Chinese Folk Music Composition based on Genetic Algorithm

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***Abstract*—The genetic algorithm (GA) uses techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover. Due to its ability to find approximate solutions of hard optimization, the GA is suited for applications in various domains. The GA-based composition system, which uses genetic algorithm to evolve music materials, has become a hot spot in the algorithmic composition. This paper discusses Chinese folk composition based on GA. A structure of GA-based Chinese folk composition system is presented. Evolutionary melody operators for Chinese folk music are proposed and the fitness functions are discussed in detail. Experimental results show that the model based on GA is feasible and effective in the process of Chinese folk music composition.**

Keywords- genetic algorithm*; *evolutionary melody operators*; *pentatonic*; *Chinese folk music

I. INTRODUCTION

With the wide application of computer and digital equipment, electronic music has entered the era of completely digitized computer music. The field of computer music includes digital musical instrument interface, digital audio, synthesis techniques, sound analysis, audio signal processing and algorithmic composition, while algorithmic composition is undoubtedly the most challenging area. Algorithmic composition is a process using the formal rules as a music creation means, so musicians can use the computer as a music creation tool to automatically composition [1]. The formal process of music has been for a long time [1,2]. As early as the 11^{th} century, Guido made a melody by assigning a different pitch to each vowel in a motet. The melody was created according to the changes of vowel. In about 14^{th} century, a uniform rhythm technology appeared in *isorhythmic motet*. After that, in the 20^{th} century, two methods of sequence composition and stochastic composition were introduced by applying the set theory and stochastic process technology to music. L.Hiller, a pioneer of modern algorithmic composition, was one of the first composers who created music making use of computer tools, with the music works named as *Illiac Suite for String Quartet*. Afterwards, a large number of musicians have begun to use computers to create music. Algorithmic composition techniques include stochastic process, music grammar, fractal, chaos, expert systems, neural networks, genetic algorithms, etc. Music composition system based on genetic algorithms has become the most active one in the algorithmic composition. These systems have achieved rich results in recent decades, including Western and some other areas of music. However, the Chinese music is less involved. Wang et al. [3] studied the fitness function of genetic algorithm, which composed of acoustical features and statistical analyzing features. It has not been used in automatic composition system. This paper presents a structure of GA-based composition system for Chinese folk music.

II. COMPOSITION WITH GENETIC ALGORITHM

The genetic algorithm is a heuristic search algorithm, which uses techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover. GA is implemented in a computer simulation in which a population of candidate solutions (called individual) to an optimization problem evolves toward better solutions. The evolution usually starts from a population of randomly generated individuals. In each generation, the fitness of each individual is evaluated; multiple individuals are selected to form a new population. The new population is then used in the next iteration of the GA. Commonly, the algorithm terminates when either a maximum number of generations has been

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produced, or a satisfactory fitness level has been reached. In the early 1990s, Horner first applied genetic algorithm to the field of algorithmic composition[4]. There have been a number of composers who attempt to evolve musical pieces by using GA-based composition systems [4-19]. Horner used genetic algorithm to implement thematic bridging[4]. Thematic bridging is the transformation of an initial music pattern to some final pattern over a specified duration. *GenJam*, which realized by Biles, is a real-time interactive performance system [5, 6]. It uses GA to evolve melodic fragments by which to construct jazz solo. Liu [8] proposed using music theory with the information from music charts in the evaluation criterion. The fitness function is generated by the weighted rules which are according to the download numbers from music charts. Prisco[9] achieved an automatic composition system for dodecaphonic music based on genetic algorithm. The *Bach in a Box* system [10] aims to generate a four part baroque harmony around a melody which is pre-defined as a structure. System in [11] was also used for four part harmony creation. Damon's automatic composing method [19] is capable of outputting a complete work, in which the style of the work is unrestricted. Ting et al.[20] proposed a phrase imitation-based evolutionary composition. The system uses music theory and imitates the characteristics of melodic progression.

Most of GA-based composition systems relate to the composition task. The tasks involve motifs generation, melody development, harmonization, arrangement and complete composition. A genetic representation of the music domain is important in GA-based composition systems. As a standard representation of GA, most systems use binary bit array to represent music pieces. The composers try to deal with how to represent pitches, durations, sequences or other music structures. During each successive generation, a proportion of individuals are selected to breed a new generation. Individuals are selected through a fitness-based process. The next step is to generate a second generation population through genetic operators, crossover and mutation. Most systems perform a one-point crossover or double-point crossover. The mutation in music systems differs from traditional GA systems, some of the basic techniques for the music development, such as reverse, invert, are used to design mutation operators.

During each generation in GA system, the selection of individuals to build a new generation is just based on fitness evaluation. Undoubtedly, how to implement fitness is an important issue in the GA-based composition systems. There are two approaches to be used to implement fitness: automatic and interactive. In GA-based system, the fitness function is always problem dependent. In music area, composition rules are the basis of the fitness implementation. Most automatic systems adopt music theoretical rules as fitness evaluation, such as in [11] and [12]. Interactive genetic algorithm is a technique that performs optimization with the human evaluation. In interactive GA-based composition system, mentors or users give fitness to each individual instead of fitness function. *GenJam* [5] is an interactive system, its ability to interact with a human performer in live performance situation is necessary to be an improviser. *Jive* [16] is also based on interactive GA.

III. GA BASED CHINESE FOLK MUSIC COMPOSITION

Melody is one of the most important means of Chinese folk music [21, 22]. While creating melodies, musicians use a variety of development ways on the theme of material to produce more musical materials and ultimately form a complete piece of music. The development ways mainly include repetition, change-head, change-tail, split, ascending, descending, free-extension, etc. The process of melody development is similar to the evolutionary operation in GA. Based on the theory of evolutionary computation; the development ways such as repetition, change-head and change-tail et al. are designed as the corresponding evolutionary melody operators.

In this paper, we propose an algorithm for GA based Chinese Folk Music Composition (GA-CFMC), in which the theme of material is regarded as evolutionary individuals, and the new individuals are created by applying evolutionary melody operators. The new individuals are evaluated by Chinese folk music rules in the form of fitness functions, while the individuals with worse fitness are eliminated and the better fitness individuals are retained until the condition is met. The material of the evolutionary operation is synthesized by the structure of the Chinese folk music, and finally output the whole production. Figure 1 illustrates the structure of Chinese folk music composition system.

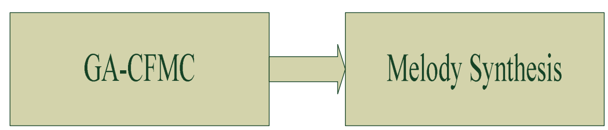

Figure 1. Structure of composition system

GA-CFMC aims at melody development for Chinese folk music. In GA-CFMC, phrases are used as chromosome individuals. Differs from traditional GA systems, GA-CFMC introduces evolutionary melody operators to replace the evolutionary operations in GA, and the new individuals are created by applying evolutionary melody operators.

A. *Representation*

The theme material of composition, whose size and length may vary according to the work to be created, can be motives, sections or phrases [23]. In this paper, phrases are used as the theme material; therefore the evolutionary individuals are phrases.

Definition 1 *Bar*

$$Bar = \left\langle note_1, note_2, \cdots, note_i, \cdots, note_l \right\rangle,$$

where l represents the number of notes contained in the bar, and the number of notes in each bar is not the same because it is relevant to the duration of each note in the bar.

$note_i = \langle note\_pit_i, note\_val_i \rangle$ represents a note in the bar, where $note\_pit_i$ is the pitch of $note_i$, and $note\_val_i$ is the duration of $note_i$.

Definition 2 *Interval serial of phrase*

$$Interval\_Seq = \left\langle Interval_1^2, Interval_2^3, \cdots, Interval_{i-1}^i, \cdots, Interval_{l-1}^l \right\rangle$$

stands for the interval relationship between adjacent notes in a bar.

Definition 3 *Phrase*

$$Phrase = \left\langle Bar^1, Bar^2, \cdots, Bar^i, \cdots, Bar^n \right\rangle = \left\langle note_1, note_2, \cdots, note_j, \cdots note_D \right\rangle$$

where n is the number of bars that make up the phrase. Here in the paper, we suppose n =4. D is the total number of notes in the phrase.

B. Fitness

Unlike the hierarchical fitness design in [3], we propose a method according to the characteristics and rules of Chinese folk music,. The fitness function is made up of three sub-fitness functions : $fitness_{mode}$, $fitness_{melody}$ and $fitness_{tonic}$. The pentatonic mode is emphasized in the proposed fitness function, which is more suitable to Chinese folk music.

$fitness_{mode}$

Pentatonic scale has been extensively used in Chinese folk music. Notes of the Chinese ancient pentatonic scale are *Gong*, *Shang*, *Jue*, *Zhi* and *Yu*. Chinese traditional music uses five tones to form five modes, i.e. *Gong*, *Shang*, *Jue*, *Zhi* and *Yu* are supposed to be the main tones and thus produce the corresponding five modes respectively.

The pentatonic modes are shown as:

$$PentaMode = \{Mode_g, Mode_s, Mode_j, Mode_z, Mode_y\},$$

where $Mode_g$, $Mode_s$, $Mode_j$, $Mode_z$, $Mode_y$ representing the *Gong-Diao*, *Shang-Diao*, *Jue-Diao*, *Zhi-Diao* and *Yu-Diao*.

Take *Yu-Diao* as an example, some explanations are given as below.

- Mode Scale Prototype

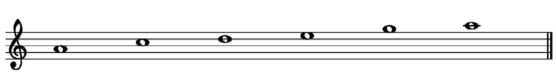

Figure 2. Mode Scale Prototype of *Yu-Diao*

Yu -Diao Basic Scale: $Scale_y = \{\mathrm{g}^1, \mathrm{a}^1, \mathrm{c}^2, \mathrm{d}^2, \mathrm{e}^2, \mathrm{g}^2\}$.

- Mode Tone Analysis

In pentatonic, tones of five degrees above and below the keynote are the supporting tones of keynote; they together with the tonic constitute the pillar of the mode. Keynote with supporting tones form the tonal steady-notes.

In *Yu-Diao* basic scale of notes, keynote of *Yu-Diao* with tone e^2 five degrees above and d^2 five degrees below, form the backbone of *Yu-Diao*, while the other tones for non-pillar.

Define *Yu -Diao* keynote and steady-notes as follows,

Yu -Diao keynote: $Keynote_y = \{tone_y\}$;

Yu -Diao steady-notes:

$Steadynote_y = \{tone_y, tone_j, tone_s\}$;

$fitness_{mode}$ investigates the usage of keynote and steady-notes of melody, counting the position, frequency and duration of notes they occur.

$fitness_{melody}$

$fitness_{melody}$ examines the melody pattern. In the creation of melody, wave patterns are mostly used to avoid a pitch straight up or straight down. Before a big jump, more than four-degree intervals, a reverse movement should be applied.

$fitness_{tonic}$

Compared to western music, Chinese folk music has the characteristic of tone calm and tranquil. The tone is mainly reflected in the relationship between intervals. The melody of western music has more jump progression; however, Chinese folk music is mostly dominated by second-to-third-degree intervals, with few big jump but step progression. $fitness_{tonic}$ is used to analyze second degree, third degree intervals in melody so as to meet the characteristics of Chinese folk music.

The fitness function $f(x)$ is shown as,

$$f(x) = \sum_{i=1}^{3} \omega_i f_i(x)$$

where $f_i(x)$,i=1,2,3 denotes $fitness_{mode}$, $fitness_{melody}$ and $fitness_{tonic}$, respectively. ω_i is the weight of fitness function.

C. evolutionary melody operators

Let phrase space $\wp$ be the space formed by all phrases; P be the parent material library; I be the child material library. Evolutionary melody operators are defined as follows.

Definition 4 Phrase repetition operator is a repetition of the parent phrase in P. A new phrase in I is defined as a mapping on the phrase space: $\Gamma_{Repeat} : \wp \to \wp$,

$$\Gamma_{Repeat}(t \to d) = \{d = t | (t \in \mathrm{P}) \wedge (d \in \mathrm{I})\}.$$

Definition 5 Phrase ascending operator is a gradual rise of the phrase t on pitch to form a new phrase d, defined as the mapping on the phrase space: $\Gamma_{Pit\_Rise} : \wp \to \wp$,

$$\Gamma_{Pit\_Rise}(t \to d) = \{d | (t \in \mathrm{P}) \wedge (d \in \mathrm{I})\}.$$

Let phrase $t = \left\langle Bar^1, Bar^2, \cdots, Bar^i, \cdots, Bar^n \right\rangle$, where

$Bar^i = \left\langle note_1^i, note_2^i, \cdots, note_j^i, \cdots, note_l^i \right\rangle$ and

$note_j^i = \left\langle note\_pit_j^i, note\_val_j^i \right\rangle$.

The pitch of each note in phrase t is increased by δ degrees to form a new phrase d as follows,

$d = \left\langle Bar^{1'}, Bar^{2'}, \cdots, Bar^{i'}, \cdots, Bar^{n'} \right\rangle$, where

$Bar^{i'} = \left\langle note_1^{i'}, note_2^{i'}, \cdots, note_j^{i'}, \cdots, note_l^{i'} \right\rangle$ and

$note_j^{i'} = \left\langle note\_pit_j^i + \delta, note\_val_j^i \right\rangle$.

Definition 6 Phrase descending operator is a gradual down of the phrase t on pitch to form a new phrase d, defined as the mapping on the phrase space: $\Gamma_{Pit\_Rise}:\wp\rightarrow\wp$,

$\Gamma_{Pit\_Down}(t\rightarrow d)=\{d|(t\in \mathrm{P})\wedge(d\in \mathrm{I})\}$.

Let phrase $t=\left\langle Bar^1,Bar^2,\cdots,Bar^i,\cdots,Bar^n\right\rangle$, where

$Bar^i=\left\langle note_1^i,note_2^i,\cdots,note_j^i,\cdots,note_l^i\right\rangle$ and

$note_j^i=\left\langle note\_pit_j^i,note\_val_j^i\right\rangle$.

The pitch of each note in phrase t is decreased by δ degrees to form a new phrase d as follows,

$d=\left\langle Bar^{1'},Bar^{2'},\cdots,Bar^{i'},\cdots,Bar^{n'}\right\rangle$, where

$Bar^{i'}=\left\langle note_1^{i'},note_2^{i'},\cdots,note_j^{i'},\cdots,note_l^{i'}\right\rangle$ and

$note_j^{i'}=\left\langle note\_pit_j^i-\delta,note\_val_j^i\right\rangle$.

Definition 7 Phrase crossover operator is an exchange of i bars at the beginning of the phrases t_1 and t_2 in P to generate new phrases d_1 and d_2 in I, defined as the mapping on the phrase space $\Gamma_{Cross}:\wp\times\wp\rightarrow\wp$,

$\Gamma_{Cross}(t_1\times t_2\rightarrow d_1,d_2)=\{d_1,d_2|(t_1,t_2\in \mathrm{P})\wedge(d_1,d_2\in \mathrm{I})\}$

where phrases t_1, t_2, d_1 and d_2 satisfy,

$t_1=\left\langle Bar_{t_1}^1,Bar_{t_1}^2,\cdots,Bar_{t_1}^i,Bar_{t_1}^{i+1},\cdots,Bar_{t_1}^n\right\rangle$

$t_2=\left\langle Bar_{t_2}^1,Bar_{t_2}^2,\cdots,Bar_{t_2}^i,Bar_{t_2}^{i+1},\cdots,Bar_{t_2}^n\right\rangle$

$d_1=\left\langle Bar_{t_2}^1,Bar_{t_2}^2,\cdots,Bar_{t_2}^i,Bar_{t_1}^{i+1},\cdots,Bar_{t_1}^n\right\rangle$

$d_2=\left\langle Bar_{t_1}^1,Bar_{t_1}^2,\cdots,Bar_{t_1}^i,Bar_{t_2}^{i+1},\cdots,Bar_{t_2}^n\right\rangle$.

Definition 8 Phrase mutation operator is defined as the mapping on the phrase space: $\Gamma_{Mutation}:\wp\rightarrow\wp$,

$\Gamma_{Mutation}(t\rightarrow d)=\{d|(t\in\mathrm{P})\wedge(d\in \mathrm{I})\}$.

Let phrase $t=\left\langle Bar^1,Bar^2,\cdots,Bar^i,\cdots,Bar^n\right\rangle$, where

$Bar^i=\left\langle note_1^i,note_2^i,\cdots,note_j^i,\cdots,note_l^i\right\rangle$ and

$note_j^i=\left\langle note\_pit_j^i,note\_val_j^i\right\rangle$.

A variation of a note in phrase t includes pitch variation and duration variation. Duration variation results in a change of the number of notes. For example, when a whole note changes to a half note, the number of notes in the bar is increased by one. When the j-th note in the i-th bar of phrase t is mutated, a new phrase d is formed as,

$d=\left\langle Bar^1,Bar^2,\cdots,Bar^{i'},\cdots,Bar^n\right\rangle$.

If only consider the pitch variation, the bar and note are as follows,

$Bar^{i'}=\left\langle note_1^i,note_2^i,\cdots,note_j^{i'},\cdots,note_l^i\right\rangle$

$note_j^{i'}=\left\langle note\_pit_j^{i'},note\_val_j^i\right\rangle$

If duration variation is also considered, a note is split into two shorter notes.

$Bar^{i'}=\left\langle note_1^i,note_2^i,\cdots,note_j^{i'},note_j^{i''},\cdots,note_l^i\right\rangle$, where

$note_j^{i'}=\left\langle note\_pit_j^{i'},note\_val_j^{i'}\right\rangle$ and

$note_j^{i''}=\left\langle note\_pit_j^{i''},note\_val_j^{i''}\right\rangle$.

D. The Algorithm of GA-CFMC

GA-CFMC

1. **Input**
   - 1.1 Mode of Chinese folk music; keynote;
   - 1.2 Beat; bars number n;
   - 1.3 Population size N; maximum iteration number M;
   - 1.4 Probability of repetition, ascending, descending, crossover, mutation.
2. **Algorithm step**
   - 2.1 Initialize the phrase population P;

   Repeat
   - 2.2 Calculate the fitness of phrase individual;
   - 2.3 Evolution operation: repetition, ascending, descending, crossover, mutation;
   - 2.4 Update the next generation of phrase population.

   Until iteration counter reaches M
3. **Output**: Phrase population

Figure 3 shows the flowchart of GA-CFMC.

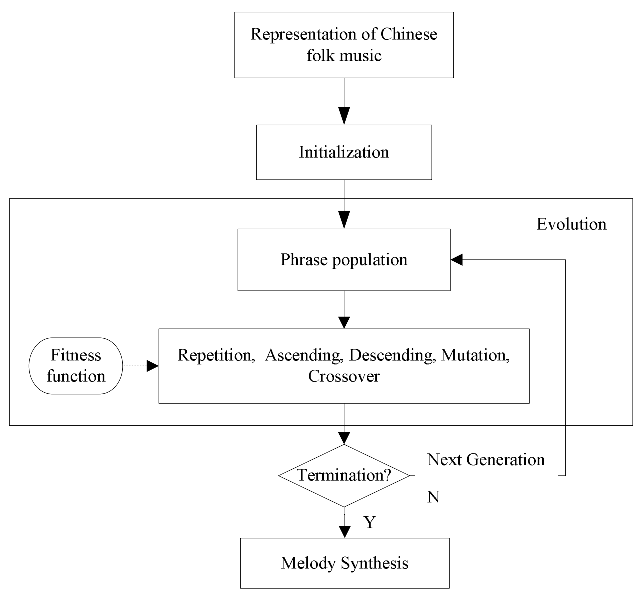

Figure 3. Flowchart of GA-CFMC

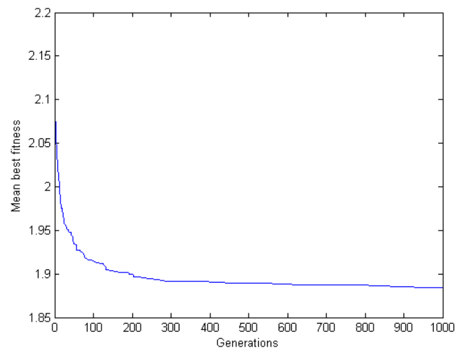

Figure 4. The mean of best fitness against generations

Figure 4 plots the mean of best fitness against generations over 30 runs of the GA-CFMC. The figure shows that GA-CFMC can effectively enhance the fitness of the phrase individuals.

IV. MELODY SYNTHESIS

After the algorithm of GA-CFMC, a series of melody material are evolved, and they are combined to form a complete melody in accordance with a Chinese melody development structure [23]. These materials are structurally synthesized according to repeatability and contrast. The melody structure is in the form of a four-phrase in which the melody is composed of four phrases, the relations among which are repetitive, similar or contrast.

Figure 5 shows a sample of composition of Chinese folk music. Mode of *Yu -Diao*, with *Gong* tone being F, rhythm set to 2/4 beat, and 16 bars in total, is given. Figure 6 shows another composition sample of *Shang-Diao,* with *Gong* tone being C.

Figure 5. Composition example of *Yu –Diao*

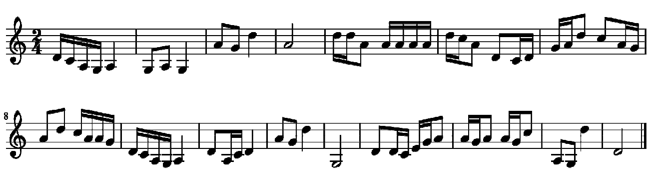

Figure 6. Composition example of *Shang-Diao*

V. CONCLUSIONS

This paper proposes an algorithm for GA-based Chinese folk composition. Based on the characteristics of Chinese folk music, fitness function is constructed to measure the individual. The evolutionary melody operators are constructed in the algorithm. A series of phrase material are evolved in GA-CFMC, and then they are combined to form a complete melody. Finally, composition examples are provided to verify the feasibility and validity in GA-CFMC. The paper makes a useful exploration of composition in Chinese folk music.

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