A Hybrid Swarm Composition for Chinese Music

Xiaomei Zheng[1,2(✉)], Weian Guo[3], Dongyang Li[1], Lei Wang[1], and Yushan Wang[2]

[1] College of Electronics and Information Engineering, Tongji University, Shanghai 201804, China
lidongyang04l2@163.com, wanglei@tongji.edu.cn
[2] College of Information, Mechanical and Electrical Engineering, Shanghai Normal University, Shanghai 200234, China
{xmzheng,amywang}@shnu.edu.cn
[3] Sino-German College of Applied Sciences, Tongji University, Shanghai 201804, China
guoweian@163.com

Abstract. Algorithm composition is an automatic process which uses formalized strategies for music expression and creation. In this paper, we use Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) to simulate the process of Chinese music creation. A hybrid swarm intelligence composition model for Chinese music is proposed. In this model, the PSO is firstly used to generate the initial music material, and then melody is developed by using the evolutionary operators in GA. Finally, a piece of music work is formed. The experimental result shows that the algorithm is feasible, and has better performance than the genetic algorithm composition.

Keywords: Hybrid swarm intelligent composition · PSO · GA · Chinese music

1 Introduction

Since the advent of computers, musicians and computer scientists have been working on computers as a tool for music thinking. For algorithmic composition, it is necessary to consider the formalization of composing behavior and rules, as well as the style of the composing system. Some composing systems can achieve Bach style hymns while some others can be used to produce jazz. So far, the methods used for composition mainly include stochastic process, artificial neural network and GA [1], among which the GA-based method has been studied extensively and achieved rich results. GA is a heuristic search algorithm, which uses a natural evolutionary model. It starts from a population representing the candidate solutions of the problem. According to the survival process of the fittest, the optimal or approximate solutions of the problem are evolved by generations. In the process of evolution, the algorithm uses a series of evolutionary operators including crossover, mutation et al. GA has been widely used in many fields because of its simple concept, easy implementation, strong robustness and suitable for parallel computing. In the field of music creation, elements which make up

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music, such as pitch and duration, are easily represented by numbers. Composing methods, such as the development of musical material, are similar to the evolutionary operations in genetic algorithms. Therefore, it is feasible to extend GA to the music search space and produce music that conforms to the music rules. In the early 90's of the last century, Horner first applied GA to the field of algorithm composition [2], followed by a large number of computer scholars and musicians having done an useful attempt and exploration. Different evolutionary composing systems are designed and a lot of music creation results have been achieved. Horner completed a computer–aided composing program in which only a simple task of thematic bridging is completed. The famous GenJam [3, 4] is an evolved composing system designed by Biles which produces a 16-bar jazz melody. Ting et al. proposed a phrase imitation-based composing system which uses music theory and imitates the characteristics of melodic progression [5]. Liu proposed an evolutionary composition using the information from music charts in the evaluation criterion [6]. The fitness function is generated by the weighted rules according to the download times from music charts. Prisco achieved an automatic composing system for dodecaphonic music based on genetic algorithm and an evolutionary composer for Bass harmonization [7, 8].

Most of the above systems are for Western music. In this paper we will study the algorithmic composition for Chinese music. In the music creation, Western music focuses on the vertical structure of the works, such as harmony, polyphonic structure; while Chinese music focuses on the horizontal melody structure of the works, such as melody development. One method for Chinese musicians to create a melody is that after a theme is conceived, more music materials can be generated by a variety of melody development techniques and the materials form a complete melody ultimately. The formalization of the method can not be well achieved with a simple GA. Therefore, a hybrid swarm intelligent Chinese music composition algorithm is designed by the combination of PSO and GA. PSO generates the initial music theme which is evolved by GA so as to produce more materials.

2 Algorithm Model

2.1 Chinese Music

Western music has a sophisticated structure, while Chinese music focuses on its intrinsic rhythm. In music composition, melody creation is emphasized and most of the works are monophonic. Melody is the most important characteristic of Chinese music. The raw material to constitute the melody is the scale. The Chinese music mainly uses pentatonic scale "*Gong*, *Shang*, *Jue*, *Zhi* and *Yu*" [9]. With a tone in pentatonic as the keynote, five modes of "*Gong-mode*, *Shang-mode*, *Jue-mode*, *Zhi-mode* and *Yu-mode*" are produced in traditional Chinese music. Notes with five-degree above or five-degree below the keynote are the steady-notes of the keynote. Steady-notes together with keynote constitute the skeleton of mode. Mode is the basis for the melody development. It determines the combination of tones in the music works. In traditional pentatonic modes, the five scales of "*Gong*, *Shang*, *Jue*, *Zhi* and *Yu*" only produce a

unison, a major second, a minor third, a perfect fourth, a perfect fifth, a minor sixth, a major sixth, an octave and other intervals.

2.2 Composition Model

According to the creative method of Chinese music, a hybrid swarm intelligent composition model based on PSO and GA is proposed as shown in Fig. 1. The model divides the automatic composition of Chinese music into different stages, i.e., music theme generation, melody development, and final synthesis of works.

Fig. 1. Composition model of Chinese music

Particle swarm optimization is used for theme generation. PSO is a swarm algorithm proposed in [10]. It simulates the process of bird search for food to solve the optimization problems. PSO considers the individual as a particle in the D-dimensional search space, which flies at a certain speed. The fly speed can be adjusted according to the individual and group's fly experience so as the particle can approximate toward the optimal solution. PSO algorithm of this thought can be used in the process of theme generation in Chinese music. In this paper, the theme is considered as a phrase which is composed of D notes. The location of the particles represents a phrase. By the flight of particles, constantly changing the notes makes the phrase meet the mode regulation and creative rules of Chinese music, and ultimately find a better phrase.

Genetic algorithm is used for the evolution of melody. Unlike most of the previous GA-based composing systems whose initial groups are randomly generated, the theme materials generated by PSO are used as the initial population of GA developer, and the materials are evolved to realize the melody development by GA. This makes the evolutionary process quick and easy.

3 Algorithm Implementation

3.1 PSO Theme Generator.

The PSO theme generator includes two major stages of rhythm controller and PSO theme optimizer.

Rhythm Controller. In [11], the principle of the rhythm decomposition of music is given. The most basic cellular structure which constitutes the rhythm is the smallest odd and even number 1 and 2. A rhythm unit can be broken down into two smallest cell structures. Suppose the shortest note is the sixteenth, whose value is 1, then the eighth unit is 2, the fourth unit is 4, the half unit is 8, and the whole unit is 16, etc. Thus 2 can

be broken down into 1 and 1, 4 can be broken down into 2 and 2, or 1 and 3. According to the beat, the number of rhythm unit per bar can be determined, and then rhythm decomposition is made in each bar.

PSO Theme Optimizer. *Particle structure. Particle*(*i*)=*Loc*[], *Vel*[], *fitness*};

$Loc[\,] = <n_1, n_2, \cdots, n_j, \cdots, n_D>$ is a location vector, where n_j represents a note, and $Vel[] = <Interval_1, \cdots, Interval_j, \cdots, Interval_D>$ is a velocity vector, where $Interval_j$ represents the speed at which note n_j moves, i.e., the interval between $n_j(t)$ and $n_j(t+1)$.

Fitness. Considering the characteristics of Chinese music, the design of fitness takes into account three factors: f_{mode}, f_{melody} and f_{tonic}. f_{mode} investigates the usage of *keynote* and *steadynotes* of melody, counting the position, frequency and duration of notes they occur. f_{melody} examines the melody pattern. In the creation of melody, wave patterns are mostly usedto avoid a pitch straight up or straight down. Before a big jump, more than four-degree intervals, a reverse movement should be applied. Compared to western music, the tone of Chinese music has the characteristic of calm and tranquil. The tone is mainly reflected in the relationship between intervals. The melody of western music has more jump progression; however, Chinese music is mostly dominated by second-to-third-degree intervals, with few big jump but step progression. f_{tonic} is used to analyze second degree, third degree intervals in melody so as to meet the characteristics of Chinese music.

Algorithm Improvement. The velocity of particle represents the change of interval. The velocity update formula is based on an operation between *D*-dimensional vectors. According to the pitch relationship of notes, we redefine the operators for velocity and location update formula.

Definition 1. Substraction in velocity update between two particles *Particle(i)* and *Particle(k)* is defined as follow,

$$Particle\,(k).Loc\,[\,] - Particle\,(i).Loc\,[\,] = <n_1^k, \cdots, n_j^k, \cdots, n_D^k> - <n_1^i, \cdots, n_j^i, \cdots, n_D^i> = <Interval_{n_1^i}^{n_1^k}, \cdots, Interval_{n_j^i}^{n_j^k}, \cdots, Interval_{n_D^i}^{n_D^k}>$$

Definition 2. Velocity update of particle is defined as follow,

$$Particle\,(i).Vel'[\,] = \omega \cdot Particle\,(i).Vel\,[\,] + C_1 \cdot rand_1(\,) \cdot (p_{i\_best}.Loc\,[\,] - Particle(i).Loc\,[\,]) + C_2 \cdot rand_2(\,) \cdot (p_{best}.Loc\,[\,] - Particle(i).Loc\,[\,])$$

Definition 3. Location update of particle is defined as follow,

$$Particle\ (i).\ Loc\ [\,] = Particle\ (i).\ Loc\ [\,] + Particle\ (i).\ Vel\ [\,] = <n_1^i, \cdots, n_j^i, \cdots, n_D^i> + <Interval_1, \cdots, Interval_j, \cdots, Interval_D> = <n_1^{i'}, \cdots, n_j^{i'}, \cdots, n_D^{i'}>$$

3.2 Evolutionary Melody Developer

Melody Development. PSO theme generator produces the theme material of melody development. The theme material of composition, whose size and length may vary according to the work to be created, could be motives, sections or phrases [12]. In this paper, phrases are used as the theme material. These phrases can be used as basic material for melody development, based on which, various developing methods of Chinese melody such as repeating, changing-head, changing-tail, split, and other techniques can be implemented to form new phrases.

Chromosome Expression. The evolutionary individuals are phrases shown as below,

$$\begin{aligned} Phrase &= <Bar^1, Bar^2, \cdots, Bar^i, \cdots, Bar^n> \\ &= <note_1, note_2, \cdots note_i, \cdots, note_D> \end{aligned}$$

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. $note_i = <note\_pit_i, note\_val_i>$ represents a note in the bar, where $note\_pit_i$ is the pitch of $note_i$, and $note\_val_i$ is the duration of $note_{i.}$.

Fitness. The fitness is used in the same measure as in the PSO theme generator. The characteristics and rules of Chinese music are used to measure the merits of the chromosome.

Evolutionary Operator. The *selection* operator uses roulette selection.

The *crossover* operators include *note-crossover* and *phrase-crossover*, where *phrase-crossover* operator is an exchange of i bars at the beginning of the phrases t_1 and t_2 to generate new phrases d_1 and d_2, shown as follow,

$$\begin{aligned} t_1 &= <Bar^1_{t_1}, \cdots, Bar^i_{t_1}, Bar^{i+1}_{t_1}, \cdots, Bar^n_{t_1}>; \\ t_2 &= <Bar^1_{t_2}, \cdots, Bar^i_{t_2}, Bar^{i+1}_{t_2}, \cdots, Bar^n_{t_2}>; \end{aligned}$$

$$\begin{aligned} d_1 &= <Bar^1_{t_2}, \cdots, Bar^i_{t_2}, Bar^{i+1}_{t_1}, \cdots, Bar^n_{t_1}>; \\ d_2 &= <Bar^1_{t_1}, \cdots, Bar^i_{t_1}, Bar^{i+1}_{t_2}, \cdots, Bar^n_{t_2}> \end{aligned}$$

The *mutation* operators include the *phrase-ascending* operator, *phrase-descending* operator, *note-variation* operator, etc. For example, *phrase-ascending* operator is a gradual rise of the phrase t on pitch to form a new phrase d,

Let phrase $t = <Bar^1, Bar^2, \cdots, Bar^i, \cdots, Bar^n>$, where

$Bar^i = <note^i_1, note^i_2, \cdots, note^i_j, \cdots, note^i_l>$ and $note^i_j = <note\_pit^i_j, note\_val^i_j>$.

The pitch of each note in phrase t is increased by δ degrees to form a new phrase d as follow, $d = <Bar^{1'}, Bar^{2'}, \cdots, Bar^{i'}, \cdots, Bar^{n'}>$, where $Bar^{i'} = <note^{i'}_1, note^{i'}_2, \cdots, note^{i'}_j, \cdots, note^{i'}_l>$ and $note^{i'}_j = <note\_pit^i_j + \delta, note\_val^i_j>$.

Note-variation operator is a note variation in phrase, which includes pitch 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. Let phrase $t = <Bar^1, Bar^2, \cdots, Bar^i, \cdots, Bar^n>$, where

$Bar^i = <note_1^i, note_2^i, \cdots, note_j^i, \cdots, note_l^i>$ and $note_j^i = ltnote\_pit_j^i, note\_val_j^i >$. If only the pitch variation is considered, the new phrase $d = <Bar^1, Bar^2, \cdots Bar^{i'}, \cdots Bar^n>$ is formed, where $Bar^{i'} = <note_1^i, note_2^i, \cdots, note_j^{i'}, \cdots, note_l^i>$ and $note_j^{i'} = <note\_pit_j^{i'}, note\_val_j^i>$.

3.3 Melody Synthesis.

After the implementation of the hybrid swarm algorithm, aseries of melody material are evolved. These materials could be combined to form a complete musicin accordance with Chinese melody development structure. The 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.

The following figure shows the composition results based on *Shang-mode* (Fig. 2).

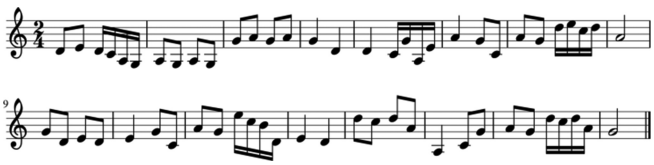

Fig. 2. Composition example of *Shang-mode*

4 Analysis and Comparison

Compared with the genetic algorithm composition (GA-CM), the hybrid swarm composition (Hybrid Swarm-CM) can obtain better results. The two algorithms run 20 times respectively, in which the maximum number of iterations is 1000 and the population size is 30. The experimental results are shown in Table 1. As can be seen from Table 1, The best fitness of Hybrid Swarm-CM is better than that of GA-CM, and minimum generation to reach the best fitness in Hybrid Swarm-CM is less than GA-CM. Figure 3 plots the mean of best fitness against generations over 20 runs of the Hybrid Swarm-CM and GA-CM. It shows that the performance of Hybrid Swarm-CMis also better than GA-CM.

Table 1. Best fitness of Hybrid Swarm-CM&GA-CM

No	Hybrid Swarm-CM		GA-CM	
	Best fitness	Generation	Best fitness	Generation
1	1.9074	155	1.9092	213
2	1.8884	218	1.9092	196
3	1.9087	76	1.9036	137
4	1.8995	168	1.9091	463
5	1.8947	105	1.9074	236
6	1.8868	124	1.9035	428
7	1.8917	113	1.9061	193
8	1.8982	203	1.8986	328
9	1.8947	243	1.9108	364
10	1.9022	95	1.9132	51
11	1.9009	226	1.9092	176
12	1.8778	34	1.9005	155
13	1.8975	352	1.912	141
14	1.8817	268	1.9074	213
15	1.8961	82	1.9246	253
16	1.8947	199	1.9101	209
17	1.9024	193	1.9258	375
18	1.8927	208	1.9238	92
19	1.8898	301	1.9035	284
20	1.8986	254	1.9078	247
Avg.	1.8952	181	1.9098	238

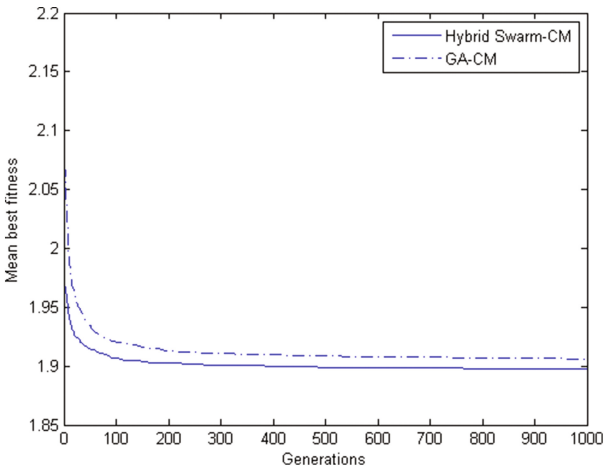

Fig. 3. Comparison of Hybrid Swarm-CM and GA-CM

5 Conclusion

Chinese music has its own creative characteristics. When composing a Chinese music, the algorithm can imitate the musicians' creative process. In this paper, by formalizing the musicians' creation mode, a hybrid swarm intelligent composition model for Chinese melody creation combined with PSO and GA is proposed. PSO algorithm is used as the initial population generator of GA, and the population is evolved by evolutionary operators in GA. Finally a complete melody work is merged through melody synthesis. Compared with the GA-based composition, the hybrid swarm composition algorithm can achieve better fitness and faster performance. However, the algorithm in this paper takes into account the characteristics of Chinese music while the emotions have not been considered. The future work will take the music emotions into account.

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