Adaptive Walk on Fitness Soundscape

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Abstract. We propose a new IEC for musical works based on an adaptive walk on a fitness landscape of sounds. In this system, there is a virtual plane that represents the genetic space of possible musical works called fitness soundscape. The user stands on the soundscape, and hears the multiple sounds that correspond to one's neighboring genotypes at the same time. These sounds come from different directions that correspond to the locations of their genotypes on the soundscape. By using the human abilities for localization and selective listening of sounds, the user can repeatedly walk toward the direction from which more favorite sounds come. This virtual environment can be realized by a home theater system with multiple speakers creating "surrounded sound". We report on the basic concept of the system, a simple prototype for musical composition with several functional features for improvement of evolutionary search, and preliminary evaluations of the system.

Keywords: interactive evolutionary computation, musical composition, fitness landscape, soundscape, virtual reality, artificial life.

1 Introduction

An interactive evolutionary computation (IEC) has been used for optimizing various artifacts which are not possible to be evaluated mechanically or automatically [1]. Based on subjective evaluations of the artifacts by a human, one's favorite artefacts in the population are selected as parents for the individuals in the next generation. By iterating this process, one can obtain better artifacts without constructing them by oneself.

IECs have been widely applied in various artistic fields. Especially, IECs have been applied in creation of musical works such as musical composition, sound design, and so on [2]. For example, Unemi constructed a musical composition system named SBEAT in which a multi-part music can be generated through simulated breeding [3]. Dahlstedt also proposed a system for synthesizing a sound with interactive evolution, in which each sound has a visual representation which corresponds to the set of parameters of the synthesizer for generating the sound [4].

In IECs for graphical works such as Dawkins's Biomorph [5], the individuals in the population can be evaluated in parallel as shown in Fig. 1 (a). On the other

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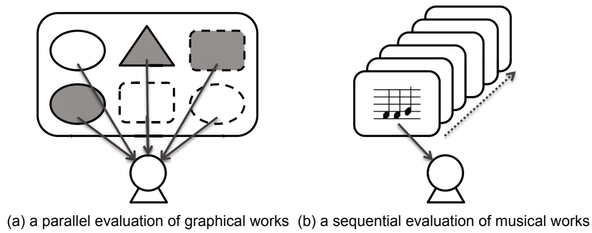


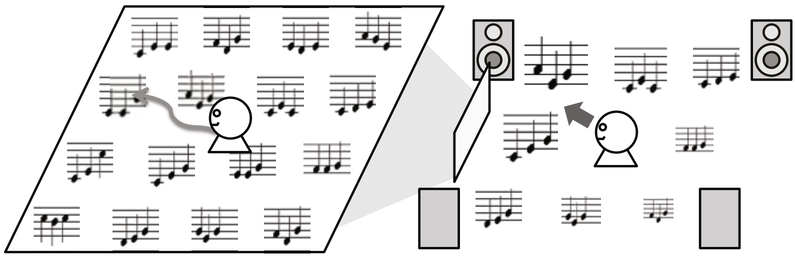
Fig. 1. The interactive evolutionary computation with a) parallel or b) sequential evaluations

hand, in IECs for musical works, the user listens to and evaluates each individual in the population one by one, as shown in Fig. 1 (b). This is due to the fact that it is basically thought as difficult to evaluate each individual correctly when the all individuals are played all at once. This is an essential difference of IECs for musical works compared with those for graphical works. Unfortunately, this sequential evaluation of individuals increases the total evaluation time and thus increases the user's temporal cost significantly. It also increases one's cognitive cost in that one needs to remember the features of individuals so as to compare between them. Thus, we often limit the population size small in order to decrease these costs, which brings about the fitness bottleneck [6].

So as to solve these problems, we focus on the cognitive abilities of human for localization and selective listening of sounds. We can localize the direction of sounds, and can concentrate on the sound we like to hear, which is called a *cocktail party effect* [7] in a broad sense. If we utilize these kinds of ability properly, there is a possibility that we can correctly evaluate the individuals in parallel even in the case of IECs for musical works.

We propose a new IEC for musical works based on an adaptive walk on the fitness landscape of sounds. In this system, there is a two-dimensional virtual plane that represents the genotypic space of possible musical works called fitness soundscape. The user stands on the soundscape, and hears the multiple sounds that correspond to one's neighboring genotypes at the same time. The sounds come from different directions that correspond to the locations of their genotypes on the soundscape. This virtual environment can be realized by a home theater system with multiple speakers creating "surrounded sound". By using the ability for localization and selective listening of sounds, the user can repeatedly walk toward the direction from which more favorite sounds come, which corresponds to the evolutionary process of the population in standard IECs.

In this paper, we introduce the basic concept of the proposed system, and a simple prototype system for musical composition. We also propose the several functional features for improvement of evolutionary search. The preliminary experiments showed that the user successfully obtained one's favorite musical work with the help of these features.



(a) fitness soundscape (b) 3D sound system with multiple speakers

Fig. 2. A conceptual image of adaptive walk on fitness soundscape

2 Adaptive Walk on Fitness Soundscape

We propose an IEC for musical works based on an adaptive walk on a fitness landscape of sounds. Here, we introduce the basic concept of the model.

The conceptual image of the model is shown in Fig. 2. A fitness landscape is often used so as to visualize and intuitively understand evolutionary dynamics of the population [8]. We assume a two-dimensional plane of genotypes that determine the individuals' phenotypes. In this model, the phenotypes represent possible musical works such as musical pieces that are going to be searched, as shown in Fig. 2 (a). Thus, we call this landscape of sounds the fitness soundscape.

The user stands on this plane and hears the sounds of one's neighboring individuals from their corresponding position all at once. This virtual sound environment can be realized by a home theater system with multiple speakers creating "surrounded sound" as shown in Fig. 2 (b).

The height of the fitness landscape is the corresponding fitness value of a genotype on a possible genetic space. The fitness of each genotype on the soundscape can be determined by a subjective evaluation by the user. Thus, the actual shape of the soundscape will be different among users depending on their subjective impression of individuals, and can change dynamically.

The adaptive evolution of the population can be represented by a hill-climbing process on the fitness landscape. We adopt this process on the fitness soundscape as an evolutionary mechanism of the model. The user can walk toward the direction from which one's favorite individuals' sounds come. The user can obtain one's more favorite sounds by repeating this hill-climbing process.

3 Prototype

We constructed a prototype of the system, which includes the several functions for improvement of an adaptive walk on the fitness soundscape. The main part of the system was constructed using Java 3D with JOAL (the Java Bindings for OpenAL API)[1], and we used the software synthesizer TiMidity++[2] for the dynamic

[1] https://joal.dev.java.net/
[2] http://timidity.sourceforge.net/

Fig. 3. A snapshot of the system

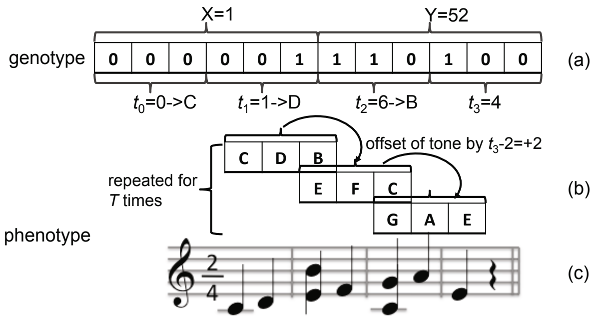


Fig. 4. The genetic description of a musical piece in the case of T=3

generation of the sound files. The real 3D sound environment was composed of a multi-channel home theater system with 7 speakers as shown in Fig. 3. A surround headphone for the home theater system with 5.1 channels can be used instead of this speaker system. We explain each part of the prototype in detail.

3.1 Genetic Description of the Individual

We assumed an evolutionary search of a musical piece as shown in Fig. 4, which is quite simple but sufficient to evaluate and demonstrate the prototype system, especially the parallel search utilizing the cocktail party effect. It also shows the genetic description of a musical piece, which is represented by a bit string with the length 12. Specifically, each genotype can be divided into 4 parts, each of which represents an integer value from 0 to 7. They determine the values of the parameters $t_0, \cdots, t_3$ respectively, as shown in Fig. 4 (a). The first three parameters determine the tones of the initial set of the three notes respectively as shown in Fig. 4 (b). The possible values of the parameter "01234567" correspond to the tones "CDEFGABC". The tones of notes in the next set are defined as those of the corresponding notes in the previous set offset by t_3-2 within the range of possible tones. This subsequent set starts to be played at the same timing of playing the last note in the previous set. By repeating this process, the T sets are generated. Fig. 4 (c) is the final phenotype of this example.

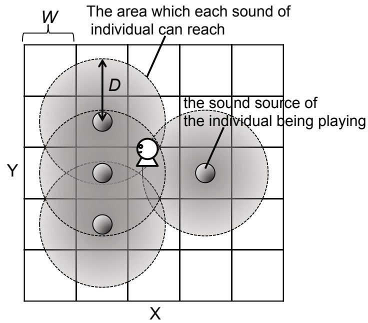


Fig. 5. An example situation of the soundscape around the user

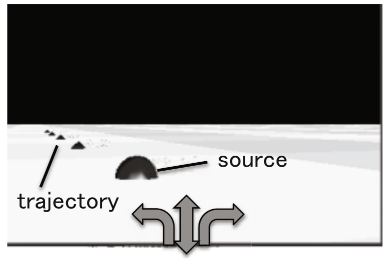


Fig. 6. A three dimensional image of the soundscape

3.2 Fitness Soundscape and Adaptive Walk

We mapped the genotypes described in the previous section into a two-dimensional space using the following simple way. We divided the bit string of each genotype into two parts, and regarded the former part as the x position $(0, \cdots, 2^6-1)$ of each genotype and the latter part as its y position $(0, \cdots, 2^6-1)$ as shown in Fig. 4 (a).

The fitness soundscape is composed of the $2^6 \times 2^6$ square-shaped areas, and each genotype (phenotype) is assigned to each corresponding area as explained above. Fig. 5 is an example situation of the soundscape around the user. The size of each area is $W \times W$ in units of Java 3D environment. When the user stands on the soundscape, at most 8 individuals on one's neighboring areas are played repeatedly in parallel. The user can determine which individuals are actually played by specifying their relative directions from one's heading by using a control panel (explained later). The sound source of each individual is placed at the center of each corresponding area. It is omnidirectional and its gain decreases linearly to 0 percent at the distance of D. In Fig. 5, the user specified that one can hear the individuals in front center, front right, front left, and rear center. However, one does not hear the sound in front left, because its distance from the user is out of the range of D. It should be noted that we do not play the individual which corresponds to the user's standing area. It is due to the fact that it can make the user difficult to localize other neighboring sounds of individuals because it is too close to the user, besides that it is not necessary for deciding the direction of evolution.

When the user has moved to the next area, the new neighboring individuals around the user's standing area are played. Thus, the user can repeatedly walk around the whole soundscape hearing and evaluating the neighboring individuals. Fig. 6 shows the three dimensional image of the fitness soundscape, which is presented to the user during adaptive walk. The user can grasp the trajectory of one's adaptive walk so far, and the relative positions of the individuals that are played now.

3.3 Functional Features for Enhancement of Adaptive Walk

So as to improve the ability of evolutionary search, we introduced the following functional features into the prototype system. The several properties of these functions can be set up using the control panel of the system shown in Fig. 7.

The adjustment of the scale of the soundscape. The user can adjust the scale of the soundscape by changing the hamming distance between the nearest neighboring genotypes, which is realized by eliminating the areas which correspond to the intermediate genotypes. By decreasing the scale ratio, the user can evaluate more different individuals at the same time, and walk toward a more distant place quickly.

The assingment of the relative positions of individuals being playing. If the all neighboring individuals are always played, there is a possibility that the user can not discriminate between them because they are too much mixed. Thus, we added the set of options that determine the relative directions of the neighboring area in which the individuals can be played. The user can adjust the total number of the individuals being playing and their relative positions from the one's heading by choosing activated individuals from the sorrounding ones in the control panel.

The random delay in the timing of play. So as to make the user easy to distinguish between individuals, we have introduced a randomly determined time interval before playing each individual.

The use of different sound types. We have also added the option whether the all individuals are played using the same sound type or are played using randomly assigned sound types. The difference in the sound types enables the user to listen to each individual more selectively.

4 Preliminary Evaluations

We have conducted the several preliminary experiments using the prototype explained in the previous section. First, we summarize basic evaluations on adaptive walk on the soundscape. By using the multiple speaker systems, we were able to localize the positions of individuals and distinguish between them even when they were played in parallel. We were also able to evaluate individuals, and walk toward the favorite ones. Thus, we can say that the user can search for favorite musical pieces based on one's subjective evaluations using this system.

Fig. 8 shows example trajectories of adaptive walk on the soundscape when the 5 different subjects searched for their favorite musical pieces. We used the settings of parameters: W=5, D=7.5 and T=4. The sounds are played with a randomly determined delay, and we adopted a unique sound type (piano) for all individuals. The relative directions of individuals being playing are front center, rear center, center right, and center left. The subjects were only allowed to use the adjustment of the scale of the soundscape.

Starting from the center of the soundscape, the subjects moved over 10-80 areas, and finally reached their favorite piece whose corresponding position were

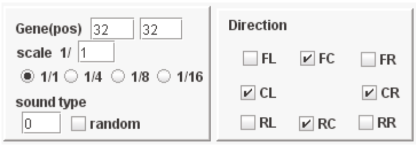


Fig. 7. The control panel of the prototype

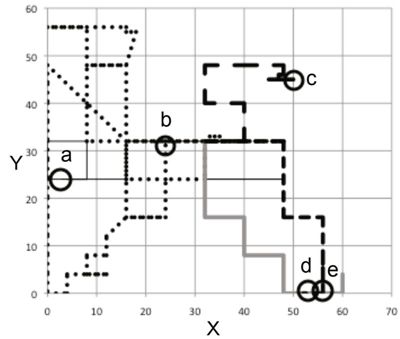


Fig. 8. Example trajectories of evolutionary search on the soundscape

Fig. 9. An evolved musical piece

indicated with a circle on the map. As the figure shows, the trajectories varied significantly, which implies that the aesthetic feeling for musical pieces of the subjects were basically different. It is also interesting that the two subjects finally reached the closer positions (d and e). Fig. 9 is an evolved sound piece which corresponds to the position c (50, 45) in Fig. 8.

It also turned out the following points with regard to the functional features. By decreasing the scale of the soundscape during early period of the search, the user could quickly reach one's favorite areas in a long distance from the initial area. It was not easy to localize the individuals in backward positions of the user compared with those in other relative positions. Thus, there is a possibility that we can improve the ability for selective listening by adjusting the number or assignment of the individuals being playing in backward positions. Also, the random delay in the timing of play and the use of different sound types made the users much easier to distinguish between individuals. However, the latter sometimes affected the intuitive impressions of the individuals strongly, and thus affected their evaluations.

In addition, a searching process on the soundscape was itself a new experience, which implies that this system can be extended to a kind of installation.

5 Conclusion

We have proposed a new interactive genetic algorithm for musical works utilizing the human abilities of localization and selective listening of sounds, which is based on adaptive walk on the fitness landscape of sounds. We constructed a prototype of the system for simple musical pieces, and conducted a preliminary evaluation of it. It was confirmed that the users were able to search for their favorite pieces by using this system. We also proposed the several functional features for improving evolutionary search.

Future work includes the more detailed evaluation of the system, the improvement of evolutionary search, and the application of this system to the interface of content selection in portable music players.

Acknowledgements

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