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Research on the Use of Computer Music in Modern Musical Composition

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Abstract. In the ever-changing society, disruptive technology not only causes a tremendous impact on the instruments that musicians play, but also how they make music and how we perceive them. Music algorithms and software as well as computational models are evolving as critical tools to give life to original musical ideas, diversify the nature of music, and create magnificent works of art. Even artificial intelligence can be applied to this vibrant field because they both deal with intellectual and emotional human activities. This paper investigates the current developments of computer music, its influence on the elements of modern music composition, and best practices of their applications in the music industry. The main purpose of this paper is to provide an overview of the use of computer music on music creation, analyze the latest trends of technical developments in music, to recognize the enormous potential of computer music along with its practical applications.

1. Introduction

Music has long been regarded as the most sophisticated and creative language throughout the world. It is accomplished by It conveys emotions in a direct and palpable way, but the inner details can be elusive to catch or feel. Over the past years, music is generally composed by a small group of people with artistic talents. However, since music is composed of a set of interconnected patterns, it can also be an excellent test field for mathematical, computational, and artificial intelligence methods. As technology evolves, a new generation of frameworks and techniques are emerging for creating music automatically yet intelligently. The algorithmic composition utilizes multiple programming languages and computer software to generate music, including GarageBand, Chordbot, and TonePad [1]. Several artificial intelligence advances, such as machine learning, neural networks, and evolutionary computation, are also put into effective use in the realm of music composition to reinforce creativity and promote innovations.

Since the United States and The United Kingdom in the 1940s have produced a real sense of the electronic computer, with the end of the Second World War, these computers with powerful computing power was soon used by scientists of all disciplines for analysis, research work. Similarly, musicians who are trying to break new ground in music are beginning to use this tool in their music. At first, the electronic computer was first used in the analysis and research of music theory, and it has a very good auxiliary role in the analysis of the style, tonality and harmonic structure of music works. After a series of experiments, American composer Richard Hillel and mathematician Leonard Isaac created the first true "computer music" in 1957. After 70 s, computer music shows the trend of accelerated development. Many computer music laboratories have been set up in the United States and Western Europe. Some internationally renowned universities have also set up special research institutes and published some monographs and periodicals. Since 1974, an international computer



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music conference has been held every year around the world. The International Computer Music Association was also formed in 1975, with the publication of Computer Music Magazine. The Stockholm Acoustical Conference has been held every ten years since 1983. Since 1992, an international symposium on musical acoustics has been held every three years, covering all aspects of computer music and musical acoustics. In Asia, Japan and China have also established a number of small computer music laboratories, the use of computer composition, computer technology for sound sampling and editing has been widely used. After the 1980s, with the continuous improvement of synthesizer technology, the further expansion of electronic technology to the digital direction, and later the emergence of MIDI technology and the popularity of personal computers, computer music began to move towards the popularization and commercialization. At the same time, of course, electronic acoustic music based on audio synthesis is also developing at an amazing speed with the help of digital technology. Since the mid-1990s, the development of computer music has been unstoppable. Digital technology has penetrated into almost all fields of computer music. Because of the microcomputer operation speed and multimedia function continuously upgrade and the development of professional audio interface, sequencer for computer software has been greatly improved, can not only make it easier to handle the MIDI data, and can handle audio information at the same time, become a sequencer, multi-track recording, processing, indented blended with a variety of functions such as to music workstation software. At the same time, a large number of software recording programs and software audio sources and software effects for computers have emerged, and most of them have superior performance, some even better than the original hardware equipment. With these audio sources, effects, recording, mixing and other software music software and professional audio card, it is completely possible to complete all the programs from musical instrument playing, audio recording, texture arrangement, audio modulation to CD burning independently on the computer. At this point, it really realized the way of music creation with computer as the core tool.

The paper aims to summarize the latest technical developments in computer music and its real-life applications in music compositions. This paper first gives a brief overview of the elements of music compositions, namely rhythm, melody, and accompaniment, and the recent research work in respective areas. It then goes into the current progress and applications of computer music. A summary of this paper will be presented in the final section.

2. Elements of Music Composition and Recent Advances

To delve into the rationale behind computer music, it would be critical to analyze a piece of music by looking at its "genetic" makeup. It has been universally accepted that musical compositions consist of a sequence of highly-organized patterns, such as rhythm, melody, and accompaniment. By diversifying the pitch, timbre, speed, and intensity, the countless combinations of these three elements have entailed different music genres and given rise to a significant amount of musical works throughout the world. The study of musical elements is a rapidly growing research area and forms the basis of computational models of its composition. Therefore, this section would elaborate on the task of making music through the process of establishing the rhythm, creating the melody, and arranging the accompaniment.

2.1. Rhythm

Rhythm refers to the connection between notes and rests, and encompasses the pattern of sound, silence, and emphasis to make music move and flow [1]. It also regulates the length and strength when notes are played to invent various notes durations and types of accents [2].

In computer music, it is not easy to find the appropriate rhythm for each tune due to the wide range of arranging notes to the beats. However, in recent years, there is a growing number of new research achievements about technological innovation in academic circles. Wang et al. introduced an integrated fitness function and utilized statistical results to access the rhythms. Patterns rated with a higher fitness value will serve as the foundation for future computer music models [3]. Towsey et al. built a genetic

algorithm based on extracted rhythmic features from world-famous pieces, and improved music arrangements in aspects of note density, rhythmic variety, and syncopation [4].

Apart from applying computational tools to evaluate rhythms, scientists even endeavored to create them automatically using computer software and more advanced algorithms. Yamamoto et al. established a GA to simulate rhythms and fill in gaps as drum beats [5]. Other studies used neural networks to model rhythms and provide the backbone for the entire group. For example, Chen et al. presented a neural network to learn the input rhythms and then generate patterns accordingly [6]. These fruitful scientific researches have transferred music composition to a task of recombining and reassigning notes and rests, thereby rearranging the rhythm in the same way.

2.2. Melody

Melody is a sophisticated arrangement of musical tones that are organized as an aesthetic entity [2]. Most compositions contain multiple melodies created by respective instruments and they are woven together to make the piece sonically pleasing. The melody usually includes two essential components: 1) Pitch. It means the quality of a sound controlled by the rate of vibrations from an instrument. This task also involves the range of instruments or vocals, the sequence of pitches, and harmony of the concurrent pitches. 2) Duration. It denotes the length of time that each note will be played for and closely relates to the pace and feel of any music.

Computer music also takes melody into account and innovates ways of generating surprisingly intriguing melodies. The most common methods include producing the whole piece in a single time, construct the melody note by note, and mimicking the structure of music input. Some research suggests to use algorithms to produce the tunes at random and then select the good ones. Yoon developed an interactive evolutionary system to produce music clips based on musical seed data [7]. Osana extracted features on pitch and duration from music samples and created an automatic composition system using GA melody [8].

2.3. Accompaniment

Accompaniment is another crucial part to support or complement the music, and it might come in as single notes, chords, or other tunes. It serves to enhance the expression of compositions and help the audience feel the harmony.

The inherent regularity of accompaniment and its cohesion to the main melody bring out computational intelligence's superiority into full play. Acevedo applied GA to find the counterpoint of music samples and eventually build the main accompaniment. It is noted that the accompaniment was subject to certain rules, such as the length of each note and the intervals should imitate those of the input melody, without destroying the overall atmosphere [9]. Onisawa also constructed an interactive GA system to create chord templates, which could evolve according to the listener's feedback [7].

In summary, computer music has penetrated each element of music composition, and is expected to exert a stronger influence with more intelligent tools coming into play.

3. Current Progress and Applications of Computer Music

Nowadays, musicians have access to plenty of tools and selections to transfer their musical thoughts into reality. Prior to the new digital era, music is composed of sounds produced by physically manipulating traditional musical instruments [10]. However, musicians find it difficult to play more than one instrument at a time, and some minor differences between instruments make it incompatible with one another.

With the advent of visual programming languages and artificial intelligence software, computer music has entered into a golden age of development and involved from isolated applications, to server-oriented architecture, and ultimately a cloud computing framework (shown in Figure. 1) The electronic musical instruments and effects processors entail thousands of unique and newer sounds. More importantly, the emergence of combining mathematical models, programming languages, and computational systems into music composition has come to the attention of the public. This section

summarizes the current advances in this area and enumerates several practical applications that have achieved abundant results.

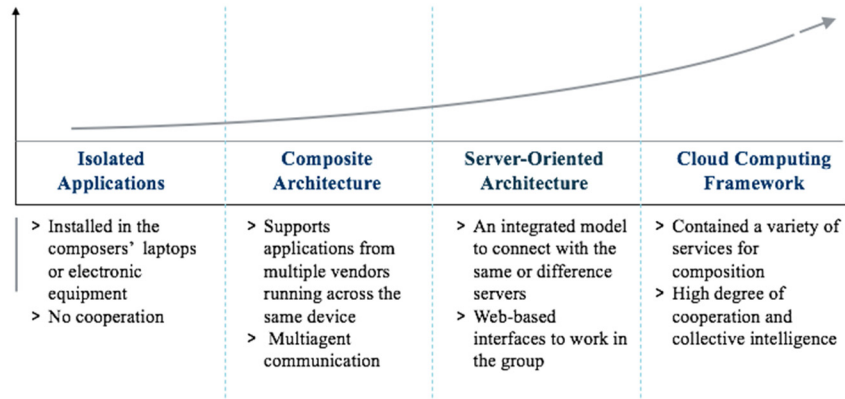


Figure 1 The Evolution of Computer Music

3.1. Current Progress

To gain a deep understanding of the current development of computer music, this paper conducted a statistical analysis of musical project data retrieved from GitHub and analyzed the source code in these repositories. The GHTorrent database includes a set of raw data in the top programming languages and an MySQL database dump [11]. By running keyword-based inquiries in SQL and manually screening selections, our dataset contains 602 projects related to computer music or algorithmic compositions, most of which are documented in Max/MSP or data files. Closer inspection of these results shows that the major programming languages or tools are C, C++, Python, Java, JavaScript, HTML, and Jupyter Notebook, and they are used for multiple purposes, such as to generate a series of tunes automatically, create beats in the drum accompaniment, and evaluate the harmony of notes across different tracks. Table 1 presents the summary statistics categorized by musical elements mentioned in the last section (rhythm, melody, and accompaniment).

Table 1 Computer Music Dataset on GitHub

	Total
Music Projects	839
Rhythm	253
Melody	167
Accompaniment	214
General Harmony	205

Table 2 GitHub Research Results Categorized by Languages

Languages	Total
Python	174
JavaScript	94
Java	80
Jupyter Notebook	43
C++	29
HTML	23
C	19
Others	61

3.2. Applications of Computer Music

3.2.1. Data-Based Interactive System. This system represents a rule-based, non-adaptive method that mostly relies on the given data or quantitative results from music analytics. It is adopted to capture critical patterns or identify statistical behavior by gathering, analyzing, and classifying music data. One classic example is the probabilistic generative modeling, which captures and explains musical features through a data-driven methodology, such as the probability of occurrence of a chord, or the frequency of note transitions over a given melody [12]. These findings are meaningful to train future models that are designed to produce particular music styles. Meanwhile, the summary statistics are quite revealing to promote the next generation of new music that combines the extracted features into different settings [12].

The Michigan Institute for Data Science at the University of Michigan has already developed a live performance system, *Crowd in C*, using data mining techniques to investigate audience preferences and interaction modes [13]. The audience can create their pieces of music and musicians would improvise on the collective musical work. The research team will conduct a detailed analysis of massive, real-time interaction data and ultimately form a “time-evolving heterogeneous network”. The active audience participation will add new features to the orchestra, which may have implications for the future development of new modeling for other types of music.

3.2.2. Evolutionary Algorithms. The evolutionary composition is another remarkable technique that gives life to automatic music generation through feature-based and interactive approaches. Although humans attribute the intangible and abstract quality to the music, there still exists some traceable patterns from a computational perspective. A variety of computer software and applications have been proposed and achieved favorable results in recognizing composers and classify music genres [14]. More advanced, evolutionary algorithms and neural networks are able to extract implicit features, including motives and emotions, to produce more complex melodies. On the other hand, in evolutionary schemes, the interactions between human and artificial machines provide fresh ideas to cross the borders of music style and formulate interesting works.

The Sound of Text project stands right at the intersection of music and evolutionary computing. The main goal of this project is to develop algorithms that transfer any text into its musical interpretations. The method is to gather both words and music content from various collections of publicly released songs and lyrics, and employ neural networks for sequence mappings and predictions [15]. As these algorithms mature, it would be possible to make the silent words “sing” again and consequently bridge the gap between music and other modalities.

3.2.3. Deep learning. Compared with the previous two applications, the use of deep learning in music composition starts late with a short history, but the impact of this innovative tool is definitely unparalleled. Deep learning integrates an immense number of computational units and effectively learns latent characteristics of musical tunes. The learning model is capable of not only reconstructing the input melodies, but also understanding the long-term structure of music with minimum human interruptions [16]. Recently, Google has been engaged in its Magenta project, which is an open-source platform utilizing music and image data to train machine learning models and to create new content [17]. For example, a group of musicians developed *Music Transformer* by modeling the connections between each note and making modifications to enhance the coherence of a single song.

3.2.4. The MIDI technology. In MIDI technology, MIDI is the digital interface of an instrument. Simply put, it is a communication protocol for connecting electronic instruments to each other and connecting electronic instruments to computers. The connection between the early electronic instruments was a problem. In 1981, American synthesizer maker Dave Smith first planned the first interface for all electronic instruments to communicate with each other, called the USI. This universal synthesizer interface made communication between electronic instruments possible. By the end of

1982, all interface issues were finally resolved and MIDI was officially open. In August 1983, electronic instrument manufacturers in the United States and Japan formally designated the MIDI1.0 specification, which became the international standard for music digitization.

The core part of MIDI composing system is the sequencer. It can record, play and edit music played by various MIDI instruments. The sequencer does not really record sound, it only records and plays MIDI data information. MIDI does not produce music by itself, but it contains all the instructions needed to produce music, such as what instrument to play, what notes to play, how fast to play, how hard to play and so on. It can be a rail track on the recording, can also be a rail track changes, when you play the keyboard on the electronic synthesizer, sequencer can record including key velocity, pitch, intensity, duration and other MIDI data information, the information cannot be directly into sound, must be sent to a MIDI interface in the electronic equipment can be read, and then according to the control information to control the sound circuit in the MIDI device, and finally into sound.

The advantages of MIDI technology are obvious. First of all, MIDI technology is very convenient for editing and modifying music. In music creation, you can simply use special sequencer software to operate the following contents: you can choose a variety of Musical Instruments; It can modify or add notes, adjust the intensity of notes, and do quantitative processing of notes; Can be arbitrarily shifted; Can move or copy, insert, or delete a section or segment; Revise the change of tempo and speed in the music. These are the most basic elements in music creation. However, some necessary modifications are needed to achieve the improvisational effect of near-real Musical Instruments and make MIDI works more humanized. It can adjust the proportion of sound image and volume, modify the overall strength, and use various controllers to give music an expression. Another advantage of MIDI technology is that it can save a lot of storage space. For example, a MIDI song with a playing time of about 4 minutes has a capacity of only over 100 KB. If it adopts the format of waveform music file, it can reach up to about 40MB. Even if MP3 technology is used for high-scale compression, it has to have a size of 4MB, which can save a lot of storage space. In the traditional way of playing, players can only play a limited number of Musical Instruments at the same time, while the emergence of MIDI, a new technology, enables players to reflect different timbre of the synthesizer on the same keyboard, and stratifies the production of music, thus opening up a new field for music creation.

3.2.5. Digital audio technology. Another area of computer music is the work of working with digital audio. Today's computer music production is not just a MIDI concept, the concept of digital audio more and more into the creation of music. Make MIDI before, then enter the recording studio to complete the recording. Nowadays, more and more composers start to set up their own studios at home and finish the post-production work such as multi-track recording, waveform editing and master tape processing by themselves, which has gradually become the mainstream trend of today's music production.

Digital audio technology is actually a technology that directly processes sound in the computer. The main tasks include: converting MIDI into digital audio signals, and retuning, synthesizing, adding echoes, chorus, reverberation and other embellishing works in the later stage of musical works; They can also input sounds such as human voices, Musical Instruments and natural effects; As well as audio files for a variety of forms of editing and reprocessing. The original MIDI sequencer was used as a composing tool and did not contain an audio component. As computers speed up and software developers compete with each other, audio production has evolved from a reliance on expensive hardware to a software-focused editing process. In terms of the main platform software, MIDI and audio are not completely separate. Many excellent professional software combine these two functional categories and have high quality. At present, there are many commonly used software with not only powerful MIDI audio sequence function, but also excellent digital audio function, which is more convenient and professional.

There are several key technologies in digital audio technology, the first of which is analog to digital (A/D) and digital to analog (D/A) transformation technology. To what extent the performance of a

digital sound system is close to the theoretical limit defined by the original signal, it can be said that it depends on the performance of analog-to-digital and digital-to-analog converters. The second key technology is efficient coding. With the increase of sampling frequency and the increase of quantization bits, the amount of digital audio signal data is very large, which brings difficulties to storage and processing. High frequency coding techniques are designed to reduce the amount of data as much as possible without compromising quality, which not only contributes to the miniaturization and multimedia of digital sound systems, but also further reduces costs. The third key technology is digital information processing technology. This technology can filter out all kinds of noise and interference in the signal through the digital filter, but also can accomplish reverberation, echo, effect processing, volume control, balance and other work through the digital signal processing. The fourth key technology is digital audio signal software production technology. In order to make the finished CD read out smoothly, it must be guaranteed by error correction, modulation and synchronization.

4. Conclusion

This paper reviews and discusses the existing approaches and applications of computer music in light of three elements of music composition. Overall, the study strengthens the idea that computer music plays an integral role in transforming traditional modes of composition and diversifying ways of creating music. This paper is also expected to shed substantial light on the direction of future research.

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