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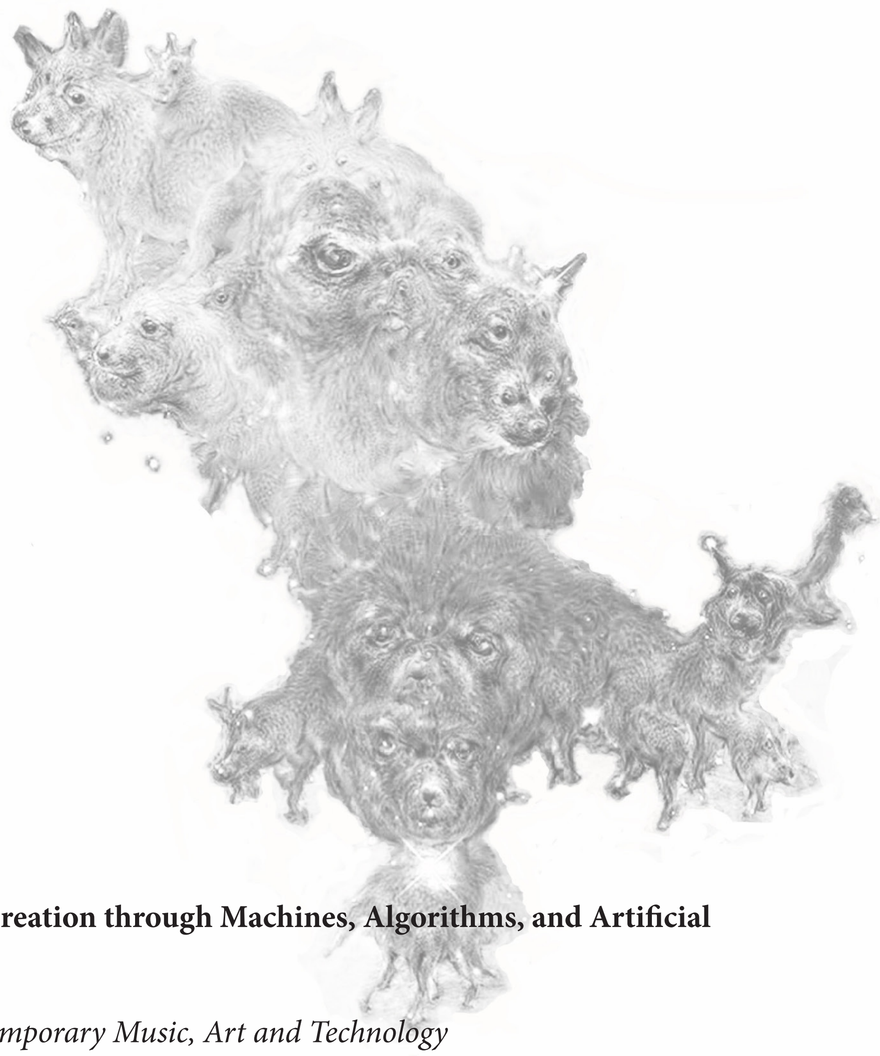

**Empowering Musical Creation through Machines, Algorithms, and Artificial Intelligence**

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# EMPOWERING MUSICAL CREATION THROUGH MACHINES, ALGORITHMS, AND ARTIFICIAL INTELLIGENCE

**Abstract:** In this paper, I describe the development of my personal research on music that transcends the limitations of human ability. I begin with an exploration of my early thoughts regarding the meaning behind the creation of a musical composition according to the creator's intentions and how to philosophically conceptualize the creation of such music if one rejects the existence of abstract Platonic Forms. I then explore the transformation of my own creative process through the introduction of software capable of playing back music in exact accord with the inputs provided to it, while enabling the creation of music that remains intriguing to the human ear even though the performance of it may sometimes be beyond the ability of humans. Subsequently, I describe my forays into music generated by earlier algorithmic systems such as the *Musikalisches Würfelspiel* and narrow artificial-intelligence programs such as WolframTones and my development of variations upon artificially generated themes in essential collaboration with the systems that created them. I also discuss some of the high-profile, advanced examples of AI-human collaboration in musical creation during the contemporary era and raise possibilities for the continued role of humans in drawing out and integrating the best artificially generated musical ideas. I express the hope that the continued advancement of musical software, algorithms, and AI will amplify human creativity by narrowing and ultimately eliminating the gap between the creator's conception of a musical idea and its practical implementation.

**Keywords:** algorhitmic music, artificial intelligence, composition software, creativity, digital music, human-machine collaboration, musical dice games, musical technology, philosophy of music, transhumanism

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## The Creator's Intentions

When I began taking piano lessons more than two decades ago, I spent more time picking out and creating my own melodies than practicing the assigned pieces. Initially I would assemble musical segments from memory; whichever segments were sufficiently appealing to me were expanded upon and played through in a process of reinforcement, until I had, in my mind and memory, a finished piece. Eventually I would record the pieces on note paper, aiming to preserve them before they had fallen out of my memory. A further improvement from the standpoint of composition permanence was achieved when I obtained an electronic piano in 2001, which had the then-advanced ability to accommodate a floppy disk onto which a MIDI-format recording of one's performance could be saved. Yet, I often imagined melodies that were more complex than my playing skills allowed me to execute. For instance, in my *Variations on Alternating Marches*, Op. 15 (Stolyarov 2002), I envisioned increasingly rapid and powerful accompaniments with each variation; maintaining these accompaniments in the left hand while playing large chords with the right hand would likely only be possible for the most talented pianists – yet I had long wanted to hear the piece exactly with these kinds of features being fully implemented (Stolyarov 2002).

Even with the music I could play, I would occasionally make errors that meant I needed to start again in order to generate a satisfactory recording. There existed an ideal of the musical work in my mind, and yet the skills of a mere human piano student were not always able to reflect that ideal correctly. At the same time, my philosophical proclivities led me to contemplate key questions surrounding this endeavor. For instance, what did it mean to make a mistake in performing a piece whose "correct" version only existed in my own mind? Some philosophers, such as Plato, would have attributed music to the world of Forms, existing apart from our material reality, and containing the ideal musical pieces, of which actual human performances would be pale shadows or imitations. David Macintosh summarizes Plato's view thus:

> Plato says such Forms exist in an abstract state but independent of minds in their own realm. Considering this Idea of a perfect triangle, we might also be tempted to take pencil and paper and draw it. Our attempts will of course fall short. Plato would say that peoples' attempts to recreate the Form will end up being a pale facsimile of the perfect Idea, just as everything in this world is an imperfect representation of its perfect Form. The Idea or Form of a triangle and the drawing we come up with is a way of comparing the perfect and imperfect. How good our drawing is will depend on our ability to recognise the Form of Triangle. Although no one has ever seen a perfect triangle, for Plato this is not a problem. If we can conceive the Idea or Form of a perfect triangle in our mind, then the

> Idea of Triangle must exist. The Forms are not limited to geometry. According to Plato, for any conceivable thing or property there is a corresponding Form, a perfect example of that thing or property. The list is almost inexhaustible (Macintosh 2012).

In the realm of music, the implication of Plato's general view would be that an ideal Form of a musical piece does exist in another realm, as long as a human mind can envision it – but any attempt by a human performer to approximate that Form will always be wanting. Plato's view also implies that for any musical work that anyone can conceive of, a perfect Form will exist. Michael Bazemore notes that, "With regard to musical ontology a Platonist would hold that a work of classical music is an abstract object" (Bazemore 2015), although Plato himself held that such music ought to be put in the service of more concrete, didactic purposes. According to Mary B. Schoen-Nazzaro, Plato, "assigns four ends to music, and he sees a certain order between them: first, music moves the emotions; second, it gives pleasure; third, it disposes toward moral goodness; and fourth, it disposes toward learning" (Schoen-Nazzaro 1978, 266). Plato's ontology of music would render his posited didactic ends of music inherently incapable of full realization, as Plato also held that, "art imitates the objects and events of ordinary life. In other words, a work of art is a copy of a copy of a Form. It is even more of an illusion than is ordinary experience. On this theory, works of art are at best entertainment, and at worst a dangerous delusion" (Clowney 2018). Plato believed that music should serve uplifting moral goals, but if the music of this world is an imitation of an imitation of a Form and therefore even farther removed from the ideal world than is everyday life, then, in Plato's framework, music ultimately could not fully actualize those goals in practice – creating an unsatisfactory conclusion.

Yet, I was not and am not a Platonist, and even the didactic ends posited by Plato do not require, in my view, that music exist in a realm of Forms apart from the physical world. A more this-worldly variant of musical Platonism can be found in the theoretical writings of composer Ferruccio Busoni (1866–1924). Erinn Elizabeth Knyt explains that,

> Unlike Plato, Busoni does not believe an *Idee* [a fundamental musical idea] to be an ideal metaphysical 'type' that the phenomenal object merely represents. He considers the Idee to be a tangible image in the mind of the composer. It is not related to specific compositions, musical tones, or rhythms. But, it is an image formed in the psyche, something drawn from the human experience. (Knyt 2010, 116)

However, Busoni's view, while more appropriately locating the source of musical ideas within the mind of the composer, still requires music's core idea or essence to exist apart from the music itself – rather, being found in the external experiences that the composer brings to the creative process. This position also raises the dilemma of how to understand and define a given work of music if the listener is not extensively familiar with the source experiences and history of the composer.

My view is more closely aligned with that of Aristotle, who posited that the essence of any object or phenomenon is present in that object or phenomenon, existing in this world and not any other superior world of ideal Forms. In Book VII of his *Metaphysics*, Aristotle writes, "The essence of a thing is what it is said to be in virtue of itself" (Mattey 1998). But then, from an Aristotelian standpoint, could there be an essence of the *correct* version of a musical work when that work had never yet been correctly instantiated into the world via a flawless performance? The notation I wrote down could be considered my intention as the creator of the music – but is the music in this intended form only a concept, an aspiration until some sufficiently capable performer were able to play it flawlessly according to the notation?

While creating music, I also wanted to find ways to accelerate the process – to reduce the distance between the conception of a piece and its implementation in practice. Historically, the practice of composition has involved extensive study of music theory, learning to play one or more instruments, a process for writing down individual notes to record the creator's intentions for the work, and then seeking out musicians to perform the work. To the extent that technology could aid in reducing the effort involved in each of those processes, I hypothesized that this would place the real-world instantiation of music closer to the creator's original envisioned nature of that music and the thoughts that generated it. The logical conclusion of this process, in my mind, would be a technological future so advanced, that a creator's thoughts could become translated into music almost instantaneously. While humankind has not yet reached such a future, it has come significantly closer in the years since I imagined the possibility.

The questions surrounding the extent to which a composer can control a musical work and the precision with which the composer's intentions can be realized have been explored in prior eras, and varying conclusions have been reached. For instance, Karlheinz Stockhausen (1928–2007), in his article "… How Time Passes…", originally published in 1957 and republished in English in 1959, undertakes a systematic discussion of the variability that occurs in human performances of musical works and suggests that the difficulty of achieving an accurate performance is increased if the composer specifies more complex elements to which the musician must adhere. Stockhausen observed, for example, that, "In some recent scores, the notation of duration-relationships has become extremely differentiated. The result has been that, with an increase of metric-rhythmic complexity, the degree of precision in playing correspondingly decreased. To put it differently, the more complicated the way in which a time-value was indicated, the less sure the performer was about when it should begin and end" (Stockhausen 1959, 30). Stockhausen's thinking regarding this dilemma ultimately led in different directions from my own, in that Stockhausen attempted to accommodate some variability within the performance of his work but sought to have such variability, “precisely specified in its statistical parameters, i.e. as deliberately composed Variable form (even though the parameters like exact onset time, duration, precise pitch, etc. of the individual events themselves, by definition, even the number of events in a collection are not specified by the composed of the variable form)” (Koenigsberg 1991, 29). For me, however – even though variability in performances may be difficult to avoid due to human error, uncertainty, or difficulty in carrying out the composer’s intentions (even when the performer is the composer) – the variable form of composition – which, to some extent, involves a loss of the definitiveness of the composer’s intentions – is not a solution to this issue. In my view, both then and now, it remains important for the vision of the composer (which is often a singular vision) to find some actualization in the external reality, if only the proper means for such actualization could be deployed. Furthermore, in my view, some kinds of variability are more consistent with the composer’s intentions than others – for instance, variations in dynamics and tempo per some (reasonably limited) discretion of the performer could potentially preserve the underlying essence of the work, but adherence to the composer’s prescribed pitch and meter is crucial when the composer has provided singular specifications. Yet if human performers could not implement the composer’s design in a manner that expressed the specific aspirations in the composer’s mind, then what else could overcome those limitations? I wished to have a reliable pathway toward hearing a sufficiently developed instance of one of my own works, and being able to say regarding it, “This is indeed what I had intended.”

## Software as Solution

The narrative in this section relates the manner in which many of the previously articulated dilemmas were resolved for me personally through the course of my poietic and musical creation enabled by computer software.

In 2007 I was first introduced to Anvil Studio, a free program for input of musical notation and its playback via computerized instruments, with the ability to export MIDI file versions of the resulting works.[2] In Anvil Studio, it is possible to assemble music, note by note, and hear it played back in the exact manner in which it was input. Subsequently, it is possible to import the resulting MIDI file into other composition programs, such as Finale, which include more realistic simulations of instruments and even a “Human Playback” feature, which attempts to emulate various potential styles of human performance. It was then possible to record the resulting enhanced version of the music in a widely shareable and playable file format, such as MP3. Here I will not attempt to make comparisons of quality between a computerized performance and a human one; rather, I posit that the arrival of composition software

2 Anvil Studio. Free music composition, notation & MIDI-creation software. https://www.anvilstudio.com/

enabled a resolution to the philosophical dilemma that I previously faced. Provided that I entered the notation exactly as I intended it to be, the playback of the notation by the computer would be a definitive instantiation of those intentions – and, if the music did not sound as I had envisioned it, then the proper recourse would be to alter the inputs given to the computer. If a human musician were to subsequently perform the piece by following the same notation, it is likely that the human musician would impart certain nuances and performance styles that computers, as of yet, are not able to emulate. However, any such aspects brought by the human musician would be *additions to* or *interpretations of* the definitive version of the music, but the definitive version created through the use of software is able to be replayed in the exact same manner as many times as one might wish to hear it (as could, potentially, the human musician's interpretation of it, if it were recorded and shared).

Computer playback therefore enables the Aristotelian essence of a work of music to come into being and be reliably instantiated within the physical world of sounds. The essence of the music is ultimately determined by its creator – the person who decides upon and inputs the notes – but it is only able to be rendered concrete by means of machines which (provided they function as configured) will not commit the kinds of errors to which all humans are vulnerable to some degree. Through the precision of musical software, ideas which might have previously only existed in the mind or on paper can become auditory realities at the push of a button. For some such works it may be necessary to supplement traditional Western notation with other instructions to fully convey the composer's intentions. Or, if the composer intends the work to solely be performed by means of computers and other electronic devices, it may, in some cases, not even be necessary to have an official score for the work; rather, instructions given to the electronic device to enable it to perform the music may be sufficient, with the output of those instructions constituting the definitive musical work.

Another major advance that musical software allowed me to realize fully was the ability to create musical works which were too technically challenging to be played by humans at all – but, because of the ability to be played back by the computer as intended, could nonetheless have their musical essences established in this world. In 2008, I was finally able to hear my *Variations on Alternating Marches* in full after inputting it into Anvil Studio. I also ventured into experiments with multi-instrumental music where some aspect of a given instrument's part would pose challenges to a human performer. For example, the Fibonacci Rondo, Op. 54 (Stolyarov 2008a) is based on the famous Fibonacci sequence of numbers, which begins as 1, 1, 2, 3, 5, 8. If one assigns the value 1 to the note C, then one can assign the following values to other notes in relation to it: 2 = D, 3 = E, 5 = G, 8 = C one octave above the "1" note. Then, using two eighth-notes, one can represent the numbers being added, while the following quarter note represents their result. So, two eighth-note C's will be followed by a quarter-note D to represent "1 + 1 = 2." Then the eighth-notes C and D, followed by a quarter-note E, represent "1 + 2 = 3."

Then the eighth-notes D and E, followed by a quarter-note G, represent "2 + 3 = 5." Then the eighth-notes E and G, followed by a quarter-note C from the next octave, represent "3 + 5 = 8." Thereafter, the same pattern is applied to other harmonies – both major and minor – to ensure a melodic progression. This composition is written for a piano, two string sections, and timpani. It probably could not be played by a human orchestra, as the 32nd-notes in one of the string sections are simply too fast for human players to produce consistently.

A subsequent experimental work of mine from 2008, titled *Man's Struggle Against Death, Op. 57*, aims to depict the sequential overcoming of the seven major types of cellular and molecular damage involved in biological aging or senescence (Stolyarov 2008b). This composition – written for organ, two pianos, harpsichord, timpani, a brass section, and a strings section – consists of seven variations on the same theme – with the theme representing the consistent, unyielding human effort to defeat death and achieve indefinite longevity. Every time that a variation on the theme is played, this represents one of the causes of senescence finally being overcome by human ingenuity. Accordingly, the melody becomes more jubilant and determined as the composition progresses, because there are fewer perils awaiting man and the amount of tasks remaining is reduced. Once the seven variations are complete (which corresponds to the attainment of indefinite life), the coda of the work is meant to evoke the last line of John Donne's sonnet, *Death, Be Not Proud*: "And death shall be no more; death, thou shalt die." Like the quest to attain indefinite life, the performance of this work would be beyond the capabilities of humans alone – but aided by machines that can replicate extremely rapid, complex note progressions, success comes within reach.

Indeed, computer-aided musical creation can be considered a fundamentally transhumanist endeavor in that it extends the capabilities of humans to bring into being music that is not constrained by the limitations of the biological human organism. A specific celebration of this premise can be found in my *Transhumanist March*, Op. 78 (Stolyarov 2014). This march for piano depicts the accelerating improvement of the human condition and the overcoming of human limitations through technological progress. An ambitious and benevolent melody intensifies throughout the piece, pushing onward to champion the radical improvement of the human condition through lifting of age-old barriers and the conquest of both space and time. While the initial theme could be played by a human, the subsequent variations on it become increasingly challenging. The march concludes with an extremely complex variation for two pianos, which play identical parts, but always staggered by one 64th-note – an effect which adds depth to the sound but could not be consistently sustained by two human pianists. Subsequently, in January 2018, I integrated parts of the Transhumanist March (as an orchestral version) into the Fourth Movement of my *Symphony No. 1*, Op. 86 (Stolyarov 2018). The themes from the *Transhumanist March*, occurring toward the end of the symphony, point toward the prospects for a brighter future of humankind, if humans can preserve all of the past gains of civilization and extrapolate upon them, creating an era where our capabilities could be greatly expanded through technology.

## Early Methods of Automated Playback

Even prior to the advent of computers, however, automated playback was available in a more limited form, due to technological progress in the design of self-playing instruments. Precursors to the player piano, or pianola, were developed as early as the 1840s, but this instrument came into widespread prominence during the first decade of the 20th century and enabled the automated playback of musical works through inserting perforated paper rolls that convey instructions to the piano. In the 20th century, several composers developed works of immense complexity for the player piano, which would be impossible for a human performer to play unaided. Conlon Nancarrow (1912–1997) composed works directly for player piano, beginning in, "the mid-1930's, when he found pianists unable to play works like the *Toccata* for Violin and Piano and the *Prelude and Blues* (both composed in 1935) at the speeds or with the clarity that he demanded" (Kozinn 1997). Indeed, Nancarrow's, "frustrations with the limitations of live performance technique led him to compose almost exclusively for mechanical player pianos" (Kozinn 1997) – a similar sentiment to the one that led me to explore the creation and playback of musical works via computer software seven decades later. Nancarrow harnessed the player piano to innovate with tempo relationships – for instance, $\sqrt{(2)}/2$ in his Player Piano Study No. 33 (1965-1969) and $e/\pi$ in his "Transcendental" Player Piano Study No. 40 (1969–1977) that no human would be able to reproduce with exactitude (Gann 1997). Indeed, even Nancarrow had to approximate, as even player pianos are only capable of a certain level of precision; for instance, "for his Study no. 33, Nancarrow approximated $\sqrt{(2)}/2$ within 99.97 percent as the ratio 41:29" (Pesic 2017, 204). However, the capabilities of the player piano still vastly expanded both the melodic complexity and the tempo varieties available for composers to deploy. Works for the player piano continue to be created by contemporary composers, including Marc-André Hamelin (b. 1961), who wrote *Circus Galop* in 1991–1994 and the *Solfegietto a cinque* in 1999 – a work which greatly expands upon C.P.E. Bach's 1766 *Solfegietto* in terms of length, complexity, and ornateness. The advantages today's computer software have over the player piano include a greater range of possible instruments to replicate, greater affordability for the composer, and greater portability of the software and its products (digital files) as compared to the large, heavy player pianos and the paper rolls that they utilize. Accordingly, access to automated playback has become greatly expanded in the age of personal computers.

## Algorithms and Humans Together

As I continued using software to create musical experiments, I pondered the possibility of harnessing the massive processing capabilities of computers to generate new musical ideas. My subsequent research into this subject suggested that this concept was not novel; indeed, endeavors in algorithmic musical composition have been pursued since the Age of Enlightenment. The Musikalisches Würfelspiel, or musical dice game, was a common creation of musicians in the mid-to-late 18th century, where each roll of the dice was mapped to a particular pre-composed measure of music, and the measures would be assembled into melodies depending on the outcomes of the dice rolls. The genre began with Johann Philipp Kirnberger's publication (1721–1783) of *Der allezeit fertige Menuetten- und Polonaisencomponist* ("The Ever-Ready Minuet and Polonaise Composer") in 1757. Kirnberger's rule set enabled the generation of 1,679,616 possible musical combinations. The Musikalisches Würfelspiel genre culminated in perhaps the most famous musical dice game which was attributed to Wolfgang Amadeus Mozart (1756–1791). This work was published posthumously in 1793 and enabled the generation of minuets and trios of 16 bars each. In this musical dice game, one would roll two six-sided dice 16 times to create the minuet and roll one six-sided die 16 times to create the trio, allowing for 6616 = 129,629,238,163,050,258,624,287,932,416 unique minuet/trio combinations.

Between 1967 and 1969, John Cage (1912–1992) and Lejaren Hiller (1924–1994) utilized components of Mozart's Musikalisches Würfelspiel to develop the multimedia composition/performance called HPSCHD, which included seven harpsichord solo pieces along with 52 tapes generated by a computer. The harpsichord solos utilized 64 out of the 176 measures from the *Musikalisches Würfelspiel*, supplemented in some of the solos by measures from six other works of Mozart, as well as excerpts from the compositions of Ludwig van Beethoven (1770–1827), Frédéric Chopin (1810–1849), Robert Schumann (1810–1856), Louis Moreau Gottschalk (1829–1869), Ferruccio Busoni, John Cage, and Lejaren Hiller. Hiller and Cage created two programs, DICEGAME, to compose the harpsichord solos, and HPSCHD, to compose the music for the computer tapes (Di Nunzio 2014).

Since at least the 1990s, independent programmers have created downloadable software instantiations of both the Kirnberger and Mozart musical dice games, automating the process and allowing finished musical combinations to be heard and downloaded in MIDI format, creating the potential for subsequent editing and development.[3]

In 2015, conducting an experiment that explored the intersection of human and

3 A program that allows the generation of music from both Kirnberger's and Mozart's dice games was developed by Peter Baumann in 2006-2007 and can be accessed and downloaded for free at http://www.combib.de/programme/musikalischewuerfelspiele.html.

algorithmic creativity, I randomly generated a minuet and trio from the Mozart *Würfelspiel* and then composed four variations on it for piano and harpsichord, resulting in a piece of nearly five minutes in length (Stolyarov 2015a). When creating the variations, I was cognizant of the near-certainty that, given the vast number of unique minuet/trio combinations attainable, this particular iteration of the Musikalisches Würfelspiel had never been heard before – and that by creating the variations and publishing an augmented version that was definitively played back by a computer program, I was concretizing into existence and imparting unique significance onto what had previously been merely one potentiality among over 129 octillion. Even though the original measures were (possibly) composed by Mozart and assembled together in a specific manner by an algorithm, it was still my decision as a creator to emphasize and build upon that particular combination, and the original minuet/trio and variations thereon became their own definitive piece with an original version that everyone could hear and which represented the real-world essence of that piece.

Algorithmic composition has advanced significantly since the early musical dice games aided by the advent of computing in the mid-20th century. Between 1955 and 1957, Lejaren Hiller and Leonard Isaacson (b. 1925) used the ILLIAC I computer at the University of Illinois at Urbana-Champaign to create the Illiac Suite, "the first musical composition for traditional instruments that was made through computer-assisted composition" – one which was informed by Hiller's view that, "the process of musical composition can be characterized as involving a series of choices of musical elements from an essentially limitless variety of musical raw materials" and that such choices could be automated by applying, "a model that allow the computer to make organizational decisions respect to musical composition features. The model adopted was the Monte Carlo method, an algorithm which uses the generation of random numbers" (Di Nunzio 2011).

In 1963 composer, architect, mathematician, and musical theorist Iannis Xenakis (1922–2001) published *Musiques formelles*, which became expanded and translated into English in 1971 under the title of *Formalized Music: Thought and Mathematics in Composition*. Xenakis articulated the idea that computers are tools to extend our ability to compose music, but that they also do not represent a fundamental disconnect from previous musical frameworks and methods of composition, which also rely on mathematical principles and mechanisms of choice within formalized frameworks. Xenakis explains that, "Computers resolve logical problems by heuristic methods. But computers are not really responsible for the introduction of mathematics into music; rather it is mathematics that makes use of the computer in composition" (Xenakis 1971, 132). Xenakis then proceeds to express six principles that provide a bridge into computerized composition:

> 1. The creative thought of man gives birth to mental mechanisms, which, in the last analysis, are merely sets of constraints and choices. This process

> takes place in all realms of thought, including the arts.
> 2. Some of these mechanisms can be expressed in mathematical terms.
> 3. Some of them are physically realizable: the wheel, motors, bombs, digital computers, analogue computers, etc.
> 4. Certain mental mechanisms may correspond to certain mechanisms of nature.
> 5. Certain mechanizable aspects of artistic creation may be simulated by certain physical mechanisms or machines which exist or may be created.
> 6. It happens that computers can be useful in certain ways (Xenakis 1971, 132–133).

Xenakis himself developed computer systems such as UPIC and GENDY to provide him with content to use in his music, although in Xenakis's process, "what the computer was outputting was not the composition itself but material with which Xenakis could compose" (Maurer 1999).

In 1965, then-17-year-old inventor Ray Kurzweil (b. 1948) appeared on the American television show "I've Got a Secret" to demonstrate an excerpt from a composition generated by a computer he had custom-built. Kurzweil later described it as his, "first pattern recognition project. I built a computer, programmed it to recognize the melodies of the music I would feed into it and then write original music using the same kinds of patterns. So it would write music, recognizable as Mozart, Bach or Chopin" (Ray Kurzweil, quoted in Candela 2004). Kurzweil went on to develop major innovations and inventions in the musical realm, including the development of the first synthesizer capable of replicating the grand piano and orchestral instruments – the Kurzweil K250 in 1984, "whose 'piano mode' was indistinguishable from a grand piano when played for musicians in listening tests" (Kane 2016). Indeed, much of my own later musical creation only became possible because of the advances in computerized instruments that built upon the principles in Kurzweil's work.

David Cope (b. 1941), a composer and former professor of music at the University of California, Santa Cruz, developed programs such as EMI (Experiments in Musical Intelligence) and the later Emily Howell, which have created thousands of pieces of music based on the styles of historical composers. These programs have also created thousands of experimental compositions that could possibly be attributed to the "style" that each program has attained through the novel recombinations of the vast assortment of musical elements and techniques with which it has been provided. Cope explains that he began his foray into the use of artificial intelligence in composition as a way to enhance his own creativity:

> I began Experiments in Musical Intelligence in 1981 as the result of a composer's block. My initial idea involved creating a computer program which would have a sense of my overall musical style and the ability to track the ideas of a current work such that at any given

> point I could request a next note, next measure, next ten measures, and so on. My hope was that this new music would not just be interesting but relevant to my style and to my current work. (Cope n.d.)

Cope describes his approach as based on the premise that,

> every work of music contains a set of instructions for creating different but highly related replications of itself. These instructions, interpreted correctly, can lead to interesting discoveries about musical structure as well as, hopefully, create new instances of stylistically-faithful music. My rationale for discovering such instructions was based, in part, on the concept of recombinancy. Recombinancy can be defined simply as a method for producing new music by recombining extant music into new logical successions. (Cope n.d.)

The recombination of known elements and techniques is not a barrier to creativity but, rather, it has been a foundation of creativity from the onset. Cope observes that, "most of the great works of Western art music exist as recombinations of the twelve pitches of the equal-tempered scale and their octave equivalents. The secret lies not in the invention of new letters or notes but in the subtlety and elegance of their recombination" (Cope n.d.). At the same time, Cope has continued to be involved in the curation of the pieces produced by EMI and Emily Howell – in the sense that it remains his decision, as a human well-versed in the history and theory of music, to identify which pieces are reasonable facsimiles of the styles of particular composers, and also to determine which of the "avant-garde" melodies generated by the programs are inherently interesting and worthy of featuring and designating as definitive works. Cope emphasizes the essential continuity between this process and the creative efforts of prior composers: "Ultimately, the computer is just a tool with which we extend our minds. The music our algorithms compose [is] just as much ours as the music created by the greatest of our personal human inspirations" (Cope n.d.).

WolframTones, developed based on the work of mathematician and computer scientist Stephen Wolfram (b. 1959), is another free music-generation engine, created in 2005. It is described as using, "various Wolfram Language algorithms to form music out of cellular automaton patterns" and attempting to, "search the universe of possible rules for ones that have relevant kinds of complex behavior" (WolframTones 2005). Some of the randomly generated 15-second musical patterns from WolframTones sound intriguing and intricate, whereas others seem more noise-like, or simplistically repetitive, or end abruptly before the 15-second time interval elapses. However, due to the ease of generation of new patterns, it again becomes the province of the human interacting with WolframTones to select the most promising patterns to download and preserve, and potentially build upon. Another experiment of mine from 2015, the *Variations on a Theme* by WolframTones, Op. 80, began with a 15-second theme generated by WolframTones for a harp and a string section, upon which I developed ten variations for a string section, three harps, and two pianos (Stolyarov 2015b). Out of the initial melodic segment, I was able to craft two distinct alternating themes that evolved with each variation and complemented one another in mood. Several listeners of the piece have commented that they enjoyed the variations more than the original WolframTones theme, and indeed, the variations were more deliberately crafted, more melodic, and were specifically designed to appeal to the human ear. However, the fact that they were inspired by and derived from a randomly generated musical segment is a testament to how the products of algorithms are able to stimulate human creativity and the development of music that clearly reflects human intentionality.

In February 2019 the Chinese technology company Huawei released a complete recording of the finished version of Franz Schubert's Symphony No. 8 – Schubert (1797–1828) had only composed the first two movements of the *Unfinished Symphony No. 8* during his lifetime.  The finished symphony was performed live at the Cadogan Hall in London, United Kingdom, on February 4, 2019.[4]

The final two movements were composed by an artificial intelligence (AI) system running on a Huawei Mate 20 pro smartphone. Per Huawei's description, "The Mate 20 Pro smartphone listened to the first two movements of Schubert's Symphony No. 8, analysed the key musical elements that make it so incredible, then generated the melody for the missing third and fourth movement from its analysis" (Huawei 2019). The orchestral score for the finished symphony was arranged by composer Lucas Cantor, who assembled the melodies provided by the Huawei smartphone into coherent Third and Fourth Movements of the symphony (Davis 2019). However, Cantor did make intentional selections regarding *which* of the melodies generated by the smartphone to integrate and also regarding *how* to orchestrate them to enable the live performance to take place. Through the collaboration with Cantor, the Huawei smartphone AI's capabilities were greatly extended – enabling the completed symphony to be created – but Cantor's own capabilities were likewise enhanced in that he could work with the numerous melodic ideas supplied by the AI. Cantor has stated that this experience was, "like having a collaborator who never gets tired, never runs out of ideas" (Davis 2019) and that it, "proves that technology offers incredible possibilities and has a significant and positive impact on modern culture" (Huawei 2019).

While the Huawei-generated Third and Fourth Movements of Schubert's Symphony No. 8 have been criticized for not being sufficiently reminiscent of Schubert's own style (Richter 2019),[5] from the standpoint of sheer technical accomplishment and the enjoyment that the movements confer on their own

4 Excerpts of performance of the Huawei Schubert Symphony No. 8 were captured in this video recording by Chris J. Kenworthy: https://www.youtube.com/watch?v=9FV75jDzse0.

5 For instance, Goetz Richter has written that, to him, "these movements sound only a little like Schubert and a lot like film music." (Richter 2019, Goetz 2019)

terms, these additions to the symphony are of significant merit. Were a human composer to create anything comparable, the result would feature prominently in that composer's oeuvre. In my impression, it is indeed the case that the Third and Fourth Movements resemble more of a late 19th-century style – perhaps evoking the music of Gustav Mahler, especially given the triumphant, epic ending. However, this does not necessarily mean that the music is "not like Schubert;" rather, it may answer a counterfactual question that arose from Schubert's tragically short life. Schubert died in 1828 at the age of 31, and, were it not for the unfortunate illness which killed him, could have potentially survived, with some luck, into the 1880s. Could his composing style have evolved to generate works similar to those last two movements? This is at least plausible. The emergence of artificially intelligent systems, drawing upon a vast database of Schubert's compositions but also capable of innovating beyond it and guided by humans who choose which of these potentially innovative pathways are explored further, allows us to at least more vividly imagine what an older Schubert's music might have sounded like.

## The Promise of Amplifying the Creator through Artificial Intelligence

While humans cannot yet compose music with a mere thought, the tools available for innovative musical creation have greatly expanded since I first wished for this possibility. Composition software and computer playback of music on increasingly realistic digital instruments allow for definitive versions – the concretized essences – of music, as intended by its creator, to come into being in the physical world. Algorithmic composition, based on both random (or pseudorandom) and preprogrammed processes, has existed for over 260 years, but now can be carried out in much more efficient and diverse ways through an expanding array of computerized tools. Presently, as prominently demonstrated by the work of David Cope and the Huawei/Cantor collaboration in completing Schubert's Symphony No. 8, narrow AI systems are becoming increasingly competent at both emulating historical composition styles and expanding them in new directions. Narrowing the gap between conception and performance also suggests various possibilities for instantiating the work of music. Composers can use software to hear their works both in the intermediate stages of creation and in their final versions. If they wish for the works to eventually be performed by human musicians, they are still able to develop scores for the musicians to follow – but it is also possible for the first recorded and published performances of the work to antedate the creation of such scores (since the computer software would already have the instructions for performing a work entered via its interface).

The future which these developments point to promises to be even more intriguing, as artificially intelligent systems become more versatile and even begin to acquire capabilities across domains, approaching the status of an artificial general intelligence. It is already possible for an AI to generate a plethora of musical ideas for a human composer to integrate into a coherent work or use to develop variations that add a human touch. At the outer edge of this frontier would be the generation of entire complete musical pieces by AI systems, where human involvement would be only in the form of a curator who decides what to publish, what to feature, and what to draw people's attention to. On the other hand, the emergence of this capability is not intended to suggest a diminished role for human composers – in fact, it is quite the contrary. The participation of algorithms and artificial intelligence does not in any way compromise the ability of music to be precisely developed to match the creator's intentions. Just as historical composers have drawn upon folk melodies for inspiration, or written variations on themes authored by other composers, so the musical creators of the present and future would be able to intentionally decide which elements from algorithms and AI systems to build into their own works. Once the decision is made and instantiated, the resulting work – no matter which proportions of its content were generated by a human as compared to an algorithm – becomes just as intentional and just as definitive as a more traditionally composed piece of music would be. The Aristotelian essence of a work of music is in the music itself, rather than in the specific pathway to its creation – so the sound of the music can encapsulate its essence as long as it accurately conveys the intention of the composer, as derived from potentially any source or process of the composer's choosing. It is possible, even, for the composer to hear an algorithmically produced musical work for the first time and subsequently, either accept that work as aligning with the composer's intentions or modify it to make it align, thereby bringing it into that composer's *oeuvre*.

The same tools that allow increasingly intricate works to be created by machines, could also broaden the possibilities and heighten the quality of what can be produced by the human mind. Already experimental technologies have been developed to detect the transmission of human brain waves and, to some extent, interpret their content. One example of such experimentation is the electroencephalogram (EEG) technology developed in 2017 at the Toyohashi University of Technology, Japan, which is able to, "recognize the numbers 0 to 9 with 90% accuracy using brain waves […] while [a human is] uttering the numbers" and which, "has also realized the recognition of 18 types of Japanese monosyllables from EEG signals with 60% accuracy, which shows the possibility of an EEG-activated typewriter in the near future" (Toyohashi University of Technology, Japan, Committee for Public Relations 2017). If future innovations extrapolate upon this technology, it is not beyond the realm of possibility, within the proximate several decades, for the capability to emerge to invent devices which could record the brain signals corresponding to a melody envisioned within a human mind and import it into a musical program that would translate it into notation and then play it back. Artificially intelligent features within the musical program could develop variations and creative orchestrations of the melody, with the human creator capable of providing input, adjusting the parameters within which these variations and orchestrations are generated, and curating the output using ever more convenient and intuitive user interfaces. Using augmented-reality glasses or holographic projections, the human creator might be able to see and work with the resulting music from any location, without even accessing a desktop or smartphone screen. The already-existing ability to hear instant playback of one's music – instead of needing to hire musicians and arrange for them to perform, as many past composers needed to do – shortens the time period between having the initial idea and its implementation, but the improving convenience of every step in the composition process will allow more time and energy to be spent on the actual development of and experimentation with musical ideas and their integrations into works of greater intricacy and ambition. The confluence of these developments will also greatly lower the practical barriers to entry involved in the creation and distribution of music. One day, hopefully within the lifetimes of the readers of this paper, any human who thinks of an interesting melody will be able to seamlessly develop it into a full-fledged, beautifully arranged work of music for the world to hear. What were once only thoughts, or potentialities, or pale reflections of the creator's wishes would come into full, vibrant reality as man and machine extend their creative symbiosis.

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# EMPOWERING MUSICAL CREATION THROUGH MACHINES, ALGORITHMS, AND ARTIFICIAL INTELLIGENCE (summary)

My early thinking on the philosophy of music and the essence of a musical work was motivated by my imagination of melodies which were more complex than my playing skills could execute. I asked questions such as, "What did it mean to make a mistake in performing a piece whose 'correct' version was only formed in my own mind?" and "From an Aristotelian standpoint, could there be an essence of the correct musical work when that work had never yet been correctly instantiated into the world via a flawless performance?" While creating music, I also wished for ways to accelerate the process – to reduce the distance between the conception of a piece and its implementation in practice. Some of these dilemmas were resolved via accessible software that enabled input of musical notation and its playback via computerized instruments. Such playback would be a definitive instantiation of those intentions – and if the music did not sound as I had envisioned it, then the proper recourse would be to alter the inputs given to the computer. Computer playback therefore enables the Aristotelian essence of a musical work to be reliably instantiated within the physical world of sounds. The essence of the music is ultimately determined by its creator – the person who decides upon and inputs the notes – but it is only able to be rendered concrete by means of machines which will not commit the kinds of errors to which all humans are vulnerable to some degree. Another major advance that musical software enabled was the ability to create musical works which were too technically challenging to be played by humans at all – but, because of the ability to be played back by the computer as intended, could nonetheless have their musical essences established in this world. Indeed, computer-aided musical creation can be considered a fundamentally transhumanist endeavor in that it extends the capabilities of humans to bring into being music that is not constrained by the limitations of the biological human organism. The idea of algorithmic composition is not novel; indeed, it was implemented in musical dice games extending as far back as Johann Philipp Kirnberger's *Der allezeit fertige Menuetten- und Polonaisencomponist* in 1757. My experiments involved creating variations on randomly generated music from Wolfgang Amadeus Mozart's *Musikalisches Würfelspiel* and a 15-second theme from WolframTones. This paper also explores the innovations in artificial intelligence and human-machine collaboration, including the works of Ray Kurzweil, David Cope, and Lucas Cantor – the composer who curated the completed version of Schubert's *Unfinished Symphony* using musical ideas generated by a Huawei smartphone AI. While humans cannot yet compose music with a mere thought, the tools available for innovative musical creation have greatly expanded since I first wished for their creation. The future which these developments point to promises to be even more intriguing, as the same tools that allow increasingly intricate works to be created by machines, could also broaden the possibilities and heighten the quality of what can be produced by the human mind.

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