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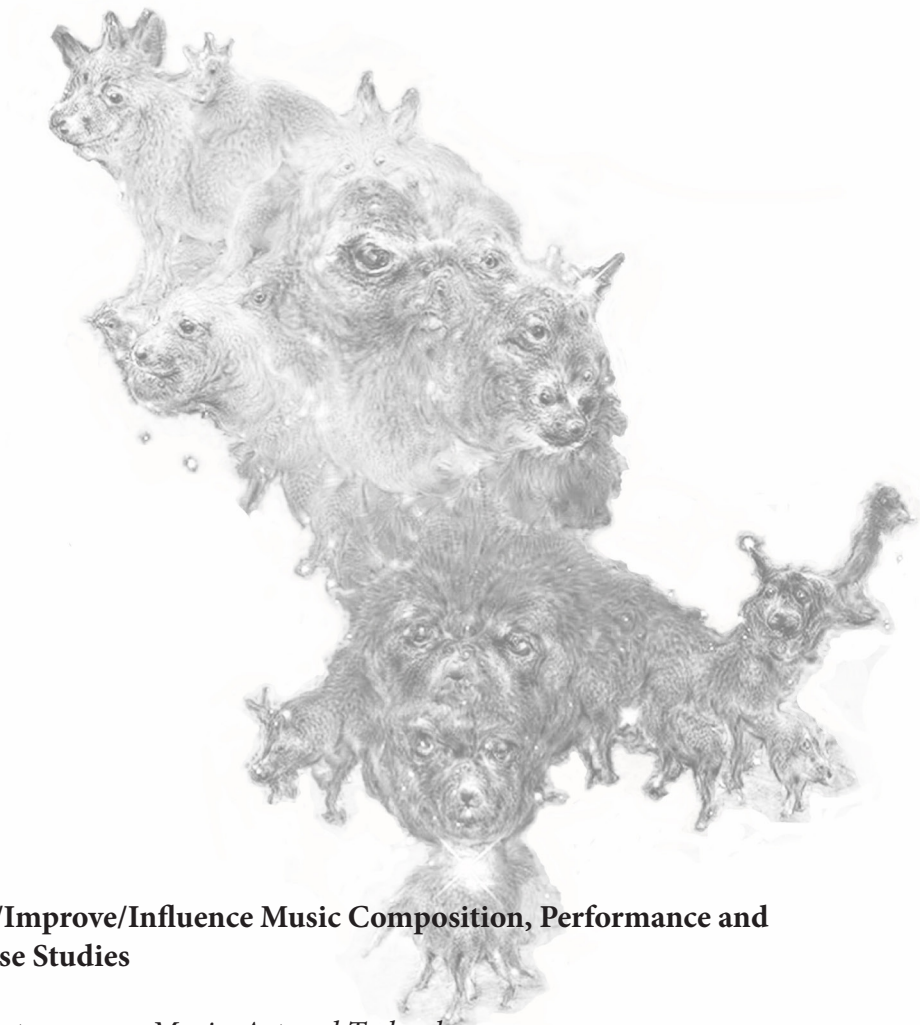

How AI can Change/Improve/Influence Music Composition, Performance and Education: Three Case Studies

Harun Zulić

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HOW AI CAN CHANGE/ IMPROVE/INFLUENCE MUSIC COMPOSITION, PERFORMANCE AND EDUCATION: THREE CASE STUDIES

Abstract: The use of artificial intelligence in science is happening more and more frequently, and often artificial intelligence can be seen in different approaches to creating music and art. In this paper, I will present some of the research that has been carried out, which involve the use of artificial intelligence in the field of composition, performance, and music education. The main focus in the field of composition will be on AIVA – the first virtual composer created with artificial intelligence, which is registered with an author's rights society. In the field of performance, we'll mostly talk about Yamaha's experiment where the world-renowned dancer Kaiji Moriyama controls a piano with his body movements, and in the context of education, this paper reviews some of the possibilities in a variety of artificial intelligence approaches to music education. Lastly, I will conclude the paper by presenting the direction of and possible future for the use of artificial intelligence in music.

Keywords: artificial intelligence, composition, performance, music education, human

Introduction

In the middle of the last century, several scholars from different fields (engineering, psychology, mathematics, economics and political science) began

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to think about creating an artificial brain. The official beginning, or its date of recognition within the academic community, occurred in 1956. The name artificial intelligence was coined in 1955 by John McCarthy.[2] "Artificial Intelligence (AI) is the part of computer science concerned with designing intelligent computer systems that exhibit the characteristics we associate with intelligence in human behaviour—understanding language, learning, reasoning, solving problems, and so on" (Barr and Feigenbaum 1981, 3). Since 1956, the development of technology has rapidly grown. Today, in the 21st century, AI is all around us. In the 63 years since AI was officially born, it's been used in a variety of fields, some of which are: finance, marketing, healthcare, medical diagnosis, robotics, automation, optical character recognition, nonlinear control, semantic webs, education, transportation, music, artificial life, game theory, computational creativity, speech recognition, bio-inspired computing, face recognition, hybrid intelligent system, etc. Considering the fact that the field of AI is very diverse and complex, in the rest of this paper we will only talk about the influence of AI on music.

Connecting artificial intelligence with music began in the mid-1960s, and it relates to research that focuses on music as a cognitive process or as a set of activities modelled with the aid of computer programs (Berz and Bowman 1995, 20). The first published paper on algorithmic music composition using the "Ural-1" computer was "An algorithmic description of process of music composition" by R. Kh. Zaripov, in 1960. Cognitive psychology had a significant role in the development of this field. One of the first significant discoveries in this field was the Ray Kurzweil computer that was programmed to compose music (New York, 1948). Kurzweil is one of the world's leading inventors, thinkers, and futurists, who is involved in a diverse number of fields including artificial intelligence, entrepreneurship, exponential organizations, future forecasting, optical character recognition (OCR), text-to-speech synthesis, speech recognition technology, and electronic keyboard instruments. At the age of 12, he became fascinated by the possibilities of the computer, and by age 15, he had written his first computer program. In one of his interviews, Kurzweil mentioned that his first project involved the computer recognizing patterns in music. Melodies composed by this computer can be compared with melodies of each composer from whom it learned to compose. This computer program led to Kurzweil winning first prize in the International Science Fair and the Westinghouse Science Talent Search.[3]

2 John McCarthy (Boston, 1927 – Stanford, 2011) was an American computer and cognitive scientist. His "contributions to computer science and artificial intelligence are legendary. He revolutionized the use of computers with his innovations in timesharing; he invented Lisp, one of the longest-lived computer languages in use; he made substantial contributions to early work in the mathematical theory of computation; he was one of the founders of the field of artificial intelligence; and he foresaw the need for knowledge representation before the field of AI was even properly born" (Hayes and Morgenstern 2007, 93).

3 "I went on I've Got a Secret. I went on and played a piece of music and then whispered in Steve Allen's ear, 'I built my own computer.' And he said, 'Well, that's impressive. What's that have to do with that piece of music you just played?' And I said, 'Well, the computer composed the piece of music.' And then Bess Myerson, who was a former Miss America, was stumped, but then Henry Morgan,

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Another very significant project of Kurzweil's was the Kurzweil Music Systems and to create this program Kurweil collaborated with multi-musician Stevie Wonder and software developer Bruce Cichowlas. They demonstrated an engineering prototype of the Kurzweil 250 (K250) in 1983 and introduced it commercially the next year. "The K250 is considered to be the first electronic musical instrument to successfully emulate the complex sound response of a grand piano and virtually all other orchestral instruments" (Kurzweil Technologies n.d.). This patent has greatly contributed to the overall development of the music industry. Years after this program was created many additional discoveries were made using artificial intelligence including: "intelligent instruments; deeper, multifaceted representations for scores and sounds; intelligent musical data bases; singing and talking input with singing and talking output; a better understanding of human musical cognition and musical universals; new musical machines with capabilities beyond those of a single performer; more intelligent sound-analysis systems; performance systems capable of intelligent response to musical sound; and new and interesting compositional rule structures," (Roads 1980, 23).

Computational art elludes to the futuristic possibilities of artificial intelligence. Despite the opinions of many that a machine is not capable of creating art, current developments and examples in computational art have presented the world with a new medium of art. Computer scientist Donald E. Knuth (1995) suggests that "science is what we understand well enough to explain to a computer. Art is everything else we do. (...) and Science advances whenever an Art becomes a Science." Kurt continues this thread of thinking saying that, "by concerning this symbiotic relationship between art and technology, computational creativity is a field that explores the evolving correlation between human intelligence and machine intelligence" (Kurt 2018, iii).

Another significant moment in the history of combining artificial intelligence and music was the first International Computer Music Conference (ICMC) held in 1974 at Michigan State University in the United States.

> "The International Computer Music Conference — The ICMA[4] cosponsors the annual ICMC, which, since its inception in 1974, has become the preeminent yearly gathering of computer music practitioners from around the world. The ICMC's unique interleaving

who was a film star, actually guessed it, which was pretty insightful. Computers were not that well known at that time" (American Academy of Achievement 2018).

4 "The International Computer Music Association is an international affiliation of individuals and institutions involved in the technical, creative, and performance aspects of computer music. It serves composers, computer software and hardware developers, researchers, and musicians who are interested in the integration of music and technology. ICMA functions include: Presenting the annual International Computer Music Conference; Professional Networking; Publication of the newsletter array; Specialized Publications, Recordings and Projects; Sponsored Research; ICMA Commissions and Awards; Membership directory; Searchable database of all musical works performed at ICMC and/or commissioned by ICMA" (ICMA 2007).

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> of professional paper presentations and concerts of new computer music compositions—refereed by ICMA-approved international panels— creates a vital synthesis of science, technology, and the art of music" (ICMA 2007).

In the rest of this paper, I will introduce artificial intelligence as an artistic phenomenon in relation to musical composition, musical performance, and music education.

Artificial Intelligence in Composition

Historically speaking, composing is the creative act of a human being acting as a composer by implementing his inspiration or inner ideas in a written form, forming a complete composition. But, is this still a valid definition in the 21st century – or even for the second half of the 20th century? The moment that the first computer that was able to compose music appeared, this definition became the subject of the questioning. Many wondered whether music composed by artificial intelligence could really be considered as originating from a creative process since the source of the composition is not human creativity, but instead software creativity.[5] However, people could overcome this barrier if the process of creativity was understood as a new way of behaving, which would include a piece of software (or one of its parts) that goes beyond the physical details of the program (Colton et al. 2015, 5). Since the origination of the first programs capable of composing music, no artificial intelligence system that composes music has become a part of the broader community of music, but now, in the 21st century, this is changing. With the rapid development of technology, artificial intelligence has enabled a faster flow of information, and thus faster ways of solving the problems we face in the digital world. Thus, the possibilities for developing newly advanced composer-software are much greater, as are the possibilities of its dissemination within the digital world. Some of the companies that are using artificial intelligence to produce music are: Popgun (2017), AIVA (2016), Melodrive (2016), Flow Machines (2016), IBM Watson Music(2016), ORB Composer (2015), Amper Music (2014), Humtap (2013), Jukedeck (2012), Ludwig 3.0 (2011), Chordpunch (2011), Google Brain: Magenta (2010), Google Experiments: Music and AI (2009), The Echo Nest (2005), Brain.FM (2003). The development of music produced by AI and the number of companies that participate in this development are significantly increasing. Numerous companies, ranging from small start-ups to key global players, have

5 "There is, of course, much progress still to be made technically, so that software can be creative and be seen to be creative, in order for consumers to be provided with valuable artefacts and enjoyable creative experiences. In addition to the technological hurdles faced, it is clear that certain sociological issues stand in the way of progress. That is, people naturally tend towards thinking that nuts-and-bolts, bits-and-bytes machines will never have a creative spark, and different sets of people instantiate this tendency in different ways" (Colton et al. 2015, 4).

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seen the future in artificial intelligence. The platforms listed above are some of the most important developments for creating music and algorithms for automating the music composition. Considering the large number of platforms, the next sections will just focus on the AIVA platform that became the first virtual artist to have its creations registered with an author's rights society.

Artificial Intelligence Virtual Artist or AIVA, "is an AI capable of composing emotional soundtracks for films, video games, commercials and any type of entertainment content" (AIVA 2016). A project of Aiva Technologies, AIVA was founded in February 2016 by Pierre Barreau,[6] Denis Shtefan, Arnaud Decker and Vincent Barreau. The source of its information is a rich history of about 30,000 scores of musical composition written by composers such as Beethoven, Mozart, Bach, etc. Learning from the significant contributors to musical history helped AIVA capture the concepts of music theory and understand the art of music composition. Also, that helped AIVA, "to create a mathematical model representation of what music is. This model is then used by Aiva to write completely unique music" (Ibid.). Along with the reinforcement of deep learning algorithm techniques found in TensorFlow, AIVA uses CUDA, TITAN X Pascal GPUs, and cuDNN. But, AIVA is still only able to compose for piano, the orchestration, arrangement, and production of the music require human skills. Also, it is important to emphasize that AIVA uses GPU computing, which has created a plagiarism checker, which is able to understand whether a created track partly or fully plagiarized from the database AIVA learned from. Besides that, several Turing tests completed with music professional participants have confirmed that the compositions of AIVA can't be differentiated as human or AI creation. The registration of its creations in an author's rights society, SACEM,[7] the author's rights society for France and Luxembourg, made it the first software to be recognized for creating unique works both formally and officially. Never before has there been a case where artificial intelligence is recognized by a rights society as a composer. Creators of AIVA say that it, "is able to write beautiful and emotional music, a deed that is considered to be deeply human" (Medium 2016).

The process of composing which AIVA uses is quite different from the process followed by human composers. It uses deep neural networks to look for patterns and rules in compositions and uses this information to learn the basics of style and music. While composing AIVA predicts what should come next in the track. After

6 Pierre Barreau is an entrepreneur, computer scientist, composer, director and chief executive officer as well. The idea of creating a virtual composer from him comes after watching the science fiction movie "Her" (The film is about a super intelligent form of AI that cannot take physical form) in which the AI composer composes a musical piece. After that, he founded AIVA with few people close to him and with similar interests.

7 "Since 1851 SACEM (Society of Authors, Composers and Publishers of Music) is a non-profit non-trading entity owned and managed by its members according to the business model of a co-operative. To guarantee authors' intellectual property rights over their works, SACEM collects and distributes royalties, thereby playing a crucial economic role to preserve musical creation" (SACEM n.d.).

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this happens, she creates a set of mathematical rules for a particular style of music, and then, she is ready to compose (Aiva Technologies 2017). However, this raises the question of how advanced this type of technology is and if it can fully replace the living composer.

> "Storytellers, film producers and the whole entertainment industry rely on music to turn moments into magic. But interactive content such as video games have hundreds of hours of gameplay, and typically only two hours of music, since human composers are limited by physical constraints. And rather than looping the same tunes over and over again, AI gives an alternative to augment human creative abilities, so that games may finally have hundreds of hours of original music" (Ibid.).

So, it seems that it will take a very long time for learning algorithms to be able to replace the human composer.

Immediately after the software was founded, AIVA composed its first composition on February 8, 2016, called *Genesis*, which is also the name for the first album that was produced with its compositions. All compositions from the album were produced by CEO Pierre Barreau. Composition Genesis is formally constructed in a variational form with epic character, which was achieved in the orchestral version of this piece. One can recognize the remarkable similarities between this composition and those created in the epic style of German composer and producer Hans Zimmer, whose music exudes masculinity, heroism, and military sound, most often expressed through the use of a great orchestra, as well as a large number of percussive instruments.

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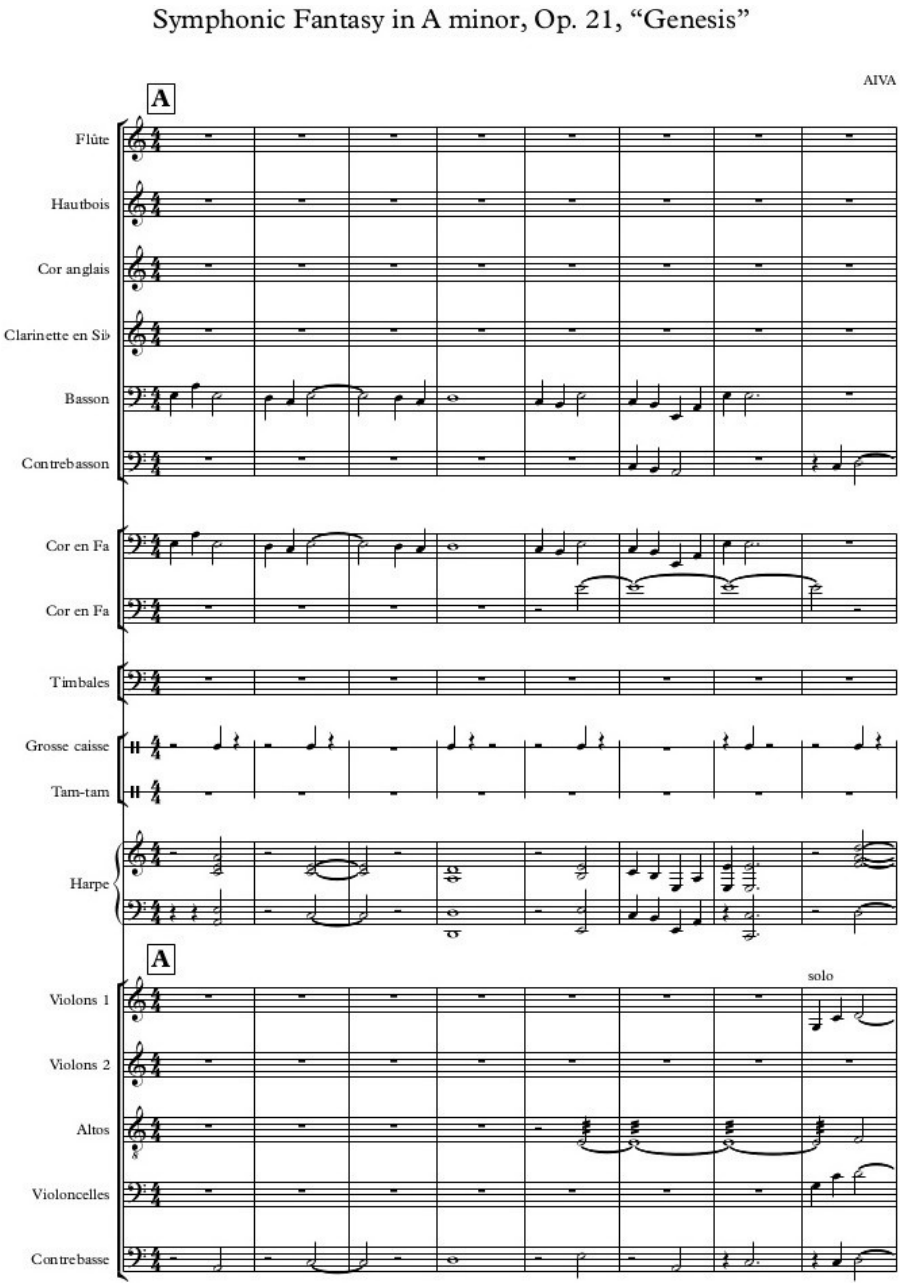

Figure 1: First page score of the composition Symphonic Fantasy in A minor, op. 21, *Genesis*

The composition consists of 38 bars divided into four parts, of which the first part (A) presents the main theme played by the bassoon and Horn in the key of F, while the other three parts (B, C and D) represent its variations, with the main thematic material being predominantly played by the string section.

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After classical music, AIVA expanded its compositions to the entirety of World music (Tango, Middle Eastern, Chinese, etc.) as well as Rock music. One of AIVA's World Style albums is 艾 娲 (ài wā),[8] inspired by the music of China.

"Much like film music has a single theme reprised several times throughout the soundtrack, we wanted to apply this idea of theme variation to our Chinese Album and have some repetition of themes present in different tracks. To achieve this, we applied techniques of deep learning to create musical variations of a theme in the Chinese album presented above. For this, we give a musical theme in MIDI format to our variation module, that then iteratively applies changes to the harmony, melody and rhythm of the piece, while staying faithful to the original theme, but moving away further from it with each iteration" (Medium 2018).

AIVA's second album was released in 2018 and contains 24 compositions from various genres.

Although the achievements of artificial intelligence in the field of composition have been impressive so far, there is still much to do if we want artistic intelligence to live up to the same abilities as a human composer. At this point, artificial intelligence still needs help while composing, mostly in orchestration and music production. But what is a very important development, is that in the field of music production artificial intelligence has reduced the time spent on repetitive tasks, especially in games. It is important to emphasize that artificial intelligence still lacks that human creative element which is very important in art. Artificial intelligence is currently just a means by which composers can find new ways of composing. Its role is currently solely dependent on the human or composer.

Artificial Intelligence in Performance

As noted earlier, artificial intelligence has played an important role in the development of computer generated music (although most efforts have been on compositional and improvisational systems). But, little effort has been devoted to using AI in performance systems. This may be due to the fact that performing, improvisation, and music composition are seen as a creative and autonomous manifestations that are not feasible for a machine. However, we cannot resist the fact that artificial intelligence is slowly becoming a nucleus of computer music. Every day through the development of new algorithms, it offers us new approaches and new knowledge needed for solving music problems.

> "When thinking about issues relating to performance (in particular) it is important to think about the way that the audience interacts with the performer and the performance, enabling the audience to fully

8 "AIVA's Chinese name '艾娲' (ài wā), also the title of this album, has a specific meaning in Mandarin. The character '艾' (ài) means "elder", and here represents the extensive knowledge that our AI has learned from the greatest composers in history. The character '娲' (wā) is from Nüwa '女娲' - the mother goddess of Chinese mythology" (Aiva 2018).

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> understand the systems that are being used, could offer performers, designers and technologists a whole range of new and exciting performative possibilities that go beyond the tradition performer – consumer paradigm and offer new ways in which the audience can effect and interpret the system used" (Chamberlain 2017).

Every day, interest in having computers perform musical tasks, by playing music, processing music, or creating music is increasing. So far, computers have only been following the commands of a human to generate and perform the compositions. In live music performance, a computer and a man collaborate, "as a versatile tape machine—playing its part (which could include multiple instruments and lines) with admirable virtuosity but in blissful ignorance of the circumstance of the performance and its fellow musicians" (Baird, Blevnis and Zahler 1993, 73). The problem with the collaboration between computer and human performers is that the computer is not able to monitor abrupt tempo changes, dynamics, articulation, or basically cooperate with the human on a high level. The computing performer should be able to recognize the mistakes of other performers and make alterations in the performance to compensate for the mistakes of others (Ibid.). But, besides these current limitations, the computer is a good accompanist for a human performer, as long as it is not the leader.

One of the last (incredible) moves in the application of artificial intelligence in musical performance is Yamaha's project, where the world-renowned dancer Kaiji Moriyama controls a piano using dance movements. The concert presentation of the project entitled "Mai Hi Ten Yu" was in Japan on November 22, 2017, and it was

Figure 2: Live performance, Mai Hi Ten Yu, 2017. © Ayane Shindo

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sponsored by Tokyo University of the Arts and Tokyo University of the Arts COI.[9] The emphasis in the performing process is on the collaboration between artificial intelligence and dancers, more specifically in this case, Kaiji Moriyama. Throughout the performance, he was accompanied by the Berlin Philharmonic Orchestra Scharoun Ensemble as musical support. The original system that Yamaha uses, turns human movements into musical expression through AI technology, as a technical collaboration for performance.

> "The AI adopted in the system, which is now under development, can identify a dancer's movement in real time by analyzing signals from four types of sensors attached to a dancer's body. This system has an original database that links melody and movements, and, with this database, the AI on the system creates suitable melody data (MIDI) from the dancer's movements instantly. The system then sends the MIDI data to a Yamaha Disklavier™[10] player piano, and it is translated into music. To convert dance movements into musical expression, the Yamaha Disklavier™ is indispensable because it can reproduce a rich range of sounds with extreme accuracy through very slight changes in piano touch. Moreover, we use a special Disklavier in the concert which was configured based on Yamaha flagship model CFX concert grand piano to express fully and completely the performance of the talented dancer Moriyama" (Yamaha 2018).

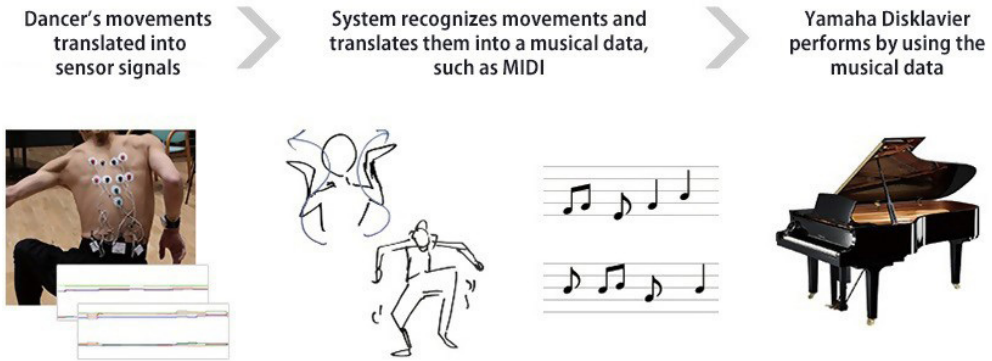

Figure 3: : Graphic representation of converting dance movements into musical expression

With this technology, dancers no longer have to adapt or adjust to music, instead music would adjust itself to the dancer's movement. Although this project was presented to the public, Yamaha's technology is not fully ready to be commercialized

9 See https://www.youtube.com/watch?v=tLFe2AzCodk, Accessed March 9, 2019.

10 "An original system developed by Yamaha, the Disklavier™ is a hybrid player piano that performs automatically and can reproduce the movements of the keyboard and pedal with extreme accuracy. The latest model, the Disklavier™ ENSPIRE, includes recordings of the original sound sources of world-famous artists. This feature enhances the enjoyment of musical performances that users can experience at their leisure" (Yamaha 2018).

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for massive practical use or as a new form of artistic expression. But it is certain that once this kind of performance software is released to the public, it will bring significant changes to the field of music and dance as well create new dimensions of artistic process.

Artificial Intelligence in Music Education

The use of computer technology in education began in the 1960s and 1970s, shortly after the emergence of artificial intelligence, with the development of what was called Intelligent Computer-Assisted Learning (ICAI) by Carbonell (1970). Soon after that, in 1982, Sleeman D. H. and Brown J. S. coined the term "Intelligent Tutoring Systems"[11] in their volume of the same title (Nkambou, Bourdeau and Mizoguchi 2010, 2). Today, AI has entered into almost all spheres of human learning, and the possibilities of its application for educational purposes continue to increase. Simon Holland lists several definitions from various authors regarding the role of artificial intelligence in education (AI-ED). The first one is that AI in Education is any application of AI techniques or methodologies to educational systems. A second, more narrow definition says that AI-ED is any computer-based learning system which has some degree of autonomous decision-making with respect to some aspect of its interaction with its users. The third definition of AI-ED that Holland points out is the use of AI methodologies and AI ways of thinking being applied to the discovery of insights and methods for use in education, whether or not AI programs are actually involved at the point of delivery (Nkambou, Bourdeau and Mizoguchi 2010, 2).

Each of these definitions refers to hypermedia i.e., multimedia contents that are interconnected. "Historically, the first use of computers in teaching music or teaching any other subject for that matter, was associated with programmed learning, derived originally from behaviorism" (Holland 1989, 22). AI in music education has long been present in schools and we are often not even aware of how much it is used. Music is a challenging field for Artificial Intelligence in Education because it requires creativity and problem solving from the students and teachers. However, the effectiveness of hypermedia in teaching is greater than the effectiveness of a classical teaching method where the teacher talks and the students listen. Many studies have confirmed that a person is able to remember about 20% of information disseminated if they only heard it, 40% if they saw and heard it, and 75% if they saw it, heard it, and actively used it. By introducing a hypermedia paradigm for creating a learning program, the motivation of students to learn is greater because of the use of different non-textual media.

Artificial intelligence in music education is at its nascent stages. Its presence

11 "Intelligent Tutoring Systems (ITSs) are complex computer programs that manage various heterogeneous types of knowledge, ranging from domain to pedagogical knowledge. Building such a system is thus not an easy task" (Nkambou, Bourdeau and Psyché 2010, 361).

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in schools is still lagging behind the use of AI in other subjects and this is also the case for the teaching of musical culture or instruments in general. The reasons for this can be economic or political, but also generally social. Unfortunately, society, especially in underdeveloped countries, refuses to accept AI as a part of our lives. However, there are many useful ways to apply AI to music education. Today there are thousands of good quality programs / apps that the teacher is able to use while teaching Music, Music theory, Solfeggio, Harmony, Counterpoint, etc. Many music programs that were developed to make Music class more interesting and productive are often only applied on an individual basis. Some of educational hypermedia music programs whose purpose is to train the recognition, or reproduction of intervals, chords, or melody scales, modes, durations, tunings, and flexible melodic dictation are Ear Trainer, Interval, Listen, MiBAC Music Lessons, Seventh Heaven, Perceive, Practica Musica, and MacGAMUT. A lot of these applications have clear educational goals, but they are still not being used in schools. One program which offers tuition in basic music theory is Practice Room. In addition to these virtual programs many generally useful musical computer tools are also applicable to education: analysis tools, innovative musician interfaces, music editors, sequencers, computer - aided composition tools and multimedia reference CD-ROMs on masterworks (Holland 2000, 2). Music Teachers should be aware of the presence of these programs and use them as aids for teaching. Of course, it would help if schools were equipped with computers or electronic equipment to make classes faster and more contemporary. It seems as if it will take some time for this approach to become the typical method of teaching music. It is important to note that for many applications, especially those that study the field of harmony and counterpoint, there is scope for improvement of existing works. Therefore, teachers are bound to recognize the limitations of the software, and be aware of whether they are appropriate for use. Nevertheless, at the moment, artificial intelligence is certainly a good means for self-learning music.

Conclusion

Since the beginning of the 21st century, we have witnessed an enormous increase in the use of artificial intelligence in science and art. Its development has led to change in human thought, due to an understanding of communication technology that allows us to ignore the confines of geography, while compressing space and time constituting a virtual reality. With the more frequent use of artificial intelligence in the field of music, some musicians feel threatened, while others remain amazed at the opportunities that it uncovers. The fact is that artificial intelligence has become an inevitable factor in our future. Today, many artists collaborate with artificial intelligence in creative endeavors and in the future, this link between artists and artificial intelligence will become even more recognizable. All the strides in artificial intelligence discussed in this paper are just the beginning of a new era, which will truly begin in the next decade of this century. Virtual artists like AIVA will become

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the reality of our everyday lives. One of the expected improvements that will surely happen is in the field of musical performance and of dance, as we have seen from the collaboration of Japanese dancer Kaiji Moriyama with AI technology. If we are still wondering whether artificial intelligence can create art that emulates human emotions, the answer is yes. If we have not convinced ourselves yet, surely the future of this technology will prove to us that this is possible.

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HOW AI CAN CHANGE/IMPROVE/INFLUENCE MUSIC COMPOSITION, PERFORMANCE AND EDUCATION: THREE CASE STUDIES
(Summary)

This paper shows the connection between artificial intelligence and its influence on composition, musical performance, and musical education. These three case studies have been discussed through the lens of the previous research carried out in this field and the research done specifically for each new development. Additionally, there is a unique case for the author's free choice. The first case is about Artificial Intelligence Virtual Artist or AIVA, the first virtual composer to have its creations registered with an author's rights society (SACEM). In the aforementioned case, the beginnings of AIVA were touched on, as well as its creations, past achievements, and the future goals for AIVA to compose direct orchestral music. The second case is about Yamaha's project where the world-renowned dancer Kaiji Moriyama controls a piano using his dance movements. This section talks about the process of the project itself and its important role for future research, considering it was the first collaboration between AI, music, and movement of its kind. The third part focuses on the importance of music programs and applications in education. Finally, the conclusion speaks to the importance of artificial intelligence for the future of humanity, primarily in the field of music, and some assumptions on which artificial intelligence will be based on in the future.

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