國立交通大學

音樂研究所

碩士論文

自動化作曲系統及其圖形化人機介面之研究

ALGORITHMIC COMPOSITION

AND GRAPHIC USER INTERFACE RESEARCH

研究生：李幸輯

指導教授：黃志方

日期：中華民國 96 年 4 月 30 日

自動化作曲系統及其圖形化人機介面之研究

國立交通大學音樂研究所音樂科技組

李幸輯

n004kimo@yahoo.com.tw

中文摘要

本論文主要係研究電腦人工智慧作曲，或稱準則作曲，是音樂和電腦兩類專業知識所開發出的音樂自動創作系統。本系統運用馬可夫鏈 (Markov Chain)，其技術是按照一個轉換表來依次選擇功能和聲的連接；該轉換表就像一個函數，其引數是當前的和聲級數，而函數值則是下一個要出現和聲級數的可能性。轉換表可以針對某一特定作曲家或某一時期風格的音樂作品進行收集和統計，來構造出相應風格的轉換表。而此轉換表，定義了這些特定音樂風格的作品中，曲調進行與其和聲外音出現之可能性，並加入上下行音程的出現機率，成為本系統核心的旋律產生引擎。

此外本核心引擎亦結合篩選理論 (Sieve Theory) ，可將不需要的音篩選掉，來製造出教會調式、全音階以及中國五聲、七聲音階風格的旋律。本系統大量分析過去偉大音樂家的三個具代表性風格時期之作品，其方法可產生類比音樂家思考的人工智慧，並配合簡易上手的圖形化使用者介面，來達到使音樂創作平台可大眾化之理想。

關鍵字：馬可夫鏈、篩選理論、準則作曲、圖形化人機介面。

Abstract

This thesis is mainly the research of artificial intelligence composition, or so called algorithmic composition. It develops the automatic composition system integrating both fields with knowledge of music and computer. This system uses “Markov Chain”, adapting the technology of choosing the function harmony sequentially according to the conversion table. This conversion table is a function, and its input argument represents the current root of the chord. Finally the possible harmonic progressions are guided and counted with the function output. It can be collected with the proper analysis for the music works of some specific styles of the composers in a certain period with the conversion tables, to construct the next state of the table for the corresponding style. Somehow the works of these specific music styles and the possibility of the melodic lines with its non-chordal tones are well defined in the conversion table, with the probability of the interval up and down, to form the melody generator engine of the system.

In addition, this engine has also combined the “Sieve Theory”, which can filter out the unwanted pitches, to create the melodic scales including Church Mode, Chinese pentatonic, and Chinese septatonic styles. This system analyzes tremendous works of the past great musicians’ works in three typical periods. The analytic methodology is to generate the artificial intelligence simulating the musicians’ thinking, with the user friendly graphic interface, to reach the ideal of establishing a popularized music composition platform.

Keywords: Markov Chain, Sieve Theory, Algorithmic Composition, Graphic User Interface.

Table of Contents

Figure

Table

Equation

Appendix

1. Introduction

From 1980s to the 1990s, with the price cost down and the development of computer science and technology, the use of PC was much more popularized, and the computer became an auxiliary tool for the music composition. At the same time, sequencer, synthesizer technology has already been developed successively, and brought into commercialization. Computer-aided composition thus was developed rapidly.

The common misconception of computer compositions is either that the computer is used solely as a composition supporting tool or for generating synthesized sounds. However, in recent years, the improvements in artificial intelligence with computer algorithmic composition have made it possible for computer to realize intellectual music independently. Computer artificial intelligence composition is a fusion of both the knowledge of musicians and computer engineers. This new type of automated composition systems allows both low-order and high-order language to be written directly. It is capable of adopting several special messages such as, MIDI communication interface, artificial intelligent controlled digital sound source system and electronic musical instrument that are linked.

Music is an art which is capable of molding one's temperament and enrich the life. However, in order to master the craft of music composition or performing, one must invest a large amount and time and money. Many people yearn for composing graceful melody or to use the language of the music to express themselves. However, to master the craft of musical language, one must understand counterpoint, harmony, acoustics, orchestration and form. The majority of people do not have such complicated music background. Given the overwhelming knowledge of music, many are discouraged and can only turn to music appreciation or other master works to fill their need.

To respond to such remorse and regrets, the demand of research in computer artificial intelligence with musical composition is alleged. The current system, objectively collects the statistics from the analyzed musical works and uses a rather humanistic approach in analysis, which aims to mimic the composition process to that of the composer.

Since the system's foundation is based on solid musical composition theory, even when the user has no musical rudimental knowledge, the system is able to surpass the language barriers, in the simplest way and paint musical ideas like that of a master composer.

The common misconception that classical music tends to leave a distant impression will be destroyed. Music composition will become interdisciplinary and the privilege of writing music will be granted to everyone as to reserve for the few trained individuals. Moreover, many musical works created by this system will be invaluable for further academic research and commercial development.

2. The Related Domestic and International Research

2.1 Algorithmic Composition with Markov Chain:

One of the simplest approaches of note selection in algorithmic composition is through Markov Chain. Markov Chain is a kind of mathematical function. The function's argument is the musical note of the current state, and its corresponding output represents all the possible musical events of the next state. This function can be custom designed for any particular musical genre. In other words, any particular musical work, or styles of a composer, could be pin pointed and custom fitted into the Markov Chain. For such Markov Chain to be precise, attentive approach must be applied while analyzing the traits of the musical works.

2.2 Stochastic Process:

Cybernetic Composer System is one of the representative models using stochastic process. Such system is able to create musical segments in the style of jazz, swing, and ragtime.

2.3 Database System:

Building music database is an obvious choice, especially when the predetermined field is defined. Hence constructing models, structures and rules became an easy task for making music database. The advantage for such method is that it provides clear inductive thinking and at the same time be able to give reasoning based on its own decisions.

Ebciogln has established a type of backtracking specification language (abbr. BSL) [39] and incorporated into CHORAL, a ruled based EXPERT SYSTEM. It is capable of constructing Bach chorale. CHORAL contains approximately 350 rules based on

BSL. These rules are custom designed to mimic J.S. Bach's harmonic language.

2.4 Musical Grammar of Automatic Music Composition:

Comparable to spoken language, musical language also has its own grammatical systems. Steedman [22] invents a kind of generative syntax, which is used to describe the Blues chord process that adjusts of 12 measures of the jazz. He later on uses categorized syntax to work on the further refinement. His system performs the left branching analysis to the structure that is considered as right branching traditionally, thus improves the ability of explanation from left to right deviation from the system. The intuition is closer to the listener and enables the system to imitate chords generation. It deduces the process complexity to be accepted by people.

2.5 Artificial Neural Network:

Recent progresses in artificial neural networks have benefited numerous musical system applications. Especially in the fields of biological perspective and cognitive perspective, artificial neural networks can study in one template set to avoid the regular formalization.

3. Characteristics of this system

3.1. Building Distinctive Musical Genre Algorithms:

The Data and algorithms are both collected and designed objectively. To avoid conflicting rules resulting from works of different musical genre, only data from music that belongs to the same genre (same composer and in the same period) will be grouped together and used per algorithm. This way several algorithms will be created with each representing a musical genre and a composer. The user will then have the freedom to choose a particular genre or composer's styles and use these algorithms to create one's own music.

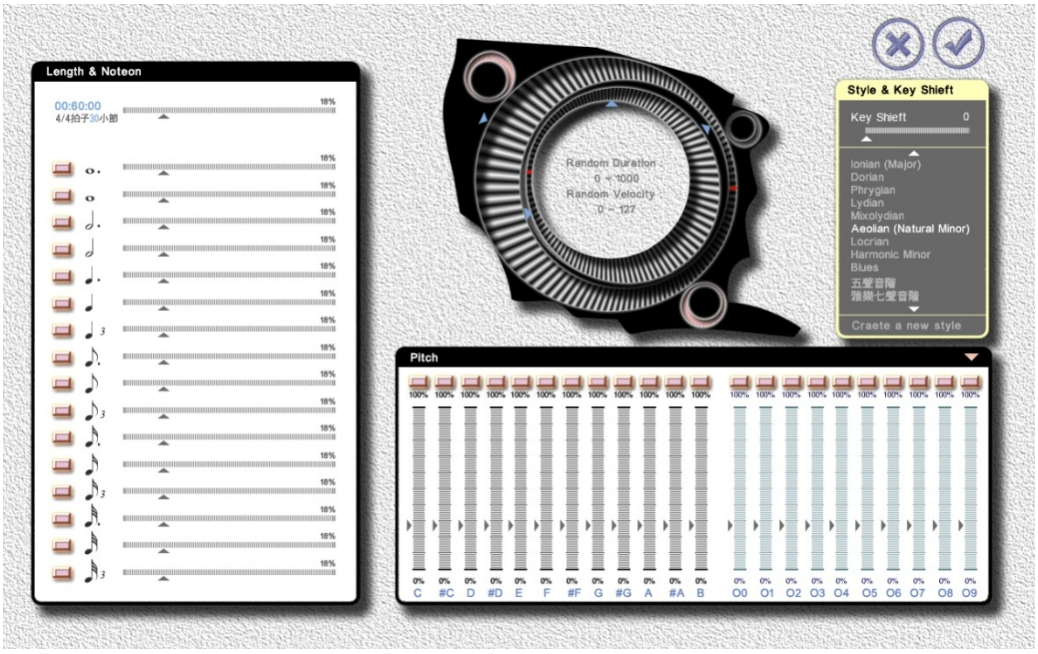

Figure 1. Sieve User Interface.

3.2 User Friendly Human-Computer Interaction (HCI) Interface:

To ease playability, the system is designed such that all complex rules are fermented into a user friendly HCI interface. The system uses visual aides to guide harmonic and melodic progression. Such compositional approach in music is reminiscent to that of collage art in paintings.

Figure 2. Choosing styles and piece the melody together.

3.3 The wide parameter setting range:

It is a user-friendly and versatile system. The system has vast amount of controls, such as: transposition, graphical dynamic interface, modes, and articulations. These tools have eased the process of composition and allow the user to realize the music within their mind.

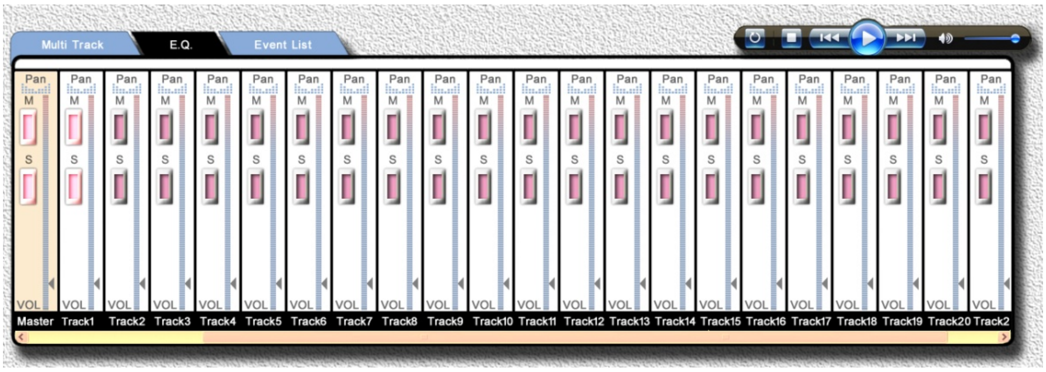

Figure 3. The equalizer interface.

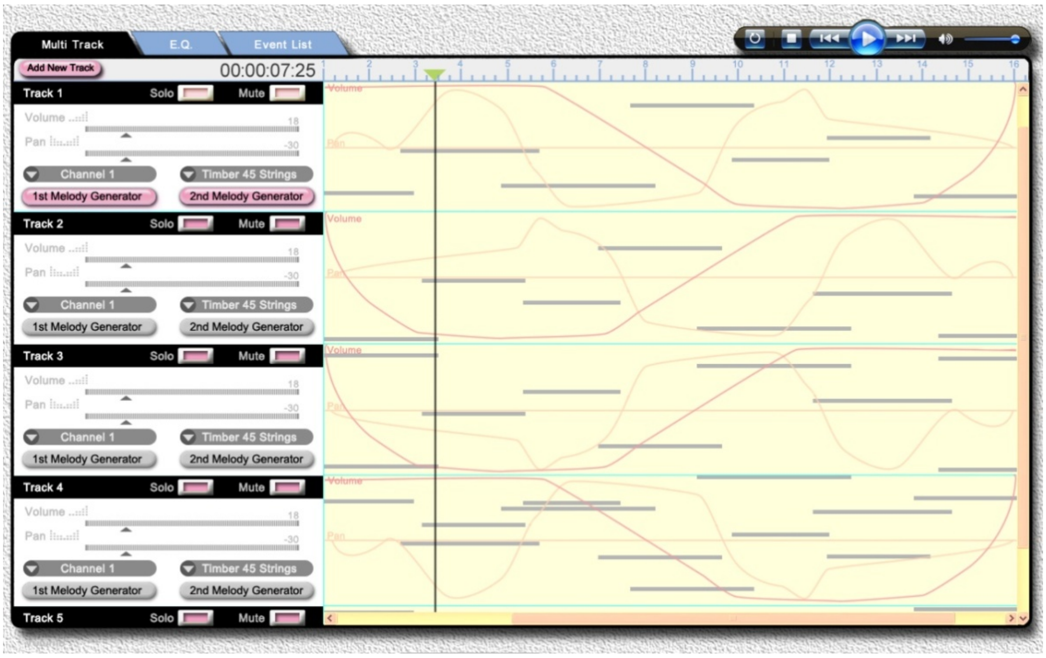

Figure 4. The multi-track editor and strain setting interface.

4. Research Method

4.1 Artificial intelligence system of simulation for composer's thinking

The system is designed to imitate the style of representative composers in each of the classical period. Ludwig van Beethoven of the Classic era (1750-1820), Frederic Chopin of the Romantic era (1820-1910), and Claude Debussy of the Impressionist era(1885-1910) are all selected for analysis and data collecting. They are the representative composers of the specific time period, and musical language differs greatly.

4.1.1 Using the algorithm of Markov chain

To understand the detailed concept of Markov Chain, we can assume to be doing a series of experiments and the probabilities resulted from every test denoted as E1, E2,… En,…(could be either finite or infinite). For every result Ek, if we can predict the outcome Pk, then for every specific sample the sequence E_{j1} E_{j2} … $E_{jn,,}$ we can define the resulting probabilities as p(E_{j1} E_{j2} … E_{jn}) =p_{j1} … P_{jn}. This is an experiment to test the individuality within the sample.

However, within the Markov Chain theory, our purpose is to destroy such hypothesis. Due to the fact there is no way that we could predict the outcome of every event. In other words「p_k」does not exist. To further discuss this issue more information must be provided.

Under this condition, we cannot provide any event E_j with a probability $p_{j.}$ However, we can provide a pair of events (E_j，E_k) with a probability p_{jk}. In this case p_{jk} can be defined as a conditional probability. It hypothesize that within the experiment, E_j has already occurred and in the following experiment E_k will appear as well. Besides p_{jk}, we also need to know the appearance probability of E_j during the first experiment. After obtaining all the necessary data, the sampled sequence E_{j0} E_{j1} … E_{jn}'s appearance probability (representing the result of the initial, first and Nth experiment respectively) can be defined as $P(E_{j0}, E_{j1}, E_{jn}) = a_j\, p_{j0j1}\, p_{j1j2} \ldots p_{jn-1jn}$.

After clearing the above concepts, we apply them with mathematical notations to represent their true quantity. Among the common terminologies, S is used to represent a conditional space and a compound of all the possible conditions during an experiment.

Therefore, X_n is a random variable. Its value is within the conditional space *S*. A set of value within *S*'s random variable X_0, X_1, X_2…,if capable of fullfilling the following criteria can be labeled as Markov Chain.

$$P(X_{n+1} = x | X_0, X_1, X_2, \ldots, X_n) = P(X_{n+1} = x | X_n) \quad (1)$$

P_{xy} or $P(x,y)$ is represented by $P(X_{n+1} = y | X_n = x)$. If we know the initial and the N_{th} result of the experiment, then "n+1"th experimental result is related to the N_{th}.

4.1.2 The application of Sieve Theory

Sieve Theory by definition means separating the wanted materials from the unwanted materials by the methods of filtering. In equal temperament, the octave is divided into 12 equal divisions. After applying the MOD function to the MIDI pitch range 0~127, we can organize them into residual class 0 to 11. Each of the number represents the pitches within the octave.

Each Residual Class's (RC) corresponding Pitch:

Random<=127 mod 12

RC	0	1	2	3	4	5	6	7	8	9	10	11
Pitch	C	#C(*b*D)	D	#D(*b*E)	E	F	#F(*b*G)	G	#G(*b*A)	A	#A(*b*B)	B

Table 1. RC's corresponding pitch within the octave.

4.1.3 Musical form style analysis of every -ism composer

Beethoven has stretched the practice of functional tonality to its limit which promotes the evolution from the classic era into romanticism. His works can be generally divided into three common periods. The first period contains works prior to 1802, the last contain works after 1818, and the middle period (1802 – 1818) which is the Testament of Heiligenstadt of the watershed. The musical genre of choice for imitation for the current musical systems is focused on the middle period and only on the piano sonata. The first step in selecting the artificial intelligence is to analyze the traditional sonata form and using it as the basis to structure the sections.

Sonata Form:

Exposition: first subject transition1 second subject transition2 codetta1

Development:

Recapitulation: first subject transition3 second subject transition4 codetta2

Base on the above analysis, the musical material can be separated into 10 minor sections. Emphasizing on the hierarchical importance of each section, the artificial intelligence network will generate the first subject and the second subject. Using the two generated subjects as the basis, the transitions and codetta will be further developed.

To further emulate composer's inspirations, the probabilities of interval progression are arranged and fitted into a table. Using random selection to allow the relationships between consecutive-interval occurrences to be in accordance to the composer's liking will shorten the distance in achieving close-imitation.

Interval upward probability table:

Intervallic distance	0 perfect unison	1 minor second	2 major second	3 minor third	4 major third	5 perfect fourth	6 aug 4th or dim 5th	7 perfect fifth	8 minor 6th	9 major 6th	10 minor 7th	11 major 7th
Probabilities	10.456 %	11.111 %	4.575 %	14.379 %	12.418 %	13.725 %	0.248 %	7.843 %	11.765 %	4.575 %	5.882 %	2.976 %

Table 2. The probability table of the upward interval for Beethoven style.

Interval downward probability table:

Intervallic distance	0 perfect unison	1 minor second	2 major second	3 minor third	4 major third	5 perfect fourth	6 aug 4th or dim 5th	7 perfect fifth	8 minor 6th	9 major 6th	10 minor 7th	11 major 7th
Probability	18.571 %	22.143 %	7.857 %	10.714 %	7.143 %	5.714 %	2.857 %	5.000 %	3.571 %	6.429 %	4.286 %	5.715 %

Table 3. The probability table of the downward interval for Beethoven style.

Nevertheless, the two dimensional progression, is only capable of representing the pitch content of a single melody. Without the concept of harmonic progression (vertical component) the imitation quality becomes pessimistic. Therefore, a large amount of classic music is analyzed for its harmonic structure and the progression is as follows:

Probability	I	II	III	IV	V	VI	VII
I	1/7	1/6	1/4	1/7	1/5	0	1/4
II	1/7	1/6	0	1/7	0	1/6	0
III	1/7	1/6	1/4	1/7	1/5	1/6	1/4
IV	1/7	0	0	1/7	0	1/6	0
V	1/7	1/6	0	1/7	1/5	1/6	0
VI	1/7	1/6	1/4	1/7	1/5	1/6	1/4
VII	1/7	1/6	1/4	1/7	1/5	1/6	1/4

Table 4. "Row" means harmony progression; "column" means the probability of Markov Chain which can be connected with harmony progression.

The probability matrix of harmony progression connection is as follows:

$$\begin{bmatrix} P\ (\mathrm{I_n}) \\ P\ (\mathrm{II_n}) \\ P\ (\mathrm{III_n}) \\ P\ (\mathrm{IV_n}) \\ P\ (\mathrm{V_n}) \\ P\ (\mathrm{VI_n}) \\ P\ (\mathrm{VII_n}) \end{bmatrix} = \begin{bmatrix} 1/7 & 1/6 & 1/4 & 1/7 & 1/5 & \mathrm{null} & 1/4 \\ 1/7 & 1/6 & \mathrm{null} & 1/7 & \mathrm{null} & 1/6 & \mathrm{null} \\ 1/7 & 1/6 & 1/4 & 1/7 & 1/5 & 1/6 & 1/4 \\ 1/7 & \mathrm{null} & \mathrm{null} & 1/7 & \mathrm{null} & 1/6 & \mathrm{null} \\ 1/7 & 1/6 & \mathrm{null} & 1/7 & 1/5 & 1/6 & \mathrm{null} \\ 1/7 & 1/6 & 1/4 & 1/7 & 1/5 & 1/6 & 1/4 \\ 1/7 & 1/6 & 1/4 & 1/7 & 1/5 & 1/6 & 1/4 \end{bmatrix}^{n-1} \begin{bmatrix} P\ (\mathrm{I_1}) \\ P\ (\mathrm{II_1}) \\ P\ (\mathrm{III_1}) \\ P\ (\mathrm{IV_1}) \\ P\ (\mathrm{V_1}) \\ P\ (\mathrm{VI_1}) \\ P\ (\mathrm{VII_1}) \end{bmatrix} \quad (2)$$

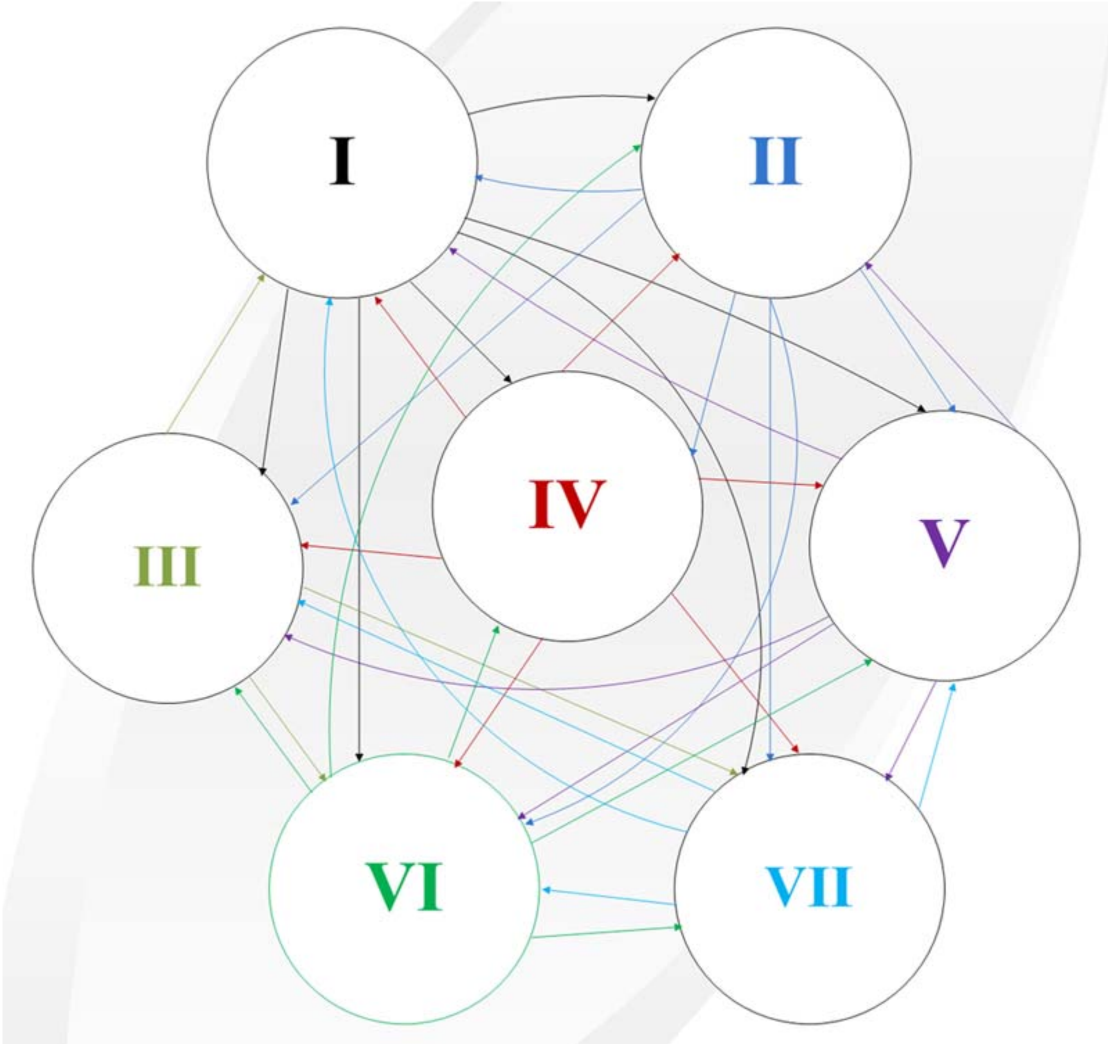

Figure 5. The diagram of Harmonic progression Markov Chain.

Since the pitch content of the main melody is more flexible than that of the harmonic progression, when assigning harmonic and melodic progressions, rules of voice leading and first and second common-chord for modulation are designed to follow composer's occurrence probability. The data collected are distributed among different databases and its index triggered to provide more bounding between harmonies.

The probability MARKOV chain change after analyzing more than half of the piano sonatas of Beethoven is the following table.

Probability	I	II	III	IV	V	VI	VII
I	15.909%	11.112%	25.786%	29.583%	51.111%	09.513%	36.364%
II	04.545%	12.110%	00.000%	14.286%	04.444%	11.539%	00.000%
III	02.273%	10.111%	24.214%	06.661%	02.222%	05.263%	09.091%
IV	13.636%	00.000%	00.000%	07.625%	00.000%	21.053%	00.000%
V	47.727%	21.224%	00.000%	27.559%	31.111%	10.526%	00.000%
VI	04.545%	23.220%	24.572%	06.684%	06.667%	36.842%	27.273%
VII	11.365%	22.223%	25.428%	07.602%	04.445%	05.264%	27.272%

Table 5. Beethoven’s Functional Harmony percetage in Markov Chain.

Beethoven style harmony progression connection probability matrix:

$$\begin{bmatrix} P(I_n) \\ P(II_n) \\ P(III_n) \\ P(IV_n) \\ P(V_n) \\ P(VI_n) \\ P(VII_n) \end{bmatrix} = \begin{bmatrix} 15.909\% & 11.112\% & 25.786\% & 29.583\% & 51.111\% & 09.513\% & 36.364\% \\ 04.545\% & 12.110\% & 00.000\% & 14.286\% & 04.444\% & 11.539\% & 00.000\% \\ 02.273\% & 10.111\% & 24.214\% & 06.661\% & 02.222\% & 05.263\% & 09.091\% \\ 13.636\% & 00.000\% & 00.000\% & 07.625\% & 00.000\% & 21.053\% & 00.000\% \\ 47.727\% & 21.224\% & 00.000\% & 27.559\% & 31.111\% & 10.526\% & 20.000\% \\ 04.545\% & 23.220\% & 24.572\% & 06.684\% & 06.667\% & 36.842\% & 27.273\% \\ 11.365\% & 22.223\% & 25.428\% & 07.602\% & 04.445\% & 05.264\% & 27.272\% \end{bmatrix}^{n-1} \begin{bmatrix} P(I_1) \\ P(II_1) \\ P(III_1) \\ P(IV_1) \\ P(V_1) \\ P(VI_1) \\ P(VII_1) \end{bmatrix} \quad (3)$$

Nocturnes style of Chopin:

Chopin is the most well known composer for his special ornamental melodies, figuration and counterpoint that are presented in his piano nocturnes, mazurkas and etudes. Chopin's works is often regarded as an extension to the early 19^{th}-century models and Bach's ornamental melodies. Often there exists the blurring of tonal functions between melodies and figures while the broken chord and the contrapuntal lines provide underlying harmonic structure.

The musical genre of choice for imitation for the current musical systems is focused on Chopin's 19 nocturnes. Nocturne is originated from the Latin word Hox, meaning the night goddess and night prayer.

The first nocturnes to be published are by pianist John Field in 1812. By year 1820 there already established certain general consistency in nocturnes, which were contributed by Field and many of his composer circles. The central idea for nocturne is to imitate the vocal style of French *romance* or Italian *aria*. This helped in the development of sustaining pedal, which allows the wide spread arpeggios to support the melody. These characteristics can be seen in Chopin's 19 nocturnes.

Other characteristics of Chopin nocturnes are: 1. Range and interval contour of the vocal styles melodies are expanded when adapting it to instrumental styles. 2 Instrumental style melodies contain both regular and irregular meter syncopations. 3. Despite the changes, instrumental style melodies are still capable of maintaining its vocal quality.

The current system, under the Chopin mode, place heavy emphasize on harmonies. The same approach applies in analyzing Chopin's nocturnes and generating the algorithms for Markov Chains. The system will use Markov Chain to select the probabilities of harmonic structure and correlating it with a corresponding melody.

The probability MARKOV chain change after analyzing nocturnes of Chopin is the following table.

Probability	I	II	III	IV	V	VI	VII
I	25.000%	07.143%	20.000%	33.333%	16.667%	00.000%	20.000%
II	25.000%	28.571%	00.000%	11.111%	33.333%	20.000%	00.000%
III	08.300%	07.143%	20.000%	11.111%	08.333%	10.000%	20.000%
IV	08.300%	07.143%	00.000%	11.111%	00.000%	10.000%	00.000%
V	08.400%	35.714%	00.000%	11.112%	16.667%	20.000%	20.000%
VI	16.700%	07.143%	40.000%	11.111%	16.667%	20.000%	20.000%
VII	08.300%	07.143%	20.000%	11.111%	08.333%	20.000%	20.000%

Table 6. Chopin's Functional Harmony percetage in Markov Chain.

Nocturnes style of Chopin harmony progression connection probability matrix:

$$\begin{bmatrix} P(I_n) \\ P(II_n) \\ P(III_n) \\ P(IV_n) \\ P(V_n) \\ P(VI_n) \\ P(VII_n) \end{bmatrix} = \begin{bmatrix} 25.000\% & 07.143\% & 20.000\% & 33.333\% & 16.667\% & 00.000\% & 20.000\% \\ 25.000\% & 28.571\% & 00.000\% & 11.111\% & 33.333\% & 20.000\% & 00.000\% \\ 08.300\% & 07.143\% & 20.000\% & 11.111\% & 08.333\% & 10.000\% & 20.000\% \\ 08.300\% & 07.143\% & 00.000\% & 11.111\% & 00.000\% & 10.000\% & 00.000\% \\ 08.400\% & 35.714\% & 00.000\% & 11.112\% & 16.667\% & 20.000\% & 20.000\% \\ 16.700\% & 07.143\% & 40.000\% & 11.111\% & 16.667\% & 20.000\% & 20.000\% \\ 08.300\% & 07.143\% & 20.000\% & 11.111\% & 08.333\% & 20.000\% & 20.000\% \end{bmatrix}^{n-1} \begin{bmatrix} P(I_1) \\ P(II_1) \\ P(III_1) \\ P(IV_1) \\ P(V_1) \\ P(VI_1) \\ P(VII_1) \end{bmatrix} \quad (4)$$

The probability table of upward interval:

Intervallic distance	0 perfect unison	1 minor second	2 major second	3 minor third	4 major third	5 perfect fourth	6 aug 4^{th} or dim 5th	7 perfect fifth	8 minor 6th	9 major 6th	10 minor 7th	11 major 7th
Probabilities	4.167 %	8.333 %	20.833 %	12.5 %	4.167 %	12.5 %	4.167 %	4.167 %	4.167 %	16.667 %	4.167 %	4.165 %

Table 7. The probability table of the upward interval for Chopin style.

The probability table of upward interval:

Intervallic distance	0 perfect unison	1 minor second	2 major second	3 minor third	4 major third	5 perfect fourth	6 aug 4^{th} or dim 5th	7 perfect fifth	8 minor 6th	9 major 6th	10 minor 7th	11 major 7th
Probabilities	6.452 %	12.903 %	29.032 %	6.452 %	3.226 %	16.129 %	3.226 %	6.452 %	6.452 %	3.226 %	3.226 %	3.224 %

Table 8. The probability table of the downward interval for Chopin style.

Debussy style :

Debussy's harmony is a fusion between modality and tonality. Besides using the common modes, Ionian, Dorian, Phrygian, Lydian, Mixolydian, Aeolian and Locrian, Pentatonic, whole-tone, and octatonic scales are also frequently used. They provide oriental flavor and tonal ambiguities especially if two are juxtaposed together. One of the major differences between Debussy's music and other composers' is the structure. Debussy relied on poetry to support his musical structure. The phrases, form tends to be more fluid and adventurous.

Debussy's melodic phrases are often fragmented and irregularly developed. Tonal colors are often supported by the interval of 7^{th} and 9^{th} and often they move in parallel motion. Interval of perfect 5^{th} is also a favorite choice to provide an oriental color style.

The current system, under the Debussy mode, emphasizes on the blurring of the tonalities. In order to achieve this Sieve theory is used to filter out unwanted intervals such as major and minor thirds, which suggest major or minor tonality. Intervals such as perfect 5^{th} and 7^{th} will be used more abundantly.

Equation of pentatonic of Movable Do System:

Random<=127 mod 12

RC	0	2	4	7	9
Pitch	C	D	E	G	A

Table 9. Pentatonic Sieve table.

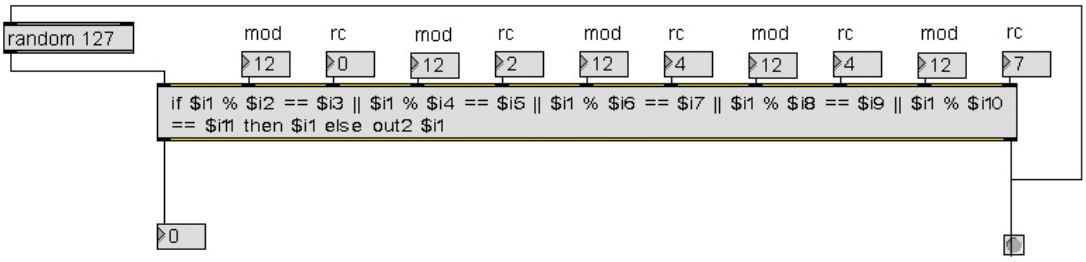

Figure 6. A part of MAX/MSP Sieve.

This MAX sieve contains the pentatonic scale. It will output the RC (residual class) 0, 2, 4, 7, and 9. All other numbers in RC will be filtered out from the right outlet.

Equation of septatonic of Movable "Do" System:

Random<=127 mod 12

RC	0	2	4	6	7	9	11
Pitch	C	D	E	#F	G	A	B

Table 10. septatonic Sieve table.

Equation of whole tone scale of Movable "Do" System:

Random<=127 mod 12

RC	0	2	4	6	8	10
Pitch	C	D	E	#F	#G	#A

Table 11. Whole tone scale sieve table.

The harmonic structure is constructed with Markov Chain algorithms, which imitates the qualities of impressionism.

After analyzing a large scale of piano works by Debussy, the Markov Chain probability tables are as follows:

Probability	I	II	III	IV	V	VI	VII
I	13.333%	28.571%	09.091%	06.667%	14.286%	16.667%	07.692%
II	20.000%	07.143%	36.364%	13.333%	21.429%	25.000%	15.385%
III	06.667%	07.143%	09.091%	20.000%	07.143%	08.333%	15.385%
IV	06.667%	00.000%	27.273%	13.333%	14.286%	25.000%	00.000%
V	13.333%	42.857%	00.000%	26.667%	07.143%	08.333%	30.769%
VI	26.667%	07.143%	09.091%	06.667%	07.143%	08.333%	07.692%
VII	13.333%	07.143%	09.090%	13.333%	28.570%	08.334%	23.077%

Table 12. Debussy's Functional Harmony percentage in Markov Chain.

Chopin style harmony progression connection probability matrix:

$$\begin{bmatrix} P(I_n) \\ P(II_n) \\ P(III_n) \\ P(IV_n) \\ P(V_n) \\ P(VI_n) \\ P(VII_n) \end{bmatrix} = \begin{bmatrix} 13.333\% & 28.571\% & 09.091\% & 06.667\% & 14.286\% & 16.667\% & 07.692\% \\ 20.000\% & 07.143\% & 36.364\% & 13.333\% & 21.429\% & 25.000\% & 15.385\% \\ 06.667\% & 07.143\% & 09.091\% & 20.000\% & 07.143\% & 08.333\% & 15.385\% \\ 06.667\% & 00.000\% & 27.273\% & 13.333\% & 14.286\% & 25.000\% & 00.000\% \\ 13.333\% & 42.857\% & 00.000\% & 26.667\% & 07.143\% & 08.333\% & 30.769\% \\ 26.667\% & 07.143\% & 09.091\% & 06.667\% & 07.143\% & 08.333\% & 07.692\% \\ 13.333\% & 07.143\% & 09.090\% & 13.333\% & 28.570\% & 08.334\% & 23.077\% \end{bmatrix}^{n-1} \begin{bmatrix} P(I_1) \\ P(II_1) \\ P(III_1) \\ P(IV_1) \\ P(V_1) \\ P(VI_1) \\ P(VII_1) \end{bmatrix} \quad (5)$$

The probability table of the upward inteval:

Intervallic distance	0 perfect unison	1 minor second	2 major second	3 minor third	4 major third	5 perfect fourth	6 aug 4^{th} or dim 5th	7 perfect fifth	8 minor 6th	9 major 6th	10 minor 7th	11 major 7th
Probabilities	5.208 %	4.688 %	19.965 %	24.826 %	15.625 %	10.069 %	4.861 %	9.201 %	1.736 %	2.083 %	0.87 %	0.868 %

Table 13. The probability table of the upward interval for Debussy style.

The probability table of the downward inteval:

Intervallic distance	0 perfect unison	1 minor second	2 major second	3 minor third	4 major third	5 perfect fourth	6 aug 4^{th} or dim 5th	7 perfect fifth	8 minor 6th	9 major 6th	10 minor 7th	11 major 7th
Probabilities	4.348 %	10.397 %	27.788 %	13.043 %	10.586 %	14.745 %	3.781 %	8.318 %	1.512 %	2.457 %	1.89 %	1.135 %

Table 14. The probability table of the downward interval for Debussy style.

4.2 **Code Definition for MIDI Technology**

MIDI file consists of the sets of binary code, and it generally has the following basic structure: header part and track part. Each part includes 1 status byte (80~FF) + 0~2 Data Byte (00~7F). Header usually includes file type, because MIDI file regards *.mid as the associate file name including three kind of formats, 0, 1, and 2.

0	1	2	3	4	5	6	7	8	9	A	B	C	D
M	T	h	D	Header length				Format		Track		Division	

Table 15. MIDI Header Format.

0	1	2	3	4	5	6	7	8	n	n+1	n+2	n+3
M	T	R	K	Track length				Format		M	M	M

Table 16. MIDI Track Format.

Each Midi file has the following contents: the hex code can be written as: “4d 54 68 64 00 00 00 06 ff ff nn nn dd dd”. The first four digits are represented in the ASCII code. “MThd” is used as the header title of the MIDI file. Then the following four bytes are the header bytes, “00 00 00 06”.

The remaining code is explained in the following table.

ff ff	Appoint midi form	00 00	Single track
		00 01	Multi-track and synchronizing
		00 02	Multi-track and asynchronizing
nn nn	Appoint the quantity of	Meta-track + multi-track	

	track	
dd dd	Appoint basic time	default 120 (00 78)，there are quantity of tick of a quarter note. Tick is a minimum unit in midi.

Table 17. MIDI Header Definition Table.

MIDI data is constituted by the same sub data format. These sub-data record each track's information in multi-track format. When adding a track, the data must be added behind the previous track and the header's "nnnn" (track number) must also be changed.

The meta-track includes all the additional information of the song, such as the title and copyright, speed of the song and system code (Sysx),etc. Both the meta-track and the individual tracks of notes need to have " 4D 54 72 6B " as a header. It is followed by a 4-byte integer, which marks the byte of this track. This does not include the preceding 4 bytes and their own 4 bytes.

All data recording component have the same structure, which is time difference and events. Time difference marks the time between the first event and the current event, its unit is called "tick" (the minimum unit of MIDI).

1 byte has 8 bits. If only 7 bits is used, it can express the number 0~127. The remaining number will be regarded as a mark. If the number expressed is above the range of the mark, it will be represented as 0. At this moment, one byte of 7 bits can express 0~127 tick. If the number goes beyond this range, such as 240, the mark will be set to 1.

Then the higher 7bits will be written down. The remaining will be the next byte. In this example 240 can decompose into 128 x 1 + 112. "1" will first be recorded in to the first byte. With the additional mark bit it will become 10000001, or 81 of hex. “112” will be recorded as the next byte. Its hex is 70. Therefore, in order to express the time 240 it will be written as 81 70. The same, if express 65535tick, can calculate out $65535=128^2 \times 3 + 128^1 \times 127 + 128^0 \times 127$, the result is 83 FF 7F. Therefore, we can know how to confirm the time difference. If mark byte is 0 then read the time difference while finishing. For example, 82 C0 03 means $128^2 \times 2 + 128^1 \times 64 + 128^0 \times 3=40963$. Using this method to record the integers is called the dynamic byte. Its original length will be changed according to the integer recorded.

Events can roughly be divided into the following types: note, controller and system information. All of the events have a unified expression structure: type + the parameter. For every note, the effective range is 0~127. Therefore by using 00~7F as "type" directly, it can be regarded as a note. For example, 3C means middle C.

The most important parameter of a note is velocity. For example, 3C 64 means a middle C note of a decimal 100 velocity. Since 1 byte has 8 bits, if a remaining 1 bit is set to 1, and combine with other 7 bits then it can express various types of information. The following table provides the detail workings of the events.

TYPE		Parameter(HEX)
Bits	Meaning	
8x	Note Off	Note Number：00~7F (Release Velocity)
		Velocity：00~7F
9x	Note On	Note Number：00~7F (Attack Velocity)
		Velocity：00~7F
Ax	Key After Touch	Note Number：00~7F
		Velocity：00~7F

Bx	Control Chainge	Controller ID：00~7F	
		Controller Value：00~7F	
Cx	Program Chainge	Program Number：00~7F	
Dx	Chainnel Pressure	Pressure Value：00~7F	
Ex	Pitch Wheel	Pitch Bend LSB：Pitch mod 128	
		Pitch Bend MSB：Pitch div 128	
F0	System code	System code bit number: dynamic bits	
		System code: "F0" not including beginning, but include "F7" of the ending.	
FF	Other format	Program type: 00~FF	
		Bits that the data take up: dynamic bits	
		Data: The number is decided by previous parameter	
00~7F	Started the parameter of the format last time.(8x、9x、Ax、Bx、Cx、Dx、Ex)		

Table 18. MIDI events table 1.

Following table listed the details of "FF". The bytes decided by data which express with "--" in the table.

Type		bits	data
bit	meaning		
00	Set up the sequence of the track	02	Sequence number: 00 00~FF FF
01	Song	--	Information of the text

	comments		
	Text of the track		Information of the text
02	Copyright of the song	--	Information of the copyright
03	Title of the song	--	Song title: Used in meta-track. Express the main title for the first time. Express the sub title for the second time.
	Track name	--	Track name
04	Instrument name	--	Text of the track
05	lyrics	--	lyrics
06	Marker	--	Use the text to mark. (Marker)
07	Starting point	--	Use the text record starting point.
2F	The track finished the sign	00	none
51	Tempo	03	3 bits integer, microsecond of 1 quarter note.
58	time signature	04	numerator
			denominator：00 (1),01 (2),02 (4),03 (8),etc.
			Metronome clock
			amounts of demisemiquaver that a quarter note includes.
59	key signature	02	Amounts of sharp and flat: -7~-1(flat)，0 (C)，1~7(sharp)

			Major/minor:　0(Major)，1(minor)
7F	Sequence specific information	--	Sequence specific information

Table 19. MIDI events table 2.

5. Future Works

Each genre of the current algorithmic composition system is designed to imitate the style of the representative composers in each of the classical period. Ludwig van Beethoven of the Classic era (1750-1820), Frederic Chopin of the Romantic era (1820-1910), and Claude Debussy of the Impressionist era(1885-1910) are all selected for analysis and data collecting. They are the key representative composers of the specific time period and each of their musical language varies greatly. The principles of Markov Chain and Sieve theory is combined with musical analysis and algorithm design to customize the artificial intelligence networks which will enhance the system's musicianship and therefore create music similar to the one created by the human.

The system library is consisted of the statistics which are objectively collected from the analysis of large amount of sampled musical works of the great composers in the three characteristic time periods. The future prospects aims to expand on the number of musical genres and styles of different composers that are involved.

In addition, different methods of music composing are incorporated with this system. Besides using the graphic interface, the user is able to input the melody of choice and allow the artificial intelligence within the system to develop variations and expand from the original.

There exist many kinds of musical form, for example: Sonata form, Rondo form, variations, minuet etc. The structure and melody of every musical form varies considerably. However, to simplify the issue, the user is only required to provide a short melody and with the systems support an entire composition can be generated from it.

Besides musical form, a library of Markov Chain could be build for generating different accompaniments for the main melody. It will make considerations in counterpoint, registers, dynamics, and vertical sonorities etc… In the current system, the Markov Chain is only based on certain sampled harmonic progression and the depending on the input material the corresponding accompaniment will be selected.

Cyberspace has increasing become a norm for the society today, with great efforts I aim to make this musical system online. The virtue of a new generation of inter-network service, such as web2.0, its virtue lies in user participation, is identical to that of the current system. By gathering knowledge from the public through cyberspace will promote the expansion on artificial intelligence of the musical systems.

6.Conclusion

The system library consists of the statistics which are objectively collected from the analysis of large amount of sampled musical works. The future prospects aims to expand on the number of musical genres and styles of different composers that are involved.

The process of music learning and creating can be desolate, depressing and exhausting. However, through collective work from the cyberspace, collaboration between users will, promote the exchange of ideas, diminish the amount of work required, stimulates imaginations, and the outcome of such artwork if carefully designed will be unimaginable.

In addition, a special-purpose database can be set up for each user's own liking. The collaborative artworks can be arranged in different hierarchical aesthetic orders and further deduced into Markov Chain and stored in the database library. The database will no longer contain past musical works but are capable of absorbing different music styles including the post-modern composition techniques from the collective artworks. This creative force will grow continuously and thus enhance the artificial intelligence of the system.

The purpose of computer program is to process all the indispensable but repetitive and time consuming calculation. For an average musician, it takes ten to even twenty years to master the craft of composition. It does required seemingly endless practices and compositional exercises to really grasp the fundamentals. However, for this privilege is not offered to the majorities.

Newton has said, “If whom I watch farther than someone else, that is because I stand at the giant's shoulder.” In this research, piling out a giant's shoulder has been attempted for the implementation of the automated composition system. Using simple and user-friendly interface, people can composed with the proper aid from the system to create complex and intelligent music.

Life is very transient, but the creativity of life is infinite. How to create unlimited possibility within a limited boundary is left for one to interpret. This research leads users to break the wide gap of composition grammar, and creates the bridges to link music with the masses accordingly.

References:

[1] Xenakis， I. 1970. “Towards a Metamusic.” *Tempo* 93:2–19.

[2] Xenakis， I. 1971. *Formalized Music.* Bloomington: Indiana University Press.

[3] Xenakis， I. 1976. *Musique， Architecture.* Paris: Casterman.

[4] Xenakis， I. 1988. “Sur le Temps.” In *Redécouvrir le Temps.*

[5] Bruxelles: Editions de l’Université de Bruxelles 193–200.

[6] Xenakis， I. 1989. “Concerning Time.” *Perspectives of New Music* 27(1):84–92.

[7] Xenakis， I. 1990. “Sieves.” *Perspectives of New Music* 28(1):58–78.

[8] Xenakis， I. 1992. *Formalized Music.* Hillsdale， New York: Pendragon Press.

[9] Xenakis， I. 1994. *Kéleütha.* Paris: L’Arche.

[10] Xenakis， I. 1996. “Determinacy and Indeterminacy.” *Organised Sound* 1(3):143–155.

[11] Wiggins G， Papadopoulos G， Phon-Amnuaisuk S， Tuson A. Evolutionary methods for musical composition. 1998. http://citeseer.ist.psu. edu/wiggins98evolutionary.html

[12] Gers FA， Schmidhuber J. LSTM recurrent networks learn simple context free and context sensitive languages. IEEE Trans. on Neural Networks， 2001， 12(6):1333−1340.

[13] Capanna A. Iannis xenakis Architect of light and sound. Nexus Network Journal， 2001，3(2). http://www.nexusjournal.com/ Capanna-en.html

[14] Cope D. MP3 Files of David Cope and Experiments in Musical Intelligence. 2005. http://arts.ucsc.edu/faculty/cope/mp3page.html

[15] Jacob BJ. Algorithmic composition as a model of creativity. Organised Sound， 1996，1(3):157−165.

[16] Jones， E. 2001. “Residue-Class Sets in the Music of Iannis

[17] Xenakis: An Analytical Algorithm and a General Intervallic Expression.”
Perspectives of New Music 39(2):229–261.
[18] Koenig， G. M. 1970. “Project Two—A Programme for Musical Composition.”
Electronic Music Reports 3. Utrecht: Institute of Sonology.
[19] Malherbe，C.，G. Assayag，and M. Castellengo. 1985. “Functional Integration of Complex Instrumental Sounds in Musical Writing.” *Proceedings of the International Computer Music Conference* San Francisco， California: International Computer Music Association: pp. 185–192.
[20] Johnson R， Cope D. Computer and musical style. 1991.
http://csml.som.ohio-state.edu/Music839C/Notes/Cope.html
[21] Biles JA. Genjam: A genetic algorithm for generating jazz solos. In: Proc. of the Int’l Computer Music Conf. San Francisco: ICMA， 1994. 131−137.
[22] Steedman M. The blues and abstract truth: Music and mental models. In: Garnham A， Oakhill J， eds. Mental Models in Cognitive Science. Erlbaum， 1996. 305−327.
[23] Bartetzki A. CMask， a stochastic event generator for Csound. 1997.
http://gnom.kgw.tu-berlin.de/~abart/CMaskMan/ CMask-Manual.htm
[24] Leman M. Artificial neural networks in music research. In: Marsden A， Pople A， eds. Computer Representations and Models in Music. London: Academic Press， 1992. 265−301.
[25] Alpen A. Techniques for algorithmic composition of music. 1995.
http://alum.hampshire.edu/~adaF92/algocomp/algocomp95.html
[26] Riotte， A. 1992. “Formalisation des échelles de hauteurs en analyse et en composition.” Actes du Colloque “Musique et Assistance Informatique.” Marseille: Musique et Informatique de Marseille.
[27] Solomos， M. 1996. *Iannis Xenakis (Echos du XXe siècle).* Mercuès: P.O.

Editions.

[28] Solomos， M. 2002. “Xenakis’ Early Works: From ‘Bartokian Project’ to ‘Abstraction’.” *Contemporary Music Review* 21(2–3):21–34.

[29] Squibbs， R. 1996. “An Analytical Approach to the Music of Iannis Xenakis: Studies of Recent Works.” Dissertation. Yale University.

[30] Squibbs， R. 2002. “Some Observations on Pitch， Texture， and Form in Xenakis’ *Mists.*” *Contemporary Music Review* 21(2–3):91–108.

[31] Chen CCJ， Miikkulainen R. Creating melodies with evolving recurrent neural networks. 2001. http://www.cs.utexas.edu/users/nn/ downloads/papers/chen.ijcnn01.pdf

[32] Unemi T. A tool for multi-part music composition by simulated breeding. In: Gedau A， ed. Artificial Life VIII. Cambridge: MIT Press， 2002. 410−413.

[33] Ames C， Domino M. Cybernetic composer: an overview. In: Balaban M， Ebcioglu K，Laske O，eds. Understanding Music with AI. Cambridge: AAAI Press，1992. 186−205.

[34] Toiviainen P. Symbolic AI versus connectionism in music research. In: Miranda E， ed. Readings in Music and Artificial Intelligence. Amsterdam: Harwood Academic Publishers， 2000. 47−67.

[35] Grout DJ. History of Western Music. 5th ed.， New York: W. W. Norton & Company， 1996.

[36] Amiot， E.， et al. 1986. “Duration Structure Generation and Recognition in Musical Writing.” *Proceedings of the International Computer Music Conference.* San Francisco， California: International Computer Music Association， pp. 185–192.

[37] Andreatta， M. 2003. “Méthodes algébriques en musique et musicologie du XXe siècle: aspects théoriques， analytiques et compositionnels.” Dissertation. École des Hautes Etudes en Sciences Sociales.

[38] Ariza， C. 2002. “Prokaryotic Groove: Rhythmic Cycles as Real-Value Encoded Genetic Algorithms.” *Proceedings of the International Computer Music Conference.* San Francisco， California: International Computer Music Association， pp. 561–567.

[39] Ariza， C. 2003. “Ornament as Data Structure: An Algorithmic Model based on Micro-Rhythms of Csángó Laments and Funeral Music.” *Proceedings of the International Computer Music Conference.* San Francisco， California: International Computer Music Association， pp. 187–193.

[40] Ariza， C. 2004. “An Object-Oriented Model of the Xenakis Sieve for Algorithmic Pitch， Rhythm， and Parameter

[41] Generation.” *Proceedings of the International Computer Music Conference.* San Francisco， California: International Computer Music Association， pp. 63–70.

[42] Biles JA. Autonomous genJam: Eliminating the fitness bottleneck by eliminating fitness. 2002. http://www.cs.usyd.edu.au/~josiah/ gecco_workshop_biles.pdf

[43] Eck D. Finding temporal structure in music: Blues improvisation with LSTM recurrent networks. In: Boulard H， ed. Neural Networks for Signal Processing XII， Proc. of the 2002 IEEE Workshop. New York: IEEE， 2002. 747−756

[44] Griffith N， Todd PM. Musical Networks. Cambridge: MIT Press， 1997.

[45] Walker E. Chaos melody theory. 2001.http://www.ziaspace.com/elaine/chaos/ChaosMelodyTheory.pdf

[46] Basset BA， Neto JJ. A stochastic musical composer based on adaptive algorithms. 1999. http://gsd.ime.usp.br/sbcm/1999/papers/ Bruno_Basseto.pdf

[47] Hochreiter S， Schmidhuber J. Long short-term memory. 1996. http://citeseer.ist.psu.edu/hochreiter96long.html

[48] Ebcioglu K. An expert system for harmonizing chorales in the style of J. S. Bach. In: Balaban M， Ebcioglu K， Laske O， eds. Understanding Music with AI. Cambridge: AAAI Press， 1992. 294−334.

[49] Cope D. Virtual Music: Computer Synthesis of Musical Style. Cambridge: MIT Press， 2001.

[50] Järvelainen H. Algorithmic musical composition. 2000. http://www.tml.tkk.fi/Studies/Tik-111.080/2000/papers/hanna/alco.pdf

[51] Lewis JP. Creation by refinement and problem of algorithmic music composition. In: Todd PM， Loy DG， eds. Music and Connectionism. Cambridge: MIT Press/Bradford Books， 1991. 212−228.

[52] Todd PM， Loy G. Music and Connectionism. Cambridge: MIT Press， 1991.

[53] Mozer MC. Neural network composition by prediction: Exploring the benefits of psychophysical constraints and multiscale processing. Cognitive Science， 1994， 6:247−280.

[54] Biles JA. GenJam in transition: From genetic jammer to generative jammer. 2002. http://www.generativeart.com/papersGA2002/ 8.pdf

Appendix

MIDI note code and GM timbre table

MIDI note code table

No.	Note code		octave	Note name
	（Binary code）	（Hex code）		
0	0000000	00	-1	C
1	0000001	01	-1	C#
2	0000010	02	-1	D
3	0000011	03	-1	D#
4	0000100	04	-1	E
5	0000101	05	-1	F
6	0000110	06	-1	F#
7	0000111	07	-1	G
8	0001000	08	-1	G#
9	0001001	09	-1	A
10	0001010	0A	-1	A#
11	0001011	0B	-1	B
12	0001100	0C	0	C
13	0001101	0D	0	C#
14	0001110	0E	0	D
15	0001111	0F	0	D#
16	0010000	10	0	E
17	0010001	11	0	F

18	0010010	12	0	F#
19	0010011	13	0	G
20	0010100	14	0	G#
21	0010101	15	0	A
22	0010110	16	0	A#
23	0010111	17	0	B
24	0011000	18	1	C
25	0011001	19	1	C#
26	0011010	1A	1	D
27	0011011	1B	1	D#
28	0011100	1C	1	E
29	0011101	1D	1	F
30	0011110	1E	1	F#
31	0011111	1F	1	G
32	0100000	20	1	G#
33	0100001	21	1	A
34	0100010	22	1	A#
35	0100011	23	1	B
36	0100100	24	2	C
37	0100101	25	2	C#
38	0100110	26	2	D
39	0100111	27	2	D#
40	0101000	28	2	E
41	0101001	29	2	F
42	0101010	2A	2	F#

43	0101011	2B	2	G
44	0101100	2C	2	G#
45	0101101	2D	2	A
46	0101110	2E	2	A#
47	0101111	2F	2	B
48	0110000	30	3	C
49	0110001	31	3	C#
50	0110010	32	3	D
51	0110011	33	3	D#
52	0110100	34	3	E
53	0110101	35	3	F
54	0110110	36	3	F#
55	0110111	37	3	G
56	0111000	38	3	G#
57	0111001	39	3	A
58	0111010	3A	3	A#
59	0111011	3B	3	B
60	0111100	3C	4	C
61	0111101	3D	4	C#
62	0111110	3E	4	D
63	0111111	3F	4	D#
64	1000000	40	4	E
65	1000001	41	4	F
66	1000010	42	4	F#
67	1000011	43	4	G

68	1000100	44	4	G#
69	1000101	45	4	A
70	1000110	46	4	A#
71	1000111	47	4	B
72	1001000	48	5	C
73	1001001	49	5	C#
74	1001010	4A	5	D
75	1001011	4B	5	D#
76	1001100	4C	5	E
77	1001101	4D	5	F
78	1001110	4E	5	F#
79	1001111	4F	5	G
80	1010000	50	5	G#
81	1010001	51	5	A
82	1010010	52	5	A#
83	1010011	53	5	B
84	1010100	54	6	C
85	1010101	55	6	C#
86	1010110	56	6	D
87	1010111	57	6	D#
88	1011000	58	6	E
89	1011001	59	6	F
90	1011010	5A	6	F#
91	1011011	5B	6	G
92	1011100	5C	6	G#

93	1011101	5D	6	A
94	1011110	5E	6	A#
95	1011111	5F	6	B
96	1100000	60	7	C
97	1100001	61	7	C#
98	1100010	62	7	D
99	1100011	63	7	D#
100	1100100	64	7	E
101	1100101	65	7	F
102	1100110	66	7	F#
103	1100111	67	7	G
104	1101000	68	7	G#
105	1101001	69	7	A
106	1101010	6A	7	A#
107	1101011	6B	7	B
108	1101100	6C	8	C
109	1101101	6D	8	C#
110	1101110	6E	8	D
111	1101111	6F	8	D#
112	1110000	70	8	E
113	1110001	71	8	F
114	1110010	72	8	F#
115	1110011	73	8	G
116	1110100	74	8	G#
117	1110101	75	8	A

118	1110110	76	8	A#
119	1110111	77	8	B
120	1111000	78	9	C
121	1111001	79	9	C#
122	1111010	7A	9	D
123	1111011	7B	9	D#
124	1111100	7C	9	E
125	1111101	7D	9	F
126	1111110	7E	9	F#
127	1111111	7F	9	G

GM timbre table

Piano	0 Acoustic Grand Piano 1 Bright Acoustic Piano 2 Electric Grand Piano 3 Honky-tonk Piano 4 Rhodes Piano 5 Chorused Piano 6 Harpsichord 7 Clavichord
Pitched Percussion	8 Celesta 9 Glockenspiel 10 Music box 11 Vibraphone 12 Marimba

	13 Xylophone 14 Tubular Bells 15 Dulcimer
Organ	16 Hammond Organ 17 Percussive Organ 18 Rock Organ 19 Church Organ 20 Reed Organ 21 Accordian 22 Harmonica 23 Tango Accordian
Guitar	24 Acoustic Guitar (nylon) 25 Acoustic Guitar (steel) 26 Electric Guitar (jazz) 27 Electric Guitar (clean) 28 Electric Guitar (muted) 29 Overdriven Guitar 30 Distortion Guitar 31 Guitar Harmonics
Bass	32 Acoustic Bass 33 Electric Bass(finger) 34 Electric Bass (pick) 35 Fretless Bass 36 Slap Bass 1 37 Slap Bass 2

	38 Synth Bass 1 39 Synth Bass 2
Strings	40 Violin 41 Viola 42 Cello 43 Contrabass 44 Tremolo Strings 45 Pizzicato Strings 46 Orchestral Harp 47 Timpani
Ensemble	48 String Ensemble 1 49 String Ensemble 2 50 Synth Strings 1 51 Synth Strings 2 52 Choir Aahs 53 Voice Oohs 54 Synth Voice 55 Orchestra Hit
Brass	56 Trumpet 57 Trombone 58 Tuba 59 Muted Trumpet 60 French Horn 61 Brass Section 62 Synth Brass 1

	63 Synth Brass 2
Reed	64 Soprano Sax 65 Alto Sax 66 Tenor Sax 67 Baritone Sax 68 Oboe 69 English Horn 70 Bassoon 71 Clarinet
Pipe	72 Piccolo 73 Flute 74 Recorder 75 Pan Flute 76 Bottle Blow 77 Shakuhachi 78 Whistle 79 Ocarina
Synth Lead	80 Lead 1 (square) 81 Lead 2 (sawtooth) 82 Lead 3 (caliope lead) 83 Lead 4 (chiff lead) 84 Lead 5 (charang) 85 Lead 6 (voice) 86 Lead 7 (fifths) 87 Lead 8 (bass+lead)

Synth Pad	88 Pad 1 (new age) 89 Pad 2 (warm) 90 Pad 3 (polysynth) 91 Pad 4 (choir) 92 Pad 5 (bowed) 93 Pad 6 (metallic) 94 Pad 7 (halo) 95 Pad 8 (sweep)
Synth Effects	96 FX 1 (rain) 97 FX 2 (soundtrack) 98 FX 3 (crystal) 99 FX 4 (atmosphere) 100 FX 5 (brightness) 101 FX 6 (goblins) 102 FX 7 (echoes) 103 FX 8 (sci-fi)
Ethnic	104 Sitar 105 Banjo 106 Shamisen 107 Koto 108 Kalimba 109 Bagpipe 110 Fiddle 111 Shanai
Percussive	112 Tinkle Bell

	113 Agogo 114 Steel Drums 115 Woodblock 116 Taiko Drum 117 Melodic Tom 118 Synth Drum 119 Reverse Cymbal
Sound Effects	120 Guitar Fret Noise 121 Breath Noise 122 Seashore 123 Bird Tweet 124 Telephone Ring 125 Helicopter 126 Applause 127 Gunshot
General MIDI percussion instruments	MIDI percussion instruments 35 Acoustic Bass Drum 36 Bass Drum 1 37 Side Stick 38 Acoustic Snare 39 Hand Clap 40 Electric Snare 41 Low Floor Tom 42 Closed Hi-Hat 43 High Floor Tom

	44 Pedal Hi-Hat 45 Low Tom 46 Open Hi-Hat 47 Low-Mid Tom 48 Hi-Mid Tom 49 Crash Cymbal 1 50 High Tom 51 Ride Cymbal 1 52 Chinese Cymbal 53 Ride Bell 54 Tambourine 55 Splash Cymbal 56 Cowbell 57 Crash Cymbal 2 58 Vibraslap 59 Ride Cymbal 2 60 Hi Bongo 61 Low Bongo 62 Mute Hi Conga 63 Open Hi Conga 64 Low Conga 65 High Timbale 66 Low Timbale 67 High Agogo 68 Low Agogo

	69 Cabasa 70 Maracas 71 Short Whistle 72 Long Whistle 73 Short Guiro 74 Long Guiro 75 Claves 76 Hi Wood Block 77 Low Wood Block 78 Mute Cuica 79 Open Cuica 80 Mute Triangle 81 Open Triangle