A Perspective," in Roger T. Dean and Alex McLean ed. *The Oxford Handbook of Algorithmic Music* (New York: Oxford University Press, 2018), pp. 11.
120 Ibid, 12.

starting point for experimentalism. Viennese label Mego and collective FM focus on noise and glitch aesthetics. Goodiepal develops an anti-academical work. Fell has a work based on algorithmic music.[121]

Computer Music Practices

Computer-assisted Composition

Computers can be used to generate music data for acoustic compositions by the means of algorithms and functions. This practice was the main focus of Lejaren Hiller and Iannis Xenakis in the 1950s. Both composers started their experimentations in the MUSICn software to generate alphanumeric data, which would be later transcribed into a score for acoustic instruments. Hiller collaborated with Cage in his composition *HPSCHD* (1969), which pseudo-randomly selected musical parameters using as source previous composed works by Mozart, Beethoven, Chopin, Schumann, Gottschalk, Busoni, Schoenberg, Cage and Hiller.[122] Moreover, Xenakis was experimenting was also experimenting with probabilistic procedures to generate values for parameters such as, timbre, instrumentation, gradient of glissando, duration and dynamic in this composition *ST/10-1, 080262* (1956).

Another composer who was fascinated in computer-assisted composition was Gottfried Michael Koenig. While he was working at the Cologne Studio in the 1960's, he developed the software PROJECT 1 and PROJECT 2 – both dedicated to assist the composition process. While PROJECT was based on serial techniques, it was more flexible and offered a wider range of

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[121] McLean and Dean, "Musical Algorithms as Tools, Languages and Partners: A Perspective," 12.
[122] Manning, *Electronic and Computer Music*, 201.

tools, like probability functions and random selections.[123] This practice relies on possibility of computer to perform numerous calculations in seconds. Composers use machines to assist in their composition, only because they are able to perform the mathematical operations faster than humans. All calculations employed in composition procedures can be performed by humans, but it is a slower process that utilizes our own effort. By using a computer, composers gain speed and accurateness on the process of performing calculations that will build the foundation for their compositions.

Fixed Media

Rooted in the practices of the GRM and the Cologne studio (tape music), fixed media compositions are pre-recorded, and computer processed pieces that do not require performers. This terminology covers a wide range of works and does not specify if the utilized sounds are recorded material or synthesized in the studio. What all of them have in common is the lack of need of a performance.[124] This practice, wihich was born in another medium was transferred to computers which proved themselves to be a suitable medium for it. All the techniques that were performed by physically manipulating the magnetic tape, can be accomplished through internal calculation in the digital medium. Computers do not require physical engagement of the composer with the raw medium, instead the operations are performed in a digital environment that allows more precision, which is a consequence of the way computers operate.

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[123] Ibid, 203-4.
[124] Hilary Mullaney, "The Composer Isn't There: A personal exploration of place in fixed media composition," PhD diss. (Plymouth University, 2012,) 31.

Live Electronics

John Cage's *Imaginary Landscape* (1939 – 52) was a pionner series that used electronic devices, such as turntables and radios, in live performances. These series of works utilized sounds produced by played recordings or electric sound devices, which could be combined with amplified sounds. Two trends emerged between the 1950-60s for live music with electronic apparatuses – "Mixed music" and "Live electronic music." Mixed music expression was characterized by combining live performances with a pre-recorded tape and some works of this genre include *Orphée 53* (1953) for soprano and tape by Schaeffer and Henry, and *Musica su due dimensioni I* (1952) for flute, cymbal and tape by Maderna. In contrast, "live electronic music" required that the sound produced by the performer would have to be processed and modified. This could be approached by filtering, modulating, flanging, phasing, panning, shape enveloping and delaying the performer's sound.[125] Some compositions of this genre are Stockhausen's *Mikrophonie* (1964-65) and Louis Andriessen's *Hoe het is* (1969). Nowadays these two practices are still in vogue, and they can be combined into a work that utilizes both approaches. Live electronic music that utilizes computers depends on the capacity of processing speed and on the size of the memory of them. Thus, the technological affordances of the utilized computer have a major influence on what sort of processing will be performed and will mold aesthetically the resulting sound.

Live Coding

Live Coding is a musical practice characterized by real-time composition through coding. This practice was born from the formalization of encoded music and resistance of traditional encoding

[125] Simon Emmerson and Denis Smalley. "Electro-acoustic music," *Grove Music Online, Oxford Music Online* <Accessed 12 May. 2022>.

forms. Composers start their performance from scratch, with no pre-composed sonic material, and throughout this event the code is in constant change. More accurate than a traditional musical score, the code is a precise representation of what happens during the musical performance.[126] Artists that contributed to this genre include Dave Griffiths and Alex McLean. The fact that computers can promptly respond to inputs is what makes this practice viable. This characteristic of computers depends on their materiality, which establishes the way they operate. Hence, this practice relies on its used medium. Due to the strong performative component of live coding, I maintain that the influence of the medium goes beyond aesthetics. Computers also shape the social and cultural situation in which live coding takes place.

Software

Digital Audio Workstation (DAW)

Digital Audio Workstations (DAW) are software developed to record, edit, and mix audio. All the functions that required analog equipment like ADTs and DA-88s, are nowadays covered by software that simulate a studio inside a computer at a more affordable cost. With the help of plug-ins, the sound can be processed in many ways (through compressors, limiters, reverbs, delays, pitch shifter etc). DAW made it easier and more affordable to utilize the effects that were used in GRM and Cologne Studios. Some of the most widely spread DAWs include Ableton Live, Cubase, Logic Pro, Pro Tools, REAPER and Studio One. This tool is a fundamental tool for musicians of every genre. A lot of these DAWs designs reference the magnetic tape medium and, as I will approach in Chapter 5, these software designs use metaphors to link what is seen in

[126] Thor Magnusson, "Algorithms as Scores: Coding Live Music," *Leonardo* Music Journal 21 (2011): 21.

the computer screen with the tape recording. Surely, this approach facilitates the use of these software, but it allows limited options of creative engagement, and the constraints are clear. All sorts of tape techniques, such as fading in and fading out, looping, and audio chopping, are possible in a DAW and even the design of the software reminds the manual operations that used to be performed with magnetic tapes. Although these software can be a great resource to compose fixed media works and to produce music in general, they do not invite the artist to engage creatively with it and question its structure. Every tool is given, and the artist needs to work in a limited environment.

OpenMusic

Based on the programming language Lisp, OpenMusic is a software developed by IRCAM to assist in the process of musical composition. In this software, the operations are accomplished by connecting objects and functions, which are contained in boxes. This software uses Lisp (a programming language based on lists processing) functions and OM functions to define and transform music data.[127] Some of the functions included in this software, such as Not-Centr – which chooses a random pitch, Alea-seq, which chooses lists of random pitches, Ana-mark, which creates a transition table of pitches based on MIDI file. Markov1, which generates a sequence of pitches based on a transition table, and kaosn, which expresses the algorithm function $f_{n+1}=cf_n(1-f_n)$. As I mentioned in Chapter 2, computers are able to perform a million calculations per second because they operate using Boolean algebra and a binary system. Since computers can perform calculations much faster than humans, they are efficient tools for composers and researchers to calculate using music data. Nonetheless, OpenMusic has its

[127] Support Ircam, "OpenMusic Presentation" (accessed 12 May 2022) <https://support.ircam.fr/docs/om/om6-manual/co/01-Presentation.html>

particular constraints thanks to the use of Lisp. The fact that this software performs operations with lists, was a source of inspiration and structuring factor in the work *Unnest* for bassoon solo that I wrote in 2020. The software generated a series of lists that determined the proportions of the musical figures within each measure. After this first layer of rhythms was generated, I reutilized the same generated lists to refound the rhythmic figures generated in the previous step. After the completion of the second layer, I redid the same process a third time, generating a third layer of rhythms. Having rhythms with nested tuplets, which were represented by list inside lists, inside lists, I organized my rhythmic material in a way to that it could be perceived a decompression of the rhythm throughout the composition, therefore establishing a unnesting trajectory.[128]

Max and Pure Data

Max is a visual program language developed by Miller Puckette in 1988 to allow the realization of the piece *Pluton* by Philippe Manoury. Initially, the patcher would only process MIDI data, but later, after being re-engineered by David Zicarelli and licensed to Opcode, “external objects” were included. In 1989, IRCAM released a new version named Max/ISPW (IRCAM Signal Processing Workstation) – allowing for real-time audio signals processing. With support of Intel’s i860 processor, this software would combine the graphical interface with the “Faster Than Sound” real-time execution engine.[129] After 1999, Cycling ’74 became the supporter of Max. A few years before the foundation of Cycling ’74, Puckette started developing the program Pure

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[128] Rodrigo Valente Pascale, “Compositions for 0 or 1 Performers,” (master’s thesis, Western Michigan University, 2021), 4-5.
[129] Internet Archive, “freesoftware@IRCAM: A briel history of MAX” (accessed 12 May 2022) <https://web.archive.org/web/20090603230029/http://freesoftware.ircam.fr/article.php3?id_article=5>

Data at the University of California San Diego.[130] Both Max and Pure Data share similar features, but Puckette decided to release Pure Dara as an open-source free software and Max/MSP is a paid software.

Max/MSP and Pure Data allow performers to process audio in real-time and are appropriate for live electronic performances. They provided an interface that permits users to create the own design of objects' toolkit with patch cord connections – covering functions, as audio and data processing. Unlike the DAWs, this software permit artists to engage creatively with the software's structure, so they can build particular functionalities to each composition. The fact that this software provides the composer with a freer environment may result in creative paralysis. However, it imposes a set of rules that make it possible for us to point some structural possibilities, which allows us to create music. This software allows us a wider range of possibilities comparing to DAWs, whose possibilities are more restrictive; on the other hand, composers rely on its set of rules that trace possibilities and are sources of creativity.

SuperCollider

Released by James McCartney in 1996, SuperCollider is an open source and free software and programming language dedicated to musicians and artists who work with real-time audio synthesis and algorithmic composition. Being designed for real-time, this software is a suitable environment for live coding and network performances, which can utilize several processing techniques, including variations of structure or surface detail, algorithmic mass production of synthesis voices, sonification of empirical data or mathematical formulas. SuperCollider allows

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[130]Internet Archive, "cycling74: MaxMSPHistory" (accessed 12 May 2022) https://web.archive.org/web/20090609205550/http://www.cycling74.com/twiki/bin/view/FAQs/MaxMSPHistory

sound creators to generate sound with not much effort and, while representing musical ideas in objects, to transform them by the means of functions and methods to composer music that transforms and manipulates sound in real-time – from micro to an macro level.[131] More than creating a language capable of real-time audio processing, McCartney was interested in creating an interface that could customize and parameterize features of sound processing. Therefore, the main characteristic of SuperCollider is that it allows composers to work and create sounds with algorithms. The development of this software brings as heritage Matthews's MusicN series unit generators.[132] This software is suitable for live electronic music and live coding, as it can synthesize, and process sounds live through code. Even though it is a very flexible environment, this software utilizes C++ programming language that imposes a set of syntax rules that need to be followed by the composer during his creative process. This kind of restrictions are fundamental, as composers depend on them as a source of creativity. As I will discuss in chapter 5, these restrictions trace structural possibilities that inspire us and without them, creative engagement would not be possible.

Conclusion

It is clear that predecessors of computer music relied on analog media, such as magnetic tape and analog synthesizers, that shaped their aesthetics and compositional procedures. These were remarkable artistic manifestations that contributed to the history of electroacoustic music and I stated that media, as consequence, shaped this history. Then, I presented an overview of

[131] James McCartney, "Foreword" in Scott Wilson, David Cottle and Nick Collins ed. *The SuperCollider Book* (Cambridge, MA: The MIT Press, 2011), pp. 9-11.
[132] Ibid, xi

computer music and showed how the shift to the digital medium changed the paradigms of electroacoustic music. Moreover, I demonstrated how the technological advancements are intimately connected to computer music practices throughout time. Finally, I presented some expressions of computer music that remain active nowadays relating them to the medium and I prompt some reflections about software widely used by musicians.

CHAPTER IV

HUMAN-COMPUTER INTERACTION

Introduction

In this chapter, I will research the interaction of humans and computers during musical creative practices, live performance, and analysis. First, I argue that the computer is responsible for modeling our behavior during the creative process, due to the *feedback loop* process. Then, I will explore some possibilities of interaction between computers and performers and how this interaction becomes complex because of the way computers operate. Finally, I will explore some ways in which computers can be a useful tool for analyzing music and how this interaction can help to shape our perception of a composition and understanding of musical concepts.

Human-Computer Interaction in Music

Creation: Composer and the Machine

Using tools provide humans with a quicker and more powerful rendering capacity. In fact, when using computers to assist out creative practice, the machine plays more the role of a partner than a neutral tool.[133] Certainly, the use of any medium shapes our creative practice and like any other medium, the computer is not different. Nietzsche emphasizes the power of the medium to shape speech when he typed into his typewriter the phrase "writing tools are also at work in our thoughts" in a message to his friend Heinrich Köselitz in 1882.[134] The relationship between us

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[133] Daniel Jones, Andrew R. Brown, and Mark d'Inverno, "The Extended Composer," in McCormack, Jon and Mark D'Inverno ed. Computers and Creativity (Heidelberg: Springer-Verlag, 2012), 175.
[134] Kittler, *Gramophone, Film, Typewriter*, 200

and our tools is reciprocal, therefore the actions involving these two agents presume the idea of *feedback loop* and this idea is the crucial point of any creative process.[135]

According to Jones, Brown and d'Inverno, when someone engages aesthetically with the creation of a work, every creative action is evaluated and serve as basis for their next action. Therefore, throughout the creative process, artists constantly repeat this loop of acting and reflecting about their last act to direct their work towards certain direction in the next act. The previous output constructs the premises for the next input, so this *feedback loop* is involved in the aesthetically engaged creation. In the case of musical composition, computers are always used in contrasting directions, to widen or to narrow our creative trajectory. They maintain that many ideas come from the exploration of new tools as we interact with unfamiliar domains. Each domain imposes a set of rules that implies cause and consequence, like tonal music where the dominant seventh chord needs to be followed by a major tonic, for example. Creative practices are achieved by loosening these rules and giving rule to "errors." These errors can be, then, analyzed and incorporated into the grammatic of the musical work. This sort of effect can be searched when exploring new interfaces, where the creator does not master its own set of rules. Using new interfaces opens the door to improvisation that result on non-normative creative practices, since we are using tools that are out of our comfort zone.[136]

On the other hand, interactivity is improved as composers gain intimacy with the used medium. While with an acoustic instrument interaction works in the realm of embodiment – that means, we rely on our muscle memory to get different sounds -, with computer the interaction

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135 Jones, Brown, and d'Inverno, "The Extended Composer," 177.
136 Ibid, 183-87.

happens in the realm of hermeneutics. Therefore, Jones, Brown and d'Inverno claim that the key for the interaction is instead in the symbolic architecture.[137]

Jones argues that interaction tools in computers to produce music can be classified by the following: *direct tool* – the composer inputs a value and the computer outputs the same with no changes (examples of this are score notation software); *reactive tool* – the input is responded proportionately (media player visualization); *procedural system* – a fixed process is unfolded after triggered; *interactive system* – one inputs a certain action with is analyzed by the computer and they respond coherently; and *adaptative systems* – which is an extension of the interactive system as it regards the history of its behavior in a period of time to determine its future outputs.[138]

After analyzing all these aspects of the human-computer interaction during the musical composition, it is possible to affirm that computers are not neutral tools they do inform our creative practice. Since our creative practice relies on the action-evaluation loop and computer is the medium giving us the output that will give basis to our next action, computers help us to give the next directions to our music and we cannot be immune to this outcome when working with these machines. Of course, experimenting with new software can be a source of creativity as we are working with unfamiliar devices and we are freed from normative rules, but mastering a tool allows us to have more interactivity with it. Furthermore, computers show themselves as powerful tools for interactivity as software can work as *direct tools*, *reactive tool*, *procedural system, interactive system* and *adaptative systems*. This gives us a full range of possibilities when engaging with musical composition, differently from traditional tools like pencil and paper, or a

137 Jones, Brown, and d'Inverno, "The Extended Composer," 188.
138 Ibid, 191.

musical instrument, which inputs are directly translated into the output. Naturally, these two traditional media also have their own agency and shape our creative practice, but, since computers are built to translate, store, and output any kind of data thanks to the universal building blocks property, they allow composers to explore a wider range of interactive possibilities.

Performance

An essential requirement to create interaction between computers and performers is computer processing speed. Computers must follow the timescales expected by humans to establish some sort of interactions between these two agents. In fact, a delay longer than 1 second is long enough for the performer to feel that his action does not have a consequence.[139] Therefore, the technological advancements towards faster processing speed was a paramount innovation that supported the ideal of real time interaction between human and machine in live performances. Interaction depends on the idea that an action by the performer will influence the computer to perform an individual task. It is helpful to divide this system into inputs, processing, and outputs to understand the nature of the human-computer interaction in live performance.

Unlike the traditional acoustic gesture, the interaction of a performer with machine does not follow the idea of the instrument as an extension of the performers body. In fact, the link between the gesture and the resulting sound is much more abstract when we are dealing with computers.[140] As will be further explained, one physical action can trigger several algorithms in the computer. The composer and theorist Dennis Smally thought that this abstract relation could bring confusion to auditors. Thus, he divided the relation of sound and its producer gesture into

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[139] Collins, *Introduction to Computer Music,* 194.
[140] Ibid, 195.

four categories of gestural surrogacy. The first-order surrogacy is pre-musical or not intentionally musical; the second-order surrogacy is related to traditional instrumental gesture; the third order surrogacy works in the realm of imagination and gesture is simply inferred, rather than clearly recognizable; and the remote surrogacy takes place when the source of the sound is unknown and it becomes unhuman.[141] Many human-computer interactions during live performance rely on the last two surrogacies, therefore the relationship between the performers gesture and the resulting sound becomes complex.

Computers necessarily need a device that interfaces the real world to establish interaction with the performers. There are input devices whose function is to translate physical movements into computer data. As the computer is a medium that grants composers and performers new possibilities, the body also can be resignified with these devices and gain a new role in music.[142] On the account of the fact that there are numerous kinds of devices and several of them are newly invented every year, I am going to focus on two specific types: control information and visual devices.

Created in the 1980s for machines, the WMIP paradigm (windows, icon, menu and pointer) is also broadly used for music software, both for live performance and music production. A MIDI interface is not required to acquire gestural data, since the computer's keys can be used.[143] MIDI controllers and tapping keys break the acoustic paradigm of "one gesture to one acoustic event," because of the numerous events that can take place with only one command, in other words a set of algorithms that result in several sounds can be related to only one physical

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[141] Denis Smalley, "Spectromorphology: explaining sound-shapes," *Organised Sound: An International Journal of Music Technology* 2, no. 2 (1997): 112.
[142] Collins, *Introduction to Computer Music,* 197.
[143] Ibid, 200.

gesture. This is the most common kind of device used and the most traditional for a performer to interact with computers.

However, the interaction between performers and computers do not need necessary to be established by typing keys, it is possible to track audio and video data to trigger computer algorithms. No sensors are necessary, the movements of the molecules or photons in the air are the only necessary agent necessary to convey gestural information.[144] This data-collection relevance lies on its connection with our senses (vision and audition). Not only can audio signals carry values that can be transduced by the computer into numerical data, but so can video signals. Through video captured by a digital camera device, the computer recognizes movements and separates objects from the rest of the scene. Clearly, these features can be used by composers to trigger sounds in a musical work. Interestingly, this possibility goes beyond the traditional idea that direct action is needed to command computers to perform a task and establishes a new kind of interaction. For instance, producing a certain frequency or amplitude in a musical instrument, or making a particular bodily moment can stimulate the computer and result in the production of a certain sound by the computer. The audio tracking interaction breaks the paradigm of the relation of body movement and sound production, because now not only the body is an agent that can produce sound through moment, but the sound itself can produce sound. Furthermore, the video tracking interaction redefines the role of the body in music. It allows physical gestures to produce sounds that are not necessarily intuitive, as any movement can trigger any computer algorithm – it only needs to be programmed.

[144] Collins, Introduction to Computer Music, 201.

As a result of audio signal tracking and analysis, an improvisational interaction can be established between a human performer and machine. In order to be established, computers must be capable of listening, understanding, and responding to a musical performance. The main interest of this practice of improvisation with the computer as an agent is to widen the possibilities of music performance. However, for this collaborative improvisation to be possible it is necessary that computers work like humans in a few manners. First, it is necessary that the system is autonomous, that means, it needs to be able to respond to unpredictable inputs in a way that was not entirely prescribed.[145] Second, it should be able to avoid cliché and obvious solution.[146] Third, it should be able to participate with contributions that do not disconnect with the musical trajectory. Finally, it should be able to perform the role of leadership, that means to establish the musical trajectory and to induce new musical directions.[147] Improvisational computer music systems may be built from the P Q f architecture, which contain three modules: P is the listening and analysis, Q is the performing or synthesis and f is the patterning and reasoning module. Therefore, live algorithm interactive improvisation has these three modules connected and should not require the control of a human to operate.[148] In this practice, it is implied that the kind of interactivity between human and machine, should not or should minimally differ from the interactivity of two distinct people.

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145 Tim Blackwell, Oliver Bown, and Michael Young, "Live Algorithms: Towards Autonomous Computer Improvisers," in McCormack, Jon and Mark D'Inverno ed. *Computers and Creativity* (Heidelberg: Springer-Verlag, 2012), 149-150.
146 Ibid, 150.
147 Ibid, 151.
148 Ibid, 152.

Interactivity in Live Coding

Live Coding places programing at the center of the performance practice – the main goal of this practice is to code and emerge the performer's musical idea at a speed that keeps the attention of the audience. Since there is the presence of a human writing a code live, maintains the human aspect of the performance, even though algorithms produce the resulting sound.[149] Like interactive improvisation, live coding stays between creative and performative practices. Taking advantage of the WMIP paradigm, the physical typing of the coder can result in series of algorithms that can produce a chain of sounds. At the same time, the software chosen by the coder and its outputs, will influence their next actions. Consequently, the software will shape the practice and its resultant work.

Machine as an Analysis Tool for Research

Sonogram

Sonograms are the graphic result of a computer spectral analysis. They visually represent sound and can be used to represent electroacoustic music. Rather than representing what humans perceive, the spectrogram is an objective representation of sound itself. For Smalley, the sonogram is a useful tool for analyzing electroacoustic music, but it should not be used as final representation of a composition of this genre, because even though it objectively maps sound data, it does not take into consideration human perception.[150] Smalley prompts interesting reflections. It is correct to affirm that sonograms are powerful tools to objectively map sound

[149] Collins, *Introduction to Computer Music*, 201.
[150] Denis Smalley, "Spectromorphology: explaining sound-shapes," 107.

events of an electroacoustic composition. On the other hand, as computers do not utilize any kind of logical filter when transducing sound into graphics, they lack human agency. Indeed, this feature is what assures objectivism to these maps and that is the reason why sonograms are a great tool. Actually, the use of objective data graphics may help us shape our perception, as things that are in the back and "cannot be heard" come to the foreground. Due to its high level of detail, listening to a composition while checking the graphic may make us have a hypersensitive audition. Therefore, these graphics become an interesting complement to our perception for musical analyses.

Analyzing MIDI

Besides sound, computers feature MIDI data analysis. Even though MIDI does not fully represent music, it contains enough amount of information to analyze melodic contour and find tonality and pulse. Eerola presents some ways in which computer MIDI analysis may be usable, such as, identifying similarities between melodic contours, to find the key to a specific composition and find the meter of a musical sequence, as well as identifying minor melodic unities (phrases and motifs).[151] These are tasks that can be performed by scholars, but when computers are instructed to perform the same tasks, the result gains an over-objective and automatic character that may help researchers reevaluate how we understand these subjects, which a lot of times are evaluated subjectively. For example, Krumhansl & Schmuckler key-finding algorithm analyzes the key of musical compositions by weighing the pitch-class importance by its duration and fitting the piece into one of the 24 key profiles (12 major or 12 minor).[152] Also, Brown proposes a system to find the meter of a musical work by using

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[151] Toumas Eerola and Petri Toiviainen, "MIR In Matlab: The MIDI Toolbox," *Proceedings of 5th International Conference on Music Information Retrieval* (2004): 22–26.
[152] Ibid, 3.

"autocorrelation function and to seek peaks from the onset structure corresponding to simple duple (2/4, 2/8, 2/2, 4/4) or simple triple meter (3/4, 3/2)."[153] This experiment was successful on finding the right meter in 80% of the attempts.[154] These experiments with computer analyses help us to rethink elementary musical concepts. Therefore, these concepts, whose identification many times remains in the realm of tacit knowledge, gain an objective character.

Conclusion

During the approach of several versions of human-computer interaction, I identified that computers are responsible for shaping our creative outcome. Because creators are in a constant feedback loop of inputting action and evaluating output that is given by a computer, it is inevitable that the computer outputs will mold the human's next action. Not only computers influence our creative output, but so do any media. Computers in particular are interesting media because the established interaction can happen at many levels according to the creator's intent: directly, reactively, procedurally, interactively, and adaptively. The interactivity between performers and computers depends on many factors, like the processing speed and the use of devices. The relationship between gesture and resultant sound operates in different ways compared to traditional instruments. The paradigm of "one gesture, one sound" is broken as only one gesture can result in a series of algorithms that can produce many sounds. This process opens new audio and video tracking possibilities, new ways in which the performer uses his produced sound and body to trigger sound. Moreover, live coding and interactive improvisation establish complex interactions that shape their creative outcome. Finally, computers can also be

[153] Eerola and Toiviainen, "MIR IN MATLAB: THE MIDI TOOLBOX," 3.
[154] Ibid, 4.

used to analyze music, which may help us shape our perception in accordance with objective data graphics and to rethink musical concepts as they need objective definition to be identified by the computer, while sometimes are understood in a subjective manner.

CHAPTER V

AESTHETIC IMPLICATIONS

Introduction

In this chapter, I will investigate how the constraints imposed by the computer medium informs the composer's work aesthetically. Furthermore, I state that exploring computer glitches, which are derived from the computer materiality and limitation, is an interesting artistic zone for exploration by musicians as it brings the materiality of the medium to the foreground. I start by prompting some reflections regarding computer constraints in many forms, such as MIDI devices we may utilize together with a computer, Video and Audio tracking constraints and software design constraints. I do not by judge these constraints, rather I sustain that these limitations are what makes creativity in the field of computer music possible. I reflect on glitch aesthetics, and I explain how this trend is a ground-breaking response to the normative use of computers in music. I conclude by stating that the media has an elevated agency in compositional work, in our creative thinking and in the history of music.

Limitations

"Affordances" and "Constraints"

In the article "Designing Constraints: Composing and Performing Digital Musical Systems," Thor Magnusson points out differences between "affordances" and "constraints" and explains how constraints play a fundamental role in creativity. Affordances can have many definitions, but all of them consider the perceived potential use of the object in relation to the agent in a nonrepresentational manner. Constraints, as approached by Margaret A. Boden, are a source of creativity as they imply an environment for "structural possibilities," and can be investigated and transformed depending on one's intentions. Magnusson divides these constraints into two categories, *subjective* and *objective constraints*. *Subjective constrains* are the expressive rules derived from a long-term practice history that builds tradition. *Objective constraints*, on the other hand, are physical restriction imposed by materiality of the environment or human tools. In opposition to affordances, constraints are not necessarily perceived from the beginning and can be understood as the agent engages with the object. While some objects have more clear affordances, such as hammers, which obviously have a hammering potential, computers invite us to a more complex interaction. As we may understand the possible limitations imposed by computers through experiencing them, Magnusson considers the concept of "constraints" to be a more suitable term to refer to the more abstract relationship of humans with computational systems and their designs.[155]

MIDI Devices Limitations

Using the mLog as an example, Magnusson indicates that interfaces, whose affordances are easily recognizable, are effective tools to constrain the wide world of possibilities provided by a programming software, like SuperCollider. Thus, composing on these devices is informed by the objective limitations of the interface itself.[156] This idea can be applied, not only to the study case, but also to other MIDI devices as well.

According to Howe Jr, using keyboard devices imposes certain limitations on composers. The first limitation is that these devices do not grant the composer accurate control over

155 Magnusson, "Designing Constraints: Composing and Performing Digital Musical Systems," 63-65.
156 Ibid, 67.

"continuous frequencies changes," such as glissandi. The implementation of controls that could potentially overcome this limitation would result in an unpractical operational design, as more than two hands would be needed to operate everything. Another limitation that is imposed by these devices is the lack of control over overtones, which are non-tempered frequencies. That said, timbral properties of sound cannot be controlled by these devices and any current change of the timber overtone structure must be done in another way. This limitation can potentially result in a lack of timbral variance in compositions that utilized MIDI keyboard controllers.[157] Taking Howe Jr consideration into account, it is possible to reaffirm Magnusson statement that when composing with a MIDI device musicians rely on the objective limitation of the interface, which in that case are the limitations of the physical object and limitation of the way it operates.

Synthesizer Limitations

Furthermore, composers face limitations while utilizing synthesizers in their creative process. Synthesizers offer *explicit controls* over musical parameters to composers, so they can structure their compositions based on these parameters. Moreover, the *operational skills* of a synthesizer will affect the composer's actions in order to make it respond (for instance, using a monophonic synthesizer will require thr composer to take certain practical decisions if they want to produce polyphonic sounds). [158] Besides the traditional parameters of pitch and duration, most of the synthesizers allow composers to manipulate the ADSR envelope (that is, attack, decay, sustain, and release). Selecting these parameters (or others) by itself, already leads composers to structure their composition based on them and leaving other parameters aside.

[157] Howe Jr, "Compositional Limitations of Electronic Music Synthesizers," 123.
[158] Ibid, 121.

Video and Audio Tracking Constraints

Magnusson explains that video tracking limitations are derived from the system itself. First, this kind of system can only track shapes that are programmed to be tracked (which can be hand, body etc). Lighting and background also are important parts of this system as they necessarily need to be constant during the tracking. Moreover, there are limitations imposed by the capacities of the tracked object itself – in the case of hands or body their flexibility and our skills to memorize gestures.[159]

Certainly, this could be extended to Audio tracking. As previously discussed in chapter 4, computers are capable of collecting data of frequencies and amplitude played by a performer. However, just like in video tracking, these parameters need to be pre-programmed and the background sound should preferentially be minimum and never louder than the sound that is intended to be captured. Not respecting the protagonism of the performer could potentially trigger algorithms that are not intended to be triggered. Nevertheless, these limitations are what make the creative engagement with the machine possible. This happens because the structure of the system allows us to get a deliberate output from the computer, establishing an interaction between performer and computer. If these constraints were not defined, the computer's output would be random – and would not build any relations with the performer's input, hence establishing no interaction.

Software Design Constraints

Even though software is currently taken as a non-material agent, its materiality can be seen in at least three instances: 1. Humans control software through physical gestures; 2. Software's

[159] Magnusson, "Designing Constraints: Composing and Performing Digital Musical Systems," 67.

functionality, that is, it "can be changed and reconfigured;" 3. The materialization of the software happens when someone uses it as the bits, data and algorithms run inside the machine. Furthermore, the materialization also occurs externally as the used inputs data, which result in output products to be aesthetically understood by the composer and audience. The materiality of software results in constraints that are a source of inspiration and challenges for the composers.[160] As cited, these constraints imply structural possibilities which will inform the creative work of the composer.

One of the features that imposes constraints to software is the design of the interface that is represented through metaphors or metonymies. Metaphors provide some familiarity to software in order to ease the interaction of the user with it.[161] By definition, metaphor is a trope that relies on the similarity between object and domain. As a consequence, computers utilize metaphoric approaches when simulating other tools and media like analogue synthesizes or tape recorders.[162] Indeed, DAWs, like Pro Tools or Logic Pro, use metaphors in their design construction to simulate a tape recording or a piano roll and their functionalities. Max/MSP, differently, operates in the realm of metonymies. Metonymies do not substitute the object by a similar domain. Actually, they work by representing an object with a characteristic of it or another object that has contiguity relation with it. Because of this different approach, Max/MSP allows users to reconfigure and program patches. Therefore, metonymic designs allow musician programmers to creatively build their own computer instrument for the purposes of their own artistic product. According to Bertel, Breinbjerg, and Pold, while a metaphoric design is very effective in giving the users familiarity with the software, it limits the functionalities of the

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[160] Olav W. Bertelsen, Morten Breinbjerg and Søren Pold. "Emerging Materiality: Reflections on Creative Use of Software in Electronic Music Composition," *Leonardo Music Journal* 42, no. 3 (2009): 199.
[161] Ibid, 199.
[162] Ibid, 200.

software to a narrow range of possibilities. In contrast, metonymic designs involve directly coding and programming. For that reason, they allow the users to remold the software's functionalities in order to attend to their artistic demands and refine the way they operate. [163]

Even though metonymic designs are powerful models that allow music programmers to reshape software as a way to shape them into their creative project, it also imposes constraints. SuperCollider is a software that allows composers a very flexible system that allows us to freely decide all the parameters of sound that are defined by it. However, since this software uses the programming language C++, it is subordinate to the set of rules that define this language. Therefore, the syntax, which defines which statements are correct, must be followed. Identifiers are used to name functions, constants, and variables, which are limited. Finally, this is not a peculiarity of this language but pf everything that happens inside the computer, the only data that can be processed is binary. No data that is non-binary can be processed by a computer unless it is converted to the digital format. In fact, the binary system together with the Boolean language is what makes everything in computers highly deterministic. Thus, every composition written in the computer medium is subordinate to determinism. Pseudo-random values can be generated, so we do not understand any patterns from a sequence of numbers. However, they are not going to be random and always based on a deterministic function.

Limited Expression as a Source of Creativity

Due to constraints that are imposed by any medium or device, we are able to engage creatively with it. Limited environments trace structural possibilities and determine the boundaries of what is feasible and what is not. Clearly, there are some systems that are highly constrained,

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[163] Bertelsen, Breinbjerg and Pold. "Emerging Materiality: Reflections on Creative Use of Software in Electronic Music Composition," 201.

increasing the potential of our expressivity as several decisions do not need to be taken by the creator. In the opposite direction, when artists face freer systems, they may feel overwhelmed by the amount of decisions that need to be taken and may be unable to create. On the other hand, even freer systems impose a set of rules that need to be followed for it to work, therefore creating boundaries and projecting possible paths to be taken by the artist.

Glitches

Overview

The limitation of computers can be further seen in their glitches, and musicians were able to work in this boundary and explore them. Glitch music was born by artistically incorporating digital glitches, like clipping, distortion, quantization errors, software bugs, system crashes, and the noise made by the hardware, into a compositional work. Although these noises are normatively avoided and hidden, computers can be used to emphasize these errors and submit them to a compositional structure. This kind of aesthetic approach has been an outstanding trend in the arts since the last years of the twentieth century. The glitch aesthetics highlights that not only new sounds can be discovered accidentally through experimentation, but also that we are not fully in control of technology and that the perspective of the digital as a perfect environment where anything is possible is misleading.[164]

The use of glitches in music questions the perspective of the digital as an immaterial perfect means since it puts the medium and its materiality in the foreground of the particular work. Stutters, skitters, skaters, distorted sounds, and the failure of the machine to accomplish

[164] Cascone, “The Aesthetics of Failure: "Post-Digital" Tendencies in Contemporary Computer Music,” 13.

tasks are not only a consequence, but a desired effect.[165] Starting in the mid-1990s, glitch aesthetics began to be approached not only in academic music but also in dance genres and some of the techniques utilized included extreme time-stretching and reducing the bit-rate to eight bits or less, therefore manipulating digital media to explore the glitch in the timbral realm. This trend grew and established itself as an aesthetic, “the aesthetic of failure.”[166]

One of the important techniques related to glitch music and one of its earlier expressions was made through CD-Skipping, which can be accomplished by denting, cutting, or damaging the readable part of a CD. The Japanese-American Yasunam Toné is claimed to be one of the first sound artists to employ CD-Skipping techniques, as he recorded CD-Skipping compositions in the late 1980’s using as material CDs with cut surface and released them in his album *Solo for Wounded CD* in 1997.[167] The German electronic music group “Oval” made also important contribution to glitch music by using CD-Skipping techniques in the 1990s. They would paint small images on the surface of the CD in order to prevent the correct reading of it by the CD-Player making it skip.[168] Both expressions go toward experimenting with the machine’s failures.

Glitches and Expression

The British composer Brian Eno made a valid statement about the use of media noise:

> Since so much of our experience is mediated in some way or another, we have deep sensitivities to the signatures of different media. Artists play with these sensitivities, digesting the new and shifting the old. In the end, the characteristic forms of a tool’s or a medium’s distortion, of its weakness and limitations, become sources of emotional meaning and intimacy[169]

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[165] Arild Fetveit, “Medium-Specific Noise,” 211

[166] Cascone, “The Aesthetics of Failure: "Post-Digital" Tendencies in Contemporary Computer Music,” 15.

[167] Nick Prior, “Putting a Glitch in the Field: Bourdieu, Actor Network Theory and Contemporary Music,” *Cultural sociology* 2, no.3 (2008-11): 306.

[168] Cascone, “The Aesthetics of Failure: "Post-Digital" Tendencies in Contemporary Computer Music,” 13.

[169] More Dark Than Shark, “The Revenge of the Intuitive” (accessed 12 May 2022) <https://www.moredarkthanshark.org/eno_int_wired-jan99.html>

Eno points out that exploring the noise of a certain medium, is not only merely an avant-garde wish to disrupt with the normative use of it, but actually a way for us to express ourselves artistically through new timbres and triggers new affects.

Another composer that reflected on noise and expressivity was the Italian Luigi Russolo. In the Futurist manifesto from 1913, he states: “machines create today such a large number of varied noises that pure sound, with its littleness and its monotony, now fails to arouse any emotion.”[170] Then, for him, music should disrupt with the limiting traditional pure sound and acquire an infinite variety of timbers and textures and the path to do so was to embrace the sound of the machines.[171] As radical as Russolo’s perspective seemed to be, he was able to capture in 1913 what Eno would approach more than eighty years later: noise is highly expressive. Furthermore, he also introduced how the advent of machines was able to change our perception of pure sound, which relates to Benjamin’s theory of “historicity of perception” that would be introduced only in 1935. Nonetheless, Eno goes beyond Russolo’s approach and talks about noise in the specificity of a medium, that is to say, working in the gray zone of the limits of a medium and demanding it to perform tasks that are predestined to failure.

Thus, the search toward glitches brings to the foreground the materiality of digital media by giving it non-transparent treatment throughout artistic works, instead of reinforcing the illusion that digital medium can be transparent, disembodied, perfect and immaterial.[172] Working within the glitch aesthetics shifts the perception of the listener from abstract traditional forms to the use of the technological media themselves and the composition process.[173] For that

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[170] Luigi Russolo, *The Art of Noise* (New York: Something Else Press, 1967), 5.
[171] Ibid, 6.
[172] Fetveit, “Medium-Specific Noise,” 197.
[173] Church, “Against the tyranny of musical form: glitch music, affect, and the sound of digital malfunction,” *Critical Studies in Media Communication* 34, no. 4 (2017): 323.

reason, glitch compositions acquire a meta-referential character, since they are referencing the limitation and failures of their own media. Furthermore, it is precise to say that investigation of noise was responsible for increased timbral potential in music by widening the range of sonic possibilities. Being still in vogue, noise transforms our aesthetics and leads a trend that is against the normative use of technology in music.[174] For Russolo, broadening the range of timbres and textures would be advancing a glitch aesthetics that successfully increases the expressive potential and expends the sensibilities of the audience. By moving the listeners perception away from traditional and abstract forms and bringing them to reflect about the materiality of the medium while listening to new timbres, glitch aesthetic reveals new kinds of affects.[175] New timbres unveil new environments that stimulates the listeners to build their own meanings, therefore exciting them.[176]

It is worthwhile to mention that the glitch aesthetics similar to computer music in general rely on the materiality of media. All the glitches explored in an artistic way are shaped and made possible by computers. It is clear that composers have a fundamental role in creation, but their creativity is also a product of aesthetic evaluations of computers' output during the composition process, as I discussed in the previous chapter. If computers mold the discourse of any musical composition made in this medium, I am led to a conclusion that is analogous to Kittler's but applied to the field of music. Stating that "the history of world is the history of media," I prompt a similar thought that the history of music is also the history of media.

174 Fetveit, "Medium-Specific Noise," 212.
175 Church, "Against the tyranny of musical form: glitch music, affect, and the sound of digital malfunction," 324.
176 Ibid, 323.

Conclusion

By pointing out limitations that composers face when choosing a computer as a medium to engage creatively, I do not undermine computer music. In opposition to this perspective, I argue that constraints resultant from computers' materiality are what enables us to engage with it creatively, as it trails structural possibilities. As Kittler already analyzed in the second half of the twentieth century, all discourse is a consequence of media technology of its historical time.[177] Thus, other media also mold our artistic product by imposition of their material restrictions. Surely, western musical notation, phonograph, magnetic tape, and synthesizers created different constraints – between them and in relation to computers – resulting in different aesthetics. In accordance with the creative *feedback loop,* media are a fundamental piece of our creative thought. This happens because after an initial input, media output a product which is evaluated by the creator and that traces the path for the creator's next input. This loop takes place throughout the whole creative process, therefore shaping our creative thinking.[178] How computer systems operate is not second to computer music, in truth, it is in the foreground of it. Computers shape computer music history, its art and the composer's creativity.

As the influence of the medium over our artistic work is inevitable, I support the materialistic perspective that we should explore sound worlds that make the medium's signature clear rather than try to hide it. Even though many sound artists take for granted that the virtual medium is immaterial, perfect, and transparent, I brought evidence throughout this thesis that demonstrates the opposite. Therefore, the digital medium has its own limitations due to its materiality. The glitch aesthetics trails an interesting, but not unique, path to shift the listeners

[177] Kittler, *Discourse Networks 1800/1900*, 369
[178] Ibid, 183.

attention from traditional and abstract forms to the compositional process and the limitations of the computer. In this way, I state that the materiality of the computer becomes the central topic of the composition. Just like western music notation allowed the development of polyphony, magnetic tapes allowed *musique concrete* to germinate, and analog synthesizers allowed *elektronische Musik* to utilize serial techniques because of their own material characteristic, I stand that exploring the features and limits of the computer, instead of treating it as a transparent medium, will gift us with new astonishing genres, techniques, and aesthetics and lead computer music to innovative paths.

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