Brief Overview of the Uses, Disuses and Reuses of the Terms Algorithm, Generative, Procedural and Metacreative: Proposition of a Diachrony for the Terminologies Associated with Computer Music

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Abstract
In the context of computer music, it is observed that the expressions 'algorithmic composition', 'generative music', 'procedural composition' and 'metacreative music' have recurrent and interchangeable use. The coexistence of these terminologies, as well as their loose and transdisciplinary uses, means that the boundaries delimiting concepts are increasingly displaced and imprecise. Therefore, the objective of this text is to provide proposals for distinctions between these terms and to present the suggestion of a diachrony in order to illustrate the uses and reuses of these terms. The methodological approach adopted was the qualitative-quantitative analysis of the articles retrieved from online academic databases. Our interest is, through terminology analysis, to understand the innovations and transformations that have impacted the field of computer-assisted music creation.

Palavras-chave: algorithmic composition; procedural composition; generative music; metacreative music.

Introduction

In 1956, Noam Chomsky published his article "Tree Models for the Description of Language", a seminal text in which he incorporated concepts from statistical mathematics into the grammatical analysis of the English language. His analytical approach revolutionized the field of linguistics at the time (Hingginbotham, 1982). Chomsky's search for basic linguistic structures capable of providing generative grammars for all English sentences culminated in his book "Aspects of the Theory of Syntax" (1965), from this work, the term *generative* became definitively established in linguistics. Within Chomsky's generative grammar, generative implies "a system of rules that explicitly and clearly assigns structural descriptions to sentences of a language" (Chomsky, 1965, p. 8). From the outset, one can see a certain affinity between this definition and the concept of an algorithm (see below). Perhaps due to this similarity, the term generative was later adopted by other areas besides linguistics and is now used in computing, psychology, and cognitive modeling.

An algorithm refers to a systematic and hierarchical organization of tasks designed to provide a solution to a problem. An algorithm is therefore a finite sequence of operations. Historically, the term 'algorithm' predates its use in computing, originating in mathematics and philosophy (see, for example, several encyclopedia entries). The earliest known use of the term in mathematics is attributed to the mathematician Abu Ja'far Muhammad ibn Mûsâ al-Khowârism (c. 825), who wrote 'Algorithmi de numero indorum'. In this work, he discussed algorithms within the context of the Indian decimal system. In addition, the concept of algorithmic processes is also found in early philosophical texts, such as Euclid's *Algorithm* (c. 300 BC) (Britannica, 2024). Leonardo di Pisa introduced the term to Italy, translating the Arabic words 'algarismo' or 'algoritmo' (Potts, 1879, p.17). The term spread to other European countries through Latin translations of Arabic algebra and Hindu arithmetic texts. In the area of music, both the terms "generative" and "algorithm" are present in various creative domains, as will be discussed below.

Chomsky's proposal saw its most evident development in Fred Lerdahl and Ray Jackendoff's book *A Generative Theory of Tonal Music* (1983). Understanding the tonal system as a language with a well-established syntax, the authors adopted the concept of *generative* similarly to Chomsky's grammar. They proposed a finite set of rules capable of generating an infinite number of possible musical structures (Hansen, 2010). Although well-known, Lerdahl and Jackendoff's book has had surprisingly little impact on music theory; it is rarely included in Brazilian course curricula. However, it remains highly relevant in several music research fields, particularly musical computation, cognition, and music psychology (Hamanaka, Hirata & Tojo, 2006; Hansen, 2010)[1].

Chomsky's legacy has spurred continuous development of theories and concepts to explain the mechanisms of diverse languages (oral, computational, musical, etc.). Various taxonomies, calculations, diagrams, and other tools have been proposed to aid in understanding of complex communicative mechanisms. Throughout the 20th century, terminologies like 'algorithm', 'generative', and 'procedural' were revisited, acquiring new forms and meanings, and becoming objects of creative exploration (Boden & Edmonds, 2009).

With the rise of the computer age, these forms and models gained new dimensions within artistic creation environments. The use of computers popularized terms such as 'algorithmic

[1] To provide a dimension of the relevance of Lerdahl and Jackendoff's work for music research, see Niels Hansen's (2010) article on the legacy of Generative Tonal Music Theory.

music', 'generative music', 'procedural music', and, later, 'metacreative music'. These terms, sometimes overlapping and sometimes distinct, are the focus of this article.

It is precisely the coexistence of several terminologies, as well as the diverse and transdisciplinary uses of similar procedures, that cause the boundaries between concepts to become increasingly blurred and imprecise (Wooller, 2005). Consequently, a time comes when a term or expression (such as computer music) ceases to be an element of differentiation and begins to act as a unifier of concepts, styles, processes, and techniques.

In their 1999 work, *All the Methods for Algorithmic Composition: A Survey, a Critical View and Future Prospects*, Papadopoulos and Wiggins highlighted the difficulties in categorizing algorithmic composition methods. This complexity extends beyond terminology to encompass the entire technical context of computer-created and computer-assisted music. In this scenario, new possibilities have emerged in the field of musical composition and sound design, thus paving the way for innovative and creative approaches.

In the late 20th and early 21st centuries, the terms 'generative', 'procedural', 'algorithm', and 'metacreative' became foundational in the development of cultural (Collins & Mclean, 2014), academic, and technological phenomena related to computer-created and computer-assisted music. These phenomena, in turn, transit in various spheres, such as raves, live performances, software creation, electronic music, automation of procedures intrinsic to musical composition, and sound design, in addition to appearing as an object of study in academic environments.

Given this context, this text aims to clarify distinctions between computer music procedures, without, however, challenging existing definitions. Our intention is to help understand the transformation of these concepts throughout recent history. Furthermore, we propose a diachronic analysis to illustrate the uses and reuses of the following terms: 'algorithmic music', 'generative music', 'procedural music', and 'metacreative music'.

As the use of the computer (whether as a tool, assistant, or co-author) has become the standard procedure for creating musical tracks and sound design in the area of video games, the review of the literature used to collect data regarding the concepts worked on here involves many authors in this specific area.

Finally, the use of the term 'computer music' itself has been, and continues to be, disputed. This is largely because computers are now involved in virtually all everyday tasks[2]. Therefore, defining compositional practice by the tool used becomes meaningless. Stravinsky, for example, was known to compose his orchestral works on the piano, yet his style was not classified as 'pianistic music'. Similarly, the term 'video art' has been challenged in visual arts, as video is no

[2] As early as 1989, Judson Rosebush stated that: "computer art has become a meaningless term, because soon virtually all art will be computerized in some way or another" (Rosebush, 1989, p.55).

longer the sole medium for capturing images since the advent of digital cameras. Historical literature on computer music also suggests other names for this emerging compositional practice, such as ‘music and information technology’, ‘musical engineering’, and ‘digital music’. In the 21st century, Italian researcher Laura Zattra (whose book has a mainly didactic purpose) proposes the following definition: “computer music means the repertoire of pieces, from the pioneering to the most recent, that use the computer in the context of musical research dedicated to the processing, transformation, and organization of sound”[3] (Zattra, 2011, p.31).

The Grove Dictionary avoids defining ‘computer music’ as an autonomous (sub)genre. Instead, it features an entry on ‘computers and music’ by John Strawn (2013).

This expression certainly encompasses the vast range of computer applications in various aspects of music making (not just composition), such as digital sound synthesis, physical modeling, automation of compositional processes, score editing, recording, mixing, and studio editing (DAW), among others.

Without delving into the intricacies of similar disputes, in this text we adopt an operational definition, namely: computer music is music that could not have been composed without the use of a computer. This definition aligns, to some extent, with that of Curtis Roads, whose definition is frequently cited in the literature (perhaps due to its appearance on Wikipedia):

> Computer music is the application of computing technology in music composition, to help human composers create new music or to have computers independently create music, such as with algorithmic composition programs. It includes the theory and application of new and existing computer software technologies and basic aspects of music, such as sound synthesis, digital signal processing, sound design, sonic diffusion, acoustics, electrical engineering, and psychoacoustics (Roads, 1996, i).

Although some authors have reservations about the use of the term “computer music”, the relevance of publications dedicated to the subject is undeniable. A milestone in the dissemination of ideas and research related to the use of computers and their various applications in music was the launch of the Computer Music Journal, published by MIT since 1977. In the inaugural issue (February 1977), editor John Snell interestingly cautioned readers that the journal was highly technical and recommended prior reading of other publications for a better understanding of the articles presented. Snell wrote:

> I would suggest first reading Max Mathews’ article “The Digital Computer as a Musical Instrument” which appeared in Vol.142, p.553 of *Science* in 1963. I would also highly recommend *The Technology of Computer Music*, also by Max Mathews with the collaboration of J. E Miller [...] published by MIT Press in 1969 (Snell, 1977, p.2).

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[3] In the original: Computer Music è il repertorio di brani, dai pionieristici ai più recenti, che usano il computer nell’ambito dela ricerca musicale dedicata all’elaborazione, a la trasformazione e all’organizzazione dei suoni.

Despite the technical content involved, 46 years after John Snell's editorial, not only the MIT magazine, but the entire technological, technical, and aesthetic context of computer music continues to interest musicians, engineers, composers, and researchers, thus indicating the relevance of the various themes embraced by this domain of the musical métier.

Methodology

To aid understanding of the establishment and transformation of the aforementioned concepts, the methodological approach adopted resembles a 'state-of-the-art' survey. However, we must clarify that this is not rigorously a state-of-the-art review. While the survey conducted was systematic and delimited, the sources consulted were restricted to literature available in English, Portuguese, Spanish, French, and Italian. Therefore, we acknowledge that a more extensive review, encompassing other languages, would be necessary to provide a truly accurate diagnosis of the current state of knowledge in computer music and thus be strictly characterized as state-of-the-art. Nevertheless, it is important to note that authors of diverse nationalities frequently choose to publish in English. This is readily apparent by examining the various authors listed in the References at the end of this article. Consequently, these publications, even if not written in the authors' native language, contribute to a significant sample for this survey.

Some encyclopedia entries provided not only definitions but also historical diachrony regarding the transformations within computer music. Two Grove entries were of particular interest. The first, 'Lejaren Hiller' (Stiller, 2001), profiled the American researcher and composer considered a pioneer in computer programming for composition. Hiller created what is historically regarded as the first musical work generated by a computer: the *ILLIAC Suite* (1957), later renamed *String Quartet No. 4* (Stiller, 2001). The second entry, 'Computers and Music' (Strawn & Shockley, 2013), has already been discussed.

The quantitative survey of production aimed at studying and creating procedures to enhance the use of computers can be conducted by searching for descriptors such as 'generative', 'procedural', 'algorithmic,' and 'metacreative' music or composition. These terms are sometimes treated by authors as complementary, synonymous, or distinct, creating the semantic problem that motivates this review. In some cases, these terminologies become part of the jargon of different academic or social groups, further complicating overall understanding of the phenomenon. Several authors, such as Dorin (2001), Järveläinen (2000), and Papadopoulos & Wiggins (1999), point out the problems caused by this lack of terminological precision. For example, Wooller and Brown (2005, p. 21) note that the terms "generative art" and "computational art" have been used together, and more or less interchangeably, since their inception. Similarly, Plut & Pasquier (2020, p. 2) state that algorithmic, procedural, and metacreative music are largely synonymous, as evidenced by a subsequent quotation.

Since the use of computers has become ubiquitous in virtually all sectors of music production, and given our specific interest in understanding the innovations and transformations that have impacted musical creation through terminology analysis, we restricted our search to texts dealing with computers as mediators or producers of musical works. Consequently, works related to research in areas such as computerized listening, computer-assisted musical transcription and notation, pitch correction software, computer-assisted musical instruction, and physical sound modeling (digital creation and recreation of musical instruments), among others, are not included in this survey.

The methodological procedure adopted here involved searching for academic, scientific, and educational works using the Google Scholar database. This database was chosen for its practicality and because it aggregates results from other important repositories, such as JSTOR and Academia.edu. The following descriptors were used: “algorithmic composition”, “algorithmic music”, “generative composition”, “generative music”, “procedural composition”, “procedural music”, “meta-creative music”, and “meta-creative composition.” For the French language, the search considered its specific characteristics, including the descriptors “informatique musicale” and “musique et ordinateur.” The initial search was conducted without date or language restrictions. Subsequently, a preliminary reading of the results was performed to screen the works, excluding those that did not address compositional aspects.

The selection of these descriptors was motivated by two potentially problematic factors. First, Plut and Pasquier (2020) suggest that these terminologies may be interchangeable. Second, our preliminary reading indicated that these terms, despite originating in different fields (mathematics, linguistics, computing, cognitive psychology, and the arts), are used interchangeably to describe the same phenomenon within music.

Although a search using the descriptor “algorithm” yields results dating back to the 19th century[4] and continuing to the present day[5] (Figure 1), this article focuses on the period from the 1960s to the present. However, Noam Chomsky’s 1956 article is included due to its fundamental role in formulating the concept of “generative.” Academic texts (including articles, books, book chapters, dissertations, and theses) were selected, read, and analyzed, with a focus on how the terminologies were presented, as well as each author’s particular uses and descriptions.

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[4] See, for example, Lowry, 1875.

[5] The search conducted in February 2024 yielded 1,390,000 results, in any language, for the descriptor “algorithm.” In January 2024 alone, 1,430 texts were published addressing this subject in relation to music (Figure 1). Interestingly, despite being a concept introduced centuries ago, the term “algorithm” still lacks a consensual definition. See, for example, Yiannis Moschovakis’s 2001 chapter titled “What is an algorithm?” which proposes a refined definition within computer science. See also “The use of the concept of algorithm in Brazilian research in music” (Oliveira, 2020) and several studies on innovations in the use of algorithms in music (Edwards, 2011; Prechl, 2014; Manaris, Stevens & Brown, 2016).

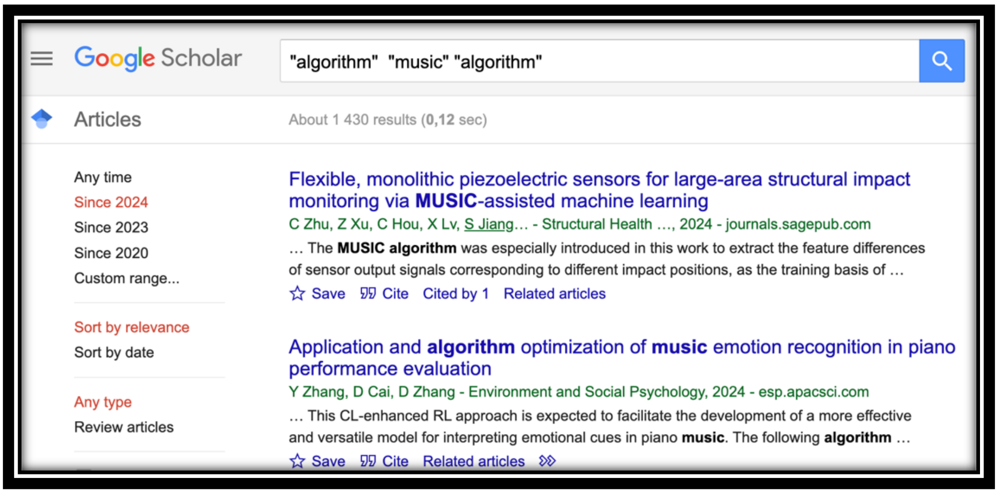


Figure 1 – Screenshot of a search performed on Google Scholar showing (just in January 2024) 1,430 results for the term “algorithm” associated to music.

Preliminary Observations

First, it is worth noting that within computer-based music creation, the literature largely focuses on electroacoustic music and video games. Electroacoustic music has predominated in the creative use of electronic equipment since at least the 1950s, beginning with the pioneering experiments of Pierre Schaeffer and Karlheinz Stockhausen. Later, with increased access to computers and software, tasks such as analysis, synthesis, processing, and sound modeling began to rely heavily on these resources.

However, in the current context of video games, due to their interactive nature, music is often entirely created, manipulated, and/or reproduced using computational algorithms with minimal human intervention (Wooller & Brown, 2005; Collins, 2009; Silva & Corrêa, 2023). In this context, computer-played music refers to the computer’s ability to select audio from a sound/music bank to accompany the player at specific moments within the game. The adoption of diverse creative techniques has made the video game industry a hub of technological innovation for musical composition. “Video games are perhaps an ideal form of media for procedural music” (Collins, 2009, p. 5), adapting to the dynamic and interactive nature of games.

Beyond what has already been discussed regarding the Grove entry on computer music, it is also interesting to note the use of other search terms employed here. While “algorithmic music” does not have its own entry, the expression “algorithmic composition” appears within bibliographic entries, such as the one on “Lejaren Hiller” (written by Andrew Stiller), a pioneer in computer music.

It is important to clarify that the term “algorithm” is not restricted to the mathematical-computational domain. Generally, an algorithm can refer to any pre-established set of operations designed to achieve a specific objective. This objective can range from solving a mathematical problem or optimizing transportation logistics for delivering goods to mapping communication networks, among other things. According to theorist David Cope (2000), precisely because of this broad scope, an algorithm is relevant whenever an activity is reduced to a series of rules or instructions that automate it. In music, algorithms are used in various ways, and particularly in composition, they appear in different forms. Cope suggests classifying these forms by observing how the algorithm participates in the compositional process. This allows for a distinction between procedures that use computers and those that do not. Computer-based compositions can be further subdivided into music composed by the computer (where the algorithm can make its own decisions during the creative process) and music composed with the computer (where the computer acts as a tool).

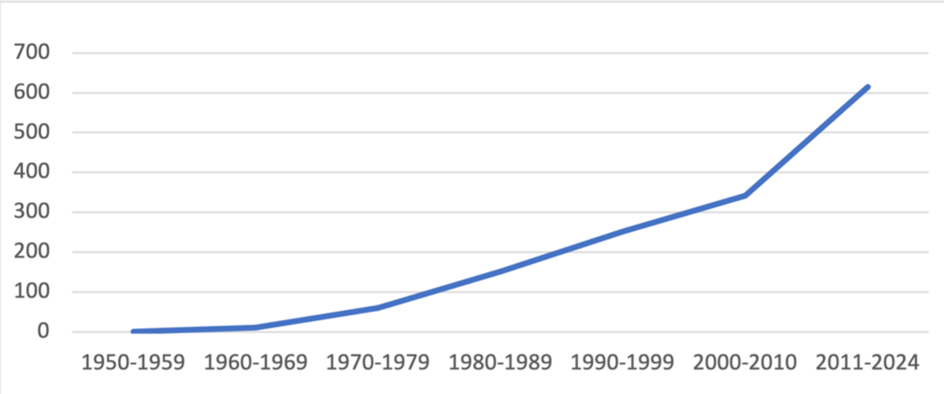
While Grove does not have an entry specifically for “generative music”, the term “generative” appears in several bibliographic entries and within other entries, such as “Laptop” (written by Edmond T. Johnson), “Brain-computer music interface” (authored by Anne Beetem Acker), and several mentions in the entry “Psychology of Music” (an extensive entry with several contributors: Diana Deutsch, Alf Gabrielsson, John Sloboda, Ian Cross, Carolyn Drake, Richard Parncutt, Stephen McAdams, Eric F. Clarke, Sandra E. Trehub, Susan O’Neill, David Hargreaves, Anthony Kemp, Adrian North, and Robert J. Zatorre).

Neither “procedural music” nor “procedural composition” has its own entry in Grove. However, the term “procedural” appears in bibliographic entries and is mentioned within some texts on theory and analysis. Its most detailed definition, though, is not found in the context of composition but rather in relation to procedural memory (Jonathan Dunsby, “Memory, Memorizing”).

As previously noted, Grove does not have an entry for “computer music.” However, the expression appears in several biographical entries, such as the one on “Max Mathews” (written by Olivia Mattis), and in institutional entries, such as “Institut de Recherche et Coodination Acoustique/Musique” (written by Peter Manning).

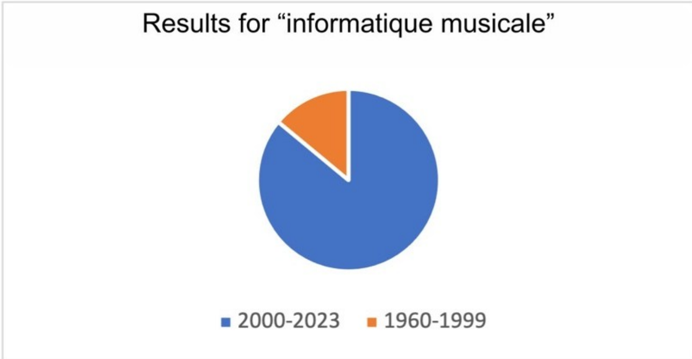
It is possible to notice that the books on computer music (Zattra, 2011; Rondeleux, 1999; Manning, 1985) tend to share a similar structure. Authors typically outline the history of computer integration into music, highlighting the work of pioneers (Lejaren Hiller and Max Mathews are consistently mentioned), the importance of early supporting institutions (such as MIT and Bell Labs), and the emergence of later institutions (like IRCAM) as the technology developed. They also emphasize the significant contributions of interdisciplinary research in music. Rondeleux, in his turn, provides a detailed analysis of the impact of computers on music, emphasizing the establishment of collaboration between composers and computer technicians (engineers, programmers, etc.). He also highlights the exponential growth of music research, driven by the digital age, and its increasing interaction with other fields, such as mathematics, acoustics, and cognitive science. Furthermore, in 1999, Rondeleux predicted that the future of computer music would lay in the creative partnership between composer and machine. This prediction is echoed in the evolving titles of the concluding chapter of Peter Manning's influential book, *Electronic and Computer Music* (1985, 1993, 2004). These titles—"Conclusion" (1985), "New Horizons in Digital Technology" (1993), and "From Computer Technology to Musical Creativity" (2004)—reflect the trajectory outlined by Rondeleux.

On the other hand, as mentioned, Grove includes an entry for "Computers and Music" (written by John Strawn, 2013, and revised by Alan Shockley). We revisit this point here to emphasize, in line with the methodology adopted in this text, that even though it is not the search term used to provide data for the survey proposed here, it is also interesting to note the high number of publications under the term "computer music". Restricting the search in Google Scholar to the English language, in which the term appears in the title, 1,450 results are obtained. Of these, 615 were published from 2011 to 2024 and 341 from 2000 to 2010. This shows that there is still great interest in the subject. The cardinal profile of the increase in publications since 1950 is shown in Graph 1.

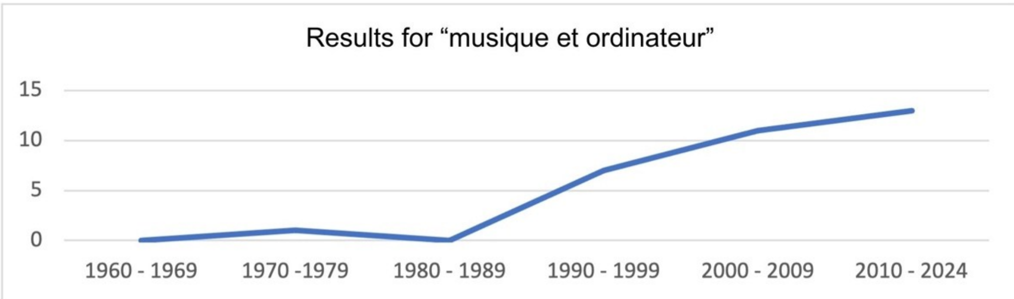


Graph 1 – Quantitative profile, by decades, of Google Scholar search results for the descriptor "computer music" in English-language titles.

A similar search in French yields the following results: "musique à l'ordinateur" = 0 results; "composition musicale par ordinateur" = 34 results; and "informatique musicale" = 3,770 results. Of the latter, 503 results are from 1960–1999, and 3,100 are from 2000–2023 (Graph 2). The descriptor "musique et ordinateur" yields 32 publications (1960–2024). The publication trend for this term is shown in Graph 3. Beyond the clear preference for "informatique musicale", a significant upward trend in publications from 2000 onward is evident, consistent with the patterns shown in Graphs 1 and 2, and indicating a substantial increase in publications on the subject.



Graph 2 – Search results with the descriptor “informatique musicale” (3770 results) indicating a concentration (3100) of publications from the year 2000 onwards.



Graph 3 – Decadal distribution (from 1960) profile of the 32 search results for “musique et ordinateur”.

1960s and 1980s: Can a computer compose music?

Currently, within the expansive field of artificial intelligence, particularly neural networks and deep learning, the question “can a computer compose music?” posed by researcher Peter Langston (1989, p. 59) seems almost irrelevant. Perhaps the question was already anachronistic by the late 1980s, given that computers had been used for compositional purposes since 1957, as previously noted. However, a subtle nuance lies within Langston’s question: the degree of human participation. The question could be rephrased as, “can a computer compose music autonomously?” Six years later, Adam Alpern (1995), in his article “Techniques for Algorithmic Composition of Music”, answered affirmatively, suggesting the possibility of creating automated music through formal processes with minimal human intervention. Nonetheless, Alpern emphasized that this music was not solely focused on the final result, but also on the process itself. This caveat highlights an initial distinction between algorithmic composition and procedural composition.

While all computer music employs algorithms, the differentiating element lies in the degree of (in)determination and freedom within the final product or task. Let’s take the definition of Papadopoulos and Wiggins (1999, p.110), so reformulating the definition of David Cope (1993): “Algorithmic composition could be described as a sequence (set) of rules (instructions, operations) for solving (accomplishing) a [particular] problem (task) [in a finite number of steps] of combining musical parts (things, elements) into a whole (composition)". From this, we realize that the algorithm has a well-defined objective. In the case of Cope, for example, the objective of the algorithm is to generate music in a specific style, such as baroque or classical (Cf: Birchfield, 2003). This goal also finds similarity to the thesis of Menezes, 2008, "Composição Algorítmica de Fugas ao Estilo de J. S. Bach" (Algorithmic Composition of Fugues in the Style of J. S. Bach). Naturally, each execution of the algorithm will produce a musical work distinct from the last, yet the style will remain consistent, as this is the programmed specification. However, within the realm of procedural composition, the outcome is flexible, open-ended, and not fully predetermined at the outset.

In the texts considered, this is the most reiterated characteristic of procedural works. David Worrall presents the following definition: the proceduralist's construction process is different from past approaches in that it does not attempt to create the "object" directly but by formulating commands and procedures that describe the behaviour of a conceptual model. The resulting image/sound is manipulated conceptually by manipulating these rules and their arguments (Worrall, 1994, p.4). In this system, the programming (sometimes referred to as scripts, to differentiate it from a traditional algorithm) does not specify the object to be created. Instead, it defines expected characteristics and behaviors, and the computer generates an output based on these parameters. Because the creation of an artistic object is indirect, through command modeling (rather than direct, as in deterministic algorithmic programming), the generated object may be unusual or unexpected. This is a defining characteristic of procedural art, where any generated product is considered aesthetically valid, as the emphasis is on the process rather than the final object.

In the realm of visual arts, Judson Rosebush (author of the Procedural Manifesto), not only reinforces the focus on the process, but also presents a compelling point regarding the aesthetic foundation of procedural art, positioning it as a "natural historical evolution of procedural conceptual art" (Rosebush, 1989, p.55). By linking procedural art to the conceptual art movement, the author emphasizes the primacy of the idea over the finished work. Moreover, by situating procedural creation within the subcategory of procedural conceptual art, Rosebush establishes that both the concept and the process are essential components of the artwork's construction and its aesthetic impact.

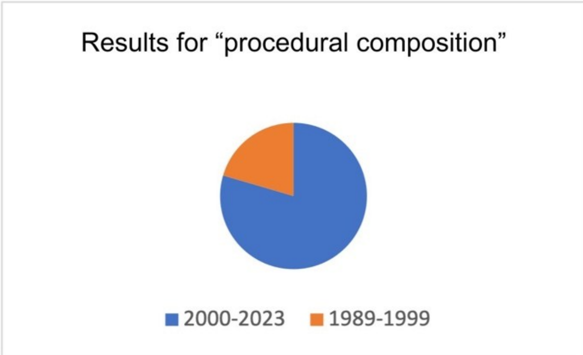
This new creative approach, granting the computer greater flexibility and placing the creative process at the forefront, sparked debate within the aesthetic sphere. Critics questioned the artistic relevance of the generated works, challenging their degree of aesthetic merit. While composers were primarily focused on exploring algorithmic possibilities, and any computer-generated result was considered valid within this experimental context (Papadopoulus, 1999), efforts were made to validate the aesthetic worth of these works through the Turing test.

Inspired by Alan Turing's proposition, it was suggested that if music generated by computers were evaluated by experts (without revealing the method of creation or the creator) and if the experts were unable to discern significant differences when compared to works composed by humans (without computer assistance), then the system could be considered successful. However, Ariza (2009, p.48) disputes the results obtained from such experiments, arguing that these tests fail to assess the full potential of the system. Given that a system offers countless variables, the responses of external listeners will inevitably be limited to a restricted range of possibilities.

Concerning the term's usage, a search using the descriptor "procedural composition", with no language restrictions, yielded 317 results. Upon filtering, the same search revealed only 3 occurrences in languages other than English: one in French, one in Spanish, and one in Portuguese (none of which pertained to music). In general, across all languages, the term began appearing in publications from 1969 onward, primarily in the context of programming.

The term's first appearance within the arts occurs in Jeanne Bamberger's 1979 MIT internal report, "Logo Music Projects: Experiments in Musical Perception and Design", which documents an experiment involving a musical game. However, the report does not use the expression to define a compositional method or a specific creative approach. Between 1989 and 1999, 63 results (21%) were found, with a notable number in the arts; some of these works refer to procedural composition as delegation theory. Numerous publications during this period discuss computer programs for creative applications based on procedural programming. From 2000 to 2023, 245 results (79%) emerged, 111 of which pertain to musical creation, and among these, 80 are specifically related to game music.

Graph 4 visually demonstrates the percentage difference in published works between 1989-1999 and 2000-2023, confirming the publication increase observed in preceding graphs. Refining the search to "procedural composition" returns six results in Portuguese, with only two pertaining to music, both from the last decade and within the video game domain. These findings suggest that, while procedural composition originated as a creative approach in the early 1990s, its resurgence within the video game industry has significantly increased the volume of publications using this term over the past two decades.



Graph 4 – Search results for “procedural composition” (no language restrictions) showing increased publications from 2000 onward.

At this juncture, a distinction can be proposed between the initial methodologies of algorithmic composition and procedural composition. Algorithmic procedures are characterized by a defined objective: the computer is tasked with creating music in a specific style. In contrast, the procedural approach emphasizes flexibility in the outcome and prioritizes the creative process. Consequently, in procedural creation, the programmer (whether the composer or a technician) operates within an environment where one designs and programs the music, subsequently assuming the roles of both spectator and critic (Brown & Sorensen, 2009). It is important to note, however, that, as will be discussed later, this distinction closely resembles the definition of generative music when that term is applied to compositional practices by artists like Brian Eno.

1990-2010: Can the computer be creative?

Once artists demonstrated that computers could compose music with minimal human intervention, and that these works could be considered within the realm of a meaningful aesthetic experience, creators shifted their focus to research concerning creativity. Finnish researcher Hanna Järveläinen summarizes the problem as follows:

> But as soon as music could be generated automatically, the question arose, whether the outcome of an algorithm could be called a composition. Generating music automatically within a given structural framework is not a sign of any particular creativity, furthermore, an arbitrary number of pieces could be popped out of the

> same algorithm. Perhaps the maker of the algorithm should rather be credited. (Järveläinen, 2000, p.2).

Experiments exploring creative computing yielded, among other significant achievements, the resurgence of the term "generative", leading to the development of "generative composition." This resurgence was partly attributable to artists' recognition of a conceptual proximity between algorithms and processes. Alan Dorin, for example, states that "when a process creates a new entity or brings about novel circumstances, it is a generative process with respect to the change(s) it brings about." (Dorin, 2001, p.53).

While experiments in generative music commenced in the mid-1990s (Brown, 2005), some authors seek to trace the origins of this procedure to considerably earlier periods. Italian composer Riccardo Tristano Tuis posits that W. A. Mozart's "Musikalisches Würfelspiel" (Musical Dice Game, 1787) can be regarded as the first generative composition algorithm (Tuis, 2010, p. 25). Giuliano Lombardo traces the "generative" pioneering to 1026 with the procedure created by Guido d'Arezzo (also mentioned by Järveläinen, 2000), clarifying that "by automatic composition I understand the formalization of a procedure that generates a composition without the need for subsequent contributions from the author beyond the initial definition of the generative rules[6]" (Lombardo, 2010, p.2). While these authors focused on historical aspects, their observations highlight two key characteristics emphasized in the reviewed literature on "generative composition." Firstly, the generation of unique, unrepeatable events. Secondly, the constrained role of the composer, who primarily participates in the conception and formalization of the process (sometimes referred to as the algorithm). Once implemented, the system can operate autonomously, independent of the composer and other agents, including musicians, producers, and artists (Biles, 2002; Brown, 2005).

Permeated with a historical interest, Boden and Edmonds published an article that, as its title indicated, aimed to clarify the definition of generative art, while also proposing taxonomies for other aspects at the intersection of art and technology: "What is generative art?" (2009). In this text, the authors distinguish between Generative Art (G-art) and Generative Computational Art (CG-art). By proposing this differentiation, they suggest that generative art, like algorithmic music, can be produced without the use of a computer (see also: Galanter, 2003). The authors also highlight a significant historical event in the arts: the first exhibition to use the term "generative" in connection with art and computing, "Generative Computergraphik", held in Stuttgart in 1965 (Boden and Edmonds, 2009). Three years later, Georg Nees, a German pioneer in computer art, published the first thesis with the same title as the exhibition, on computer-generated art (Nake, 2018).

[6] In the original: Per composizione automatica intendo la formalizzazione di una procedura che generi una composizione senza bisogno di ulteriore apporto da parte dell'autore se non quello della difinizione iniziale delle regole generative.

British artist Brian Eno is commonly credited with coining the term “generative music” (Lombardo, 2010; Brown, 2005). After using the program Koan Pro, created by SSEYO (Intermorphic since 2007), in 1995, Brian Eno released “Generative Music 1 – with SSEYO Koan Software” in 1996[7]. This was a floppy disk containing 12 of Eno’s generative pieces, along with a soundcard. Brian Eno later created his own generative music app, called Reflection (Eno, 2009). In the documentary “Brian Eno – In Conversation” (2009)[8], Eno defines generative music as “a limited stock of material that is being recombined, mixed and emerges in different forms.” He explains that the artist’s role is not to produce works, but to invent a system that produces them. Once created, the system continues to produce infinite (re)combinations that are perceived as new (since the results are not repeated), but maintain a perceptible sound familiarity.

Searches using the descriptors “generative music” and “generative composition” yield distinct results, indicating that both terms have specific uses. However, some observations are necessary. In most texts on “generative composition”, the expression “generative music” also appears. In all of the languages searched, the term “generative music” yields significantly more results than “generative composition”, indicating a preference for that term. Searches using both descriptors show a significant increase in production from the year 2000 onwards. With the exception of Portuguese, there is a significant number of texts in the area of video games (Table 1), indicating that, although incipient in Portuguese-speaking countries, researchers have a fertile area that still lacks research.

Descriptor	**1960 - 2000**	**2001 - 2024**	**Refinement**	**% after delimitation**
Música generativa	3	73	*Videojuegos*	47 (64%)
Musique generative	2	36	*Jeux vidéo*	23 (63%)
Musica generativa	3	29	*Videogiochi*	21 (72%)
Música generativa	0	56	Videogames	21 (37,5%)

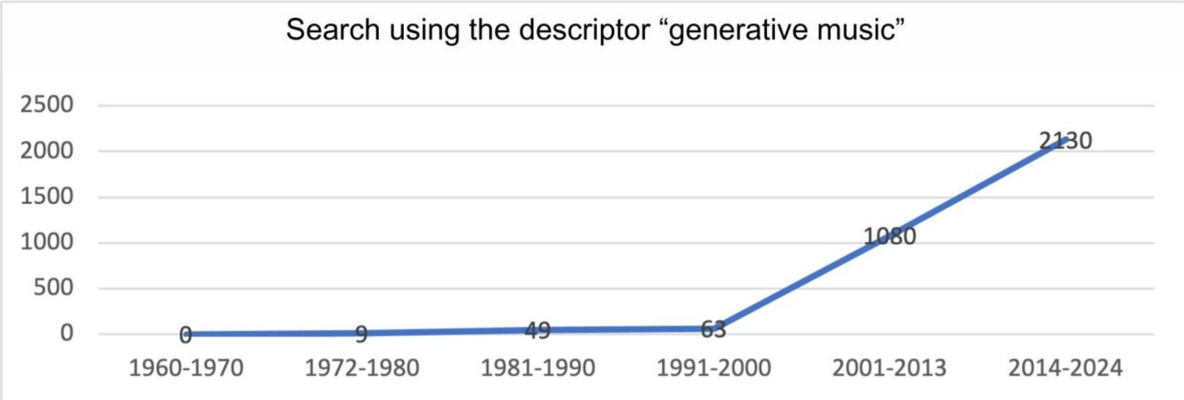
Table 1 – Search results for the descriptor ‘generative music’, classified by language and in two periods, followed by the percentage of the total in the video games area.

A search restricted to the English language using the descriptor “generative music” yields 3,450 results, with 3,220 from 2001 to 2024 and 121 from 1960 to 2000. Graph 5 illustrates the cardinal profile of the increase in production, separated by decades. Although the search, restricted to the English language, using the descriptor “generative composition”, yields fewer

[7] Information available at: https://intermorphic.com/archive/sseyo/koan/generativemusic1/

[8] *Brian Eno – In Conversation*, Artscape ABC, Australia, 2009. Documentary available at: https://www.youtube.com/watch?v=Ywxo4dOHUPE

results (382), as in other languages, it is possible to observe the same profile of increase in texts in the last two decades, in addition to a significant amount of works in the area of video games (or game music), namely: 215 results, corresponding to 56% of the overall total. The results for "generative composition" are classified by decades as follows: 1960 to 1970 = 2; 1971 to 1980 = 3; 1981 to 1990 = 9; 1991 to 2000 = 13; 2001 to 2013 = 131; 2014 to 2024 = 215.



Graph 5 – Quantitative profile, by decade, of the 3,450 search results limited to English, using the descriptor "generative music."

Another possible deduction from the survey is the revival of the term "generative music" from the year 2000 onwards, which became widely used by researchers working with computational creativity. In addition, the term began to be reused in an interdisciplinary way, for example: in the creation of programs (Järveläinen, 2000; Dorin, 2001; Biles, 2002), expanding fields of automated creation to include other cognitive domains (emotion, Birchfield, 2003; psychology of form perception, Collins, 2009), in the field of theory and analysis (Hamanaka, Hirata & Tojo, 2006; Boden & Edmonds, 2009; Meneguette, 2011), in the area of musical composition for films (Hedemann, Sorensen, & Brown, 2008); sonification (Al-Rifaie, 2015); in dance (Carlson, 2016); rescuing the linguistic concepts presented by Chomsky in 1956 (Wooller, 2005; Meneguette, 2011; Naddeo, 2014); in relation to live performance, musical notation, and electroacoustic music (Eigenfeldt, 2014); and generative methods as a way of evaluating musical generative systems themselves (Yang & Lerch, 2018).

Finally, it also appears in studies on the perceptual impacts of generative music, in which the authors investigate the renewal of listening implied by this new compositional attitude. One of these works comes from the Irish singer and researcher Michelle O'Rourke who, in her thesis entitled "The Ontology of Generative Music Listening" (2014), proposes the following definition for the term: "Generative music can be broadly defined as a compositional practice which sets a system into motion with some degree of autonomy which in turn results in a complex musical generation" (O'Rourke, 2014, p. 2). It is observed that this definition is very close to the definition offered by Philip Galanter (2003, p. 4), certainly the most cited definition for the term “generative art.”

Particularly in the area of electronic games, it is observed that the incorporation of the term “generative” occurred due to the intention of composers and game designers to develop methods that would allow the computer to generate realistic results increasingly similar to those found in the natural environment (such as wind flow, fire movements and colors, sound effects of environments, etc.) and in human behavior (different body attitudes and forms of verbal expression). It is thus noted that the procedure adopted implies the existence of an objective to be achieved (separating itself from the procedural method, which allowed results not directed at the fulfillment of a specific task); however, the achievement of this objective must include unrepeatable solutions.

Despite the growing number of publications on generative music, authors have not reached a consensus on a precise definition of the term. Since the preference in the video game field is for the term “procedural composition” (see below), but methods that could be called generative are applied, confusion increases. Wooler, for example, commenting on Brian Eno, points out that one of the characteristics of generative music is “being procedural, that is, music created through processes mediated and executed by a computer” (Wooler, 2005, p. 109). In this understanding, generative music would encompass procedural music, but not vice versa. Plut and Pasquier (2020) present a “state of the art” of generative music in the video game environment. In the extensive survey they conducted, they comment on Karen Collins’ statement that in video games all music is, in some way, procedural. However, the authors use the term “generative” as a synonym for “procedural.” They then offer the following definition:

> *generative* music is music that is created via systemic automation, and is sometimes called procedural music, musical metacreation, or algorithmic music. These terms are mostly synonymous and can be used interchangeably, but we will use “generative music” for simplicity (Plut & Pasquier, 2020, p.2).

Guided by this definition, the authors conclude that Mozart’s “Musical Dice Game” is an adaptive piece, but not generative, procedural, or algorithmic. From this perspective, if music cannot be separated from the game, then it does not have systemic autonomy and, consequently, cannot be classified as generative (Plut and Pasquier, 2020). However, this understanding is biased and could be challenged, considering that the objective of the “Musical Dice Game” is to create music (following the rules prescribed by the algorithm’s programmer, in this case, Mozart). Since every game requires an objective to be achieved, a condition also verified in the case of Mozart, there would be no justification for a necessary independence between music and game, as exists in other modern games. In view of this, the authors’ statement would only be supported if it were limited to the context of digital games. But even so, there may be (or perhaps already are) exceptions. It is important to note, however, that

Plut and Pasquier's article deals exclusively with generative music in the context of video games. Thus, the "state of the art" proposed by them would be more accurately described as a survey of generative systems developed or used in the context of video games – the authors identify and analyze 34 generative systems for composing music for video games.

Based on the survey conducted here, another possible deduction is the resumption of the term "generative" in the context of the digital games industry due to the need for the continuous creation of different music during gameplay. This problem was solved with the development of so-called cellular automata (Järveläinen, 2000), genetic and evolutionary algorithms, which, in turn, motivated some authors to demand this evolutionary (also called biological) aspect as a characteristic of generative music. The combination of several methods (mathematical, evolutionary, grammatical – Papadopoulos & Wiggins, 1999) and techniques (Langston, 1989) made it possible to modify musical parameters in real time during gameplay. Since the amount of music to be created in advance by conventional compositional procedures is very large considering the high interactivity of games (Silva & Corrêa, 2023), the solution was to delegate the generation of these new pieces to the computer during gameplay. Thus, another characteristic of generative composition is the commonly noted function of the composer, limited to the moment of implementation of the system, which subsequently dispenses with the participation of this and other involved artists. This was achieved largely through the use of deterministic algorithms (offering greater control over the final result) to replace stochastic ones – which, due to the high degree of randomness involved, make it impossible to predict the result (Järveläinen, 2000).

2010 onwards: extended cognition

Maurice Conti, in his TED Talk (2016), contextualized the advances in computing and formulated what he believes to be the definitive path in the human-machine partnership: augmented cognition. In this scenario, the direction to be taken in deep learning in the field of artificial intelligence would be towards intuition. It is not, therefore, a question of producing a program that allows the computer to be creative, but rather of enabling it to learn from humans to make decisions based on intuition. Conti called this next stage augmented cognition. He explains that it is a two-way street, where computers learn from humans who will subsequently have their cognitive apparatus also augmented. Conti defined this stage as the moment of collaboration between humans and computers in which "technologies amplifying our cognitive abilities so we can imagine and design things that were simply out of our reach as plain old un-augmented humans" (Conti, 2016, 7:40). The meaning of intuitive artificial intelligence (or intuitive computing) and the degree of autonomy of algorithms is illustrated in Figure 2, in which we can once again see the reuse of the term "generative" as the context of greater decisive freedom for the algorithm.

Figure 2 – Direction proposed by Maurice Conti for intuitive computing.

Maurice Conti's demonstrations and predictions (confirming what Rondeleux, 1999, had anticipated), indicating the re-actualization of generative procedures involving human-machine synergy, aim to clarify what he called intuitive computing. However, this collaborative procedure between people and AI is also called metacreativity. Specifically in the area of music, metacreative music and musical metacreation are adopted.

Notably, in the last decade (see Chart 6), a group of creators of interactive musical systems and composers linked to the video game industry started the Musical Metacreation (MuMe) movement. Since then, the number of experiments and subsequent publications has increased exponentially. These experiments aim to develop creative computer programs for creating music for video games. Obviously, from this initial idea, other composers have also started to use these systems in other, more conventional musical contexts, not restricted to digital games. One of the promoters of this interdisciplinary creative procedure, researcher Philippe Pasquier (with more than 200 publications in computing and the arts), defines musical metacreation as:

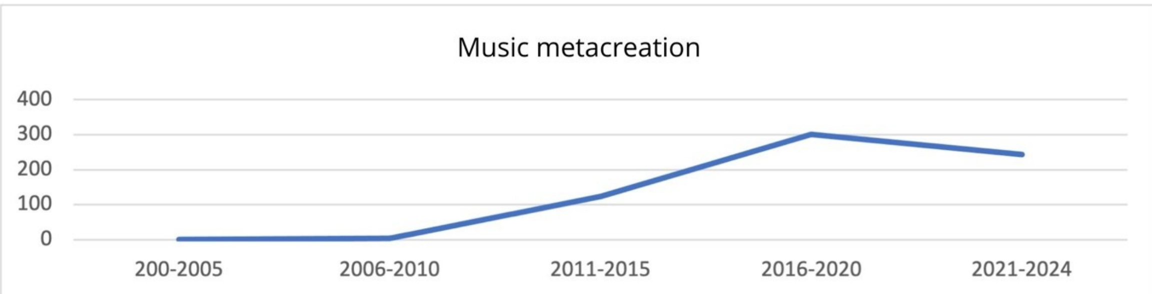
> a subfield of computational creativity that focuses on endowing machines with the ability to achieve creative musical tasks, such as composition, interpretation, improvisation, accompaniment, mixing, etc. It covers all dimensions of the theory and practice of computational generative music systems, ranging from purely artistic approaches to purely scientific ones, inclusive of discourses relevant to this topic from the humanities. (Pasquier, 2017, p.1).

In the context of research focused on human-computer interaction, the very concept of creativity had to be revised (Agres, Forth, & Wiggins, 2016; Carnovalini, 2019). Similarly, researchers have established a distinction between Artificial Intelligence and Computational Creativity, understanding the latter as the search for systems in which there is no best result or ideal solution for a given problem or task to be performed. In the specific case of the arts, for example, this aspect is seen in the attempt to create choreographies, poems, paintings, and music. These "tasks" cannot be reduced to a single optimal or most efficient result, as they involve aesthetic preferences rather than rationalizable objective results (Pasquier, 2017).

Considering the publications in musical metacreation, the points of convergence among the authors are evident: all agree that musical metacreation is a subarea of computational creativity (thus involving deep learning and artificial life) directed at musical composition (Tatar & Pasquier, 2019; Pasquier, 2017). All emphasize that it is a scientific and interdisciplinary field (Carnovalini, 2019). All present similar definitions for the movement (Eigenfeldt, 2013; Pasquier, 2017; Bodily & Ventura, 2018). Most emphasize that musical metacreation makes use of generative procedures (Agres, Forth, & Wiggins, 2016). All emphasize the active participation of the computer in the creative process (Eigenfeldt, 2013).

Alongside these convergences, we can also perceive a great proximity between the essence (or foundation) of musical metacreation and the intuitive computing presented by Maurice Conti. The distinction to be made is that Conti considered the field of computational creativity as a whole, while MuMe is specifically directed at musical composition.

In a search performed with the descriptor “musical metacreation”, we obtained 678 results for all languages (302 in the area of video games). Of these, four are texts in Portuguese, all from 2015; however, only two works could be considered as actually belonging to the area of musical metacreation. This occurs because Google Scholar includes in the search the references used by the authors. It follows that, even if the author of a given text has not discussed musical metacreation, nor analyzed works created using this procedure, but has merely cited some work in the area, this text will appear in the search results. This aspect was also noted in some of the texts in French, Italian, and Spanish. The results for these other languages were: seven publications in French (all from 2015 onwards), five in Spanish (all from 2020 onwards), and one in Italian (2020). It is clear that the vast majority of published works are in English and began in 2006 onwards. The cardinal profile of the results obtained with the descriptor “musical metacreation” is illustrated in Graph 6, separated by five-year periods. It is worth noting that the decrease in works between 2021 and 2024 is due to the fact that we are still at the beginning of 2024. Thus, the profile should continue to rise, surpassing the number of publications from the previous five-year period. This points to an increased interest in research in this area.



Graph 6 – Quantitative profile of the 678 results for the search, in any language, with the descriptor “musical metacreation”. There are no results for the period before 2006.

Final Remarks

Based on the bibliographic survey conducted, a clear path can be identified since the beginning of computer music: the search for computer autonomy within compositional systems. While all computer music is algorithmic (since the computer's operating system and installed programs are coded in algorithms), not all algorithmic music uses the computer. To address this distinction, programmers have been searching for more precise ways to name the procedures developed and adopted in algorithmic music. Consequently, guided by the intention of providing the machine with greater independence from external agents and the freedom to perform tasks offering less restrictive results, artists and programmers have been continually renewing and/or replacing procedures that sometimes converged and sometimes diverged.

Thus, the initial phase of algorithmic music (1950s to 1970s) achieved the goal of enabling the computer to compose music. It is interesting to note that music, in this context, can be considered from an ontological perspective as a formal problem (Liu and Ting, 2016). This perspective allows for the application of problem-solving approaches, leading to the automation and creation of algorithmic music. However, significant participation from the composer (or programmer) remained necessary in this domain.

Once this goal was achieved, the focus shifted to the level of dependence on the computer. Procedural music made a step forward by granting greater freedom to the results, achieved through more flexible algorithms. In this approach, procedural algorithms were instructed not to achieve a specific goal, but to generate a product (music or painting, for example) based on the description of a desired conceptual model's behavior. Thus, the process itself became more important than the final product. Having progressed beyond this stage, the subsequent pursuit aimed at achieving total independence for the computer, leading to a new phase characterized by the use of generative algorithms.

Generative art can, to a certain extent, be understood as a derivation of the generative grammar proposed by Chomsky. Both share commonalities, such as the ability to generate a wide range of diverse results from a finite set of rules. However, they diverge in their focus: generative grammar emphasizes analysis, breaking down sentences to identify the fundamental linguistic structures that constitute the language's generative grammar, while generative art emphasizes creation (Nadeo, 2014). Nevertheless, both draw upon biological or evolutionary concepts. Chomsky posited the existence of an innate and genetic cognitive apparatus that enables language acquisition. Similarly, artists employing generative procedures make extensive use of evolutionary algorithms, striving for results where superior solutions supersede less satisfactory ones.

The resurgence, and consequently reuse, of the term ‘generative,’ particularly since 2000, has shaped a sub-area of art known as generative art, which seeks to grant computers greater autonomy in the creative process. This reduced role for the composer also addresses a demand from the digital gaming industry, where numerous works are needed to accommodate the vast interactive possibilities of a game. Generative creation procedures solve several challenges of real-time musical creation in gameplay, as they are processed rapidly and conserve storage space.

The subsequent step towards systemic independence involved developing methods to enable computers to generate results deemed creative. The musical metacreation movement has conducted extensive research in this domain. However, the pursuit of absolute autonomy for the computer, relative to the composer, appears to have diminished in priority. The current trend emphasizes collaborative, synergistic actions between humans and computers to achieve unpredictable results for complex tasks that defy rationalizable solutions. This partnership would usher in a further stage where computers produce solutions considered intuitive—not restricted to logical parameters—and humans experience an expansion of their cognitive capabilities.

Based on these considerations, we can propose the following diachronic progression, within the context of computer music, for the use of the terms ‘algorithm,’ ‘generative,’ ‘procedural,’ and ‘metacreative’:

‘Algorithm’ – used prior to the advent of the computer. From 1957 onward, it began to denote the procedure by which the computer performs the task of composing music, albeit with significant human intervention. Nevertheless, ‘algorithm’ remains widely employed as an umbrella term in computer music research. Indeed, algorithmic music has become nearly synonymous with music created and assisted by computers.

‘Procedural’ – algorithms become less restrictive regarding the task to be performed. Consequently, the focus shifts to the process rather than solely the product. The computer can generate novel musical results, with reduced dependence on human intervention.

‘Generative’ – algorithms aim to produce unique events with a diminished role for the composer. Deterministic and passive algorithms are replaced by non-restrictive algorithms. The resulting outputs are now considered creative.

‘Musical metacreation’ – an interaction between computers and human agents in which computers generate creative results (informed by intuition) and human agents experience cognitive expansion.

Despite the emergence of new procedures, it is important to emphasize that techniques are not suppressed or eliminated. Rather, new procedures refine existing ones, and new terminology is proposed to provide greater precision. Consequently, the application of earlier procedures does not entirely cease. Terms may fall into temporary disuse, only to reappear later with transformed meanings. For instance, regarding the term 'algorithmic music,' beyond the numerous studies referenced earlier in this article, we can cite the contemporary use of compositional algorithms based on the capture of emotions measured by EEG (Kirke and Miranda, 2011). Examples also include algorithms designed to teach composition to non-musicians (Marchini, 2016) and algorithms aimed at utilizing music for therapeutic purposes (Raglio & Vico, 2017). The term 'generative' fell into disuse during the 1980s and 1990s, only to be revived within the context of creative computing from 2000 onwards.

Finally, it is essential to recognize that the considerations presented here must be understood within a dynamic, rather than static, context. To illustrate this, a growing movement, known as Procedural Content Generation (PCG), has emerged since 2011, which reuses the term 'procedural' (Togelius, 2011). This involves generating content within digital games with minimal or no human intervention. Research in PCG constitutes a subfield of artificial intelligence (AI) research (Smith, 2015). It is noteworthy that PCG focuses on a compilation of standards, methods, and techniques designed to assist digital developers, encompassing individual songs or complete soundtracks for video games (Oliveira, 2015; Shaker, Togelius, and Nelson, 2016; Castro, 2017). The vast majority of PCG research is conducted within the realm of digital games. Alba Amato (2017) elucidates that PCG emerges as a cost-effective solution for the industrial production of games, as procedural content generates narratives, extends gameplay duration, and can even facilitate games with infinite replayability.

In light of this, it is evident that the transformations, uses, disuses, and reuses of the terminologies considered here must be understood not as impasses, but as dynamic conceptual processes.

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