Interactive Evolutionary Computation: System Optimization Based on Human Subjective Evaluation

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***Abstract*— We first describe the background and technical aspects of an interactive EC (evolutionary computation). Then, we overview the research on its application in three major fields — artistic, engineering, and educational — and on human interface. We also list approximately 90 references on interactive EC for further study.**

1 Introduction

When using optimization techniques, we usually have a numerical goal and a cost or evaluation function which calculates the error between the numerical goal and the actual outputs of a system. Typical cases are control systems. When it is easier for humans to evaluate a system output than to calculate the numerical error, an alternative model of a human evaluation function is designed and used in the optimization system. For example, S/N ratio or human perception models are used to optimize/design noise reduction filters for noisy speech or images.

The human evaluation function is not easily modeled. In general, modeling becomes difficult when the system evaluation is based on personal preference or values. For example, only the user can evaluate the suitability of a hearing aid or the timbre of a synthesizer.

Interactive Evolutionary Computation (EC) is the optimization technology that uses human evaluation in the optimization systems instead of a human evaluation model. Simply stated, the interactive EC is an EC whose fitness function is replaced by a human. It is said that the interactive EC is a technology embedding subjective human evaluation *KANSEI* into system optimization; where *KANSEI* is the total concept of intuition, preference, subjectivity, sensation, perception, cognition, and other psychological processing functions.

We describe the technical aspects of the interactive EC in the next section and overview its research in sections 3 and 4. Due to space limitations, we have avoided detailed descriptions of each research, but include references to both English and Japanese papers for the readers' convenience. We recommend the readers interested in this field read the reference of [75] as well. This paper includes brief introductions to most references, though it has few Japanese references.

2 Technical aspects of the Interactive EC

The interactive EC uses two different spaces for its search. The human operator evaluates the output of the target system according to the distance between the target goal and the system output in psychological space, while the EC searches in the feature parameter space based on the human evaluation. Figure 1 illustrates this relation. Here, synthesized sound, the desired sound image, and the parameters of the synthesizer, correspond to the system output, target goal, and feature parameters, respectively. It can be said that the interactive EC is the optimization technology where the EC and a human search are cooperatively based on the mapping between the two spaces.

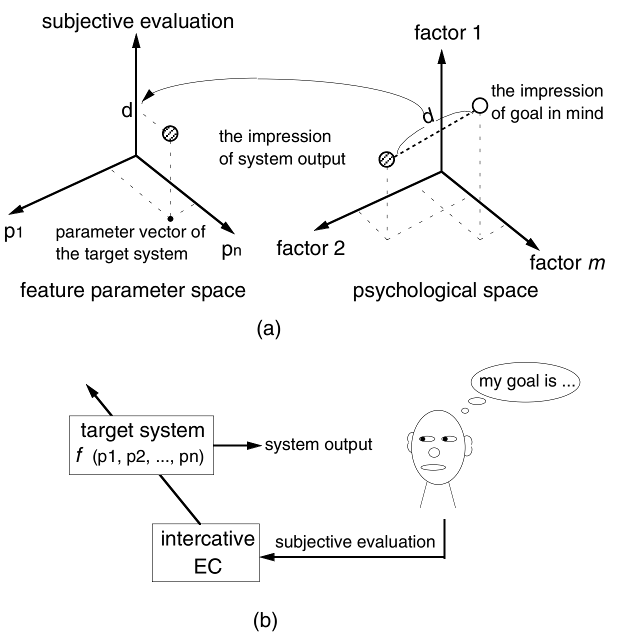

Figure 1: The EC searches in a parameter space and human evaluation in a psychological space. The evaluation of a parameter vector of the target system on a parameter space is the distance between the ideal goal in mind and the impression of the system output on psychological space.

Human operators do not always evaluate genotype or phenotype individuals directly, but rather the output of the target system realized by the individuals. For example, a human operator does not evaluate filter coefficients but the images or sounds processed by the filter.

The target coordinates (preference) and distance measure (evaluation value) in psychological space tend to fluctuate. Even if the same images or sounds are displayed to the human operator separately, his or her subjective evaluation values may fluctuate. Under such unstable conditions, we would like to search out the target in the feature parameter space that is mapped to the nearest point of the target in psychological space; this is the requirement for the interactive EC. Fortunately, it is said that the EC search is largely unaffected by noise. It is reported that the EC convergence is not practically influenced by the fluctuating evaluation in a simulation based on measured human fluctuated evaluation [69, 51].

The predominant reason why the fluctuating evaluation does not become a severe problem is that the interactive EC is not expected to converge to an exact point but to a rough area. Every point in the area is same to a human if he or she cannot distinguish them. Unlike normal EC searching, the interactive EC does not always search for one target, such as to find out a completely same face as given one. Instead, it targets several different individuals in the same impression area wheni the task is, for example, to obtain the design hints for car models in next year.

Technical problems remain. As the interactive EC cannot use many individuals and searching generations because of resulting human fatigue, we need to develop a new EC which effectively searches with a few individuals and within a few searching generations. The number of displayed individuals is determined by either the size of images which can be displayed spatially or by the capacity of the human memory for music or movies which are sequentially displayed. As with the population size, the number of searching generations is limited to ten to twenty generations at the most due to the fatigue of human operators. Several trials to solve these problems are mentioned in section 4.

To put the interactive EC to practical use, it is necessary to expand its application fields, evaluate its effectiveness in these fields, and develop interface search methods that reduce human fatigue. Also, it is necessary to evaluate the effectiveness of the interactive EC through subjective and statistical tests, because the interactive EC cooperates with a human operator. Although it may not seem easy to quantitatively evaluate the effect of the interactive EC, as in the field of creation support, we cannot expect it to become a practical technology unless we do so.

3 Interactive EC Applications

3.1 Artistic Applications

Research on image creation based on the interactive EC has been presented in art and artificial life; interactive EC-based drawing lines, such as morphological lines of insects [16, 17, 65], plant lines based on the L-system [43], and face drawing [6, 7, 46]: interactive EC-based CG, such as for creating [61, 62, 63, 64, 8, 9, 81, 82, 83, 38, 87], 3-D CG rendering of artificial life art [80], and animal and plant CG [21]. CG animated motion is also generated with the interaction with an animator [84, 85]. 3-D CG design and music allocation in a virtual reality (VR) environment use the interactive GP (genetic programming) [15, 55, 18], though their main objective is not art itself but the research of the virtual environment.

The Auto-regression model which is frequently used for time sequential analysis is used to modify the shape of the CG model [22].

Since 3-D CG is a photographic simulation, various lighting conditions can cause different CG impressions. It is difficult for most amateur CG designers who are not skilled at lighting to decide the best lighting conditions.

The interactive EC was used to optimize the position and type of light sources, luminous intensity, and color according to CG users' subjective evaluation for the impression of the given 3-D CG images [1, 2, 3, 4, 5]. Their subjective and statistical tests have shown that the lighting support system based on the interactive EC is significantly useful for CG users who have less lighting skill but not for skilled CG users.

The practical art of industrial design is also an application field of the interactive EC. Applications include the shape design of a concrete arch dam [56], suspension bridges [19], cars [31, 20], and one-piece dresses [47, 48]. Interactive EC based layout design [40, 41, 42, 24] which can be applied to several fields such as a hypercard layout on a display, GUI display design, or office layout, would be categorized in this section.

Another image application outside of graphic art and industrial design is the composing of montage pictures [13].

The interactive EC was also applied to melody production [11, 12] and rhythm production for percussion section [23]. It was used to tune the parameters of an FM sound synthesizer to create the desired timber [28].

3.2 Engineering Applications

Use of the interactive EC has recently expanded in the field of engineering [73]. It includes speech processing, hearing aids, virtual reality, database retrieval, data mining, and image processing.

A recovering filter for distorted speech was designed based on human perception, and its performance was confirmed by subjective tests [88, 89].

Prosody control is essential in speech synthesis. The interactive EC was used to control the prosodic parameters, such as pitch, intensity, duration, and tempo, and change the voice into five impressions such as *cheerful*, *angry*, and so on [58, 59, 60].

Recently digital hearing aids which adopt several signal processing techniques have been put on the market. Although they are more capable than analog hearing aids, there is no optimization method for the hearing aids except for trial and error. The main reason for this is that nobody knows precisely how another person hears. As the interactive EC can optimize systems based on human subjective evaluation, the hearing aid fitting is a good application task [49, 53].

Trials to obtain control rules for VR have been conducted. The degree of VR feeling cannot be measured but can be evaluated by a human. Kamohara et al. have tried to obtain control rules for an arm wrestling robot that let a human player feel as if the opponent were a human using the interactive EC [29, 30].

Content-based media database retrieval does not use keywords but coordinates in a psychological space. In interactive EC-based database retrieval [32, 33, 14, 37, 46, 45], EC searches feature parameters of images or music, and a human evaluates the distance between target and retrieved media in a psychological space.

Knowledge obtained by data mining methods is required to be simple and understandable, and human evaluation and modification are needed to obtain such knowledge. Terano et al. used the interactive EC to obtain marketing strategy for oral care goods from 2,000 questionnaires [26, 76, 77, 78, 27, 79]. Venturini et al. used this technique to make data distribution maps for knowledge acquisition [86]. Tabata et al. obtained identification rules for the damage patterns of stainless steel by interrupting their normal GA search and giving human evaluations every 100th generation [66].

Image enhancement is helpful and necessary for medical doctors to detect diseased tissue with speed and accuracy. Poli et al. applied the interactive GP to design image filters that enhance MRI (magnetic resonance image) and color an image which results when two echo-cardiographic images are merged into one for comparison [57].

It is difficult for beginners to determine the filtering order since the order in which the same filters are arranged results in different retouched images. Muto et al. used simulated breeding (an interactive EC with 1 bit evaluation) to determine the sequence of image filtering [44].

3.3 Education, Edutainment, and Therapy

Since the interactive EC displays several individuals, sometimes they inspire a human operator; this implies that the interactive EC is useful for stimulating human creativity. Kuriyama et al. use this characteristic of the interactive EC for a writing support system for children [34, 35, 36].

Edutainment and games have similar characteristics. NN-based moving robots for children developed by Lund et al. fit in this category [54, 39]. The connections of their NN that input robot sensor information and output movement control values evolve according to the selection of robots with better movement by children.

Pagliarini et al. developed several games including the above NN-based moving robots; they are an artificial life survival game, painting graphics based on NN evolution, and drawing faces [54]. Their drawing face software is also used for mental therapy.

4 Human–Computer Interface

Human fatigue remains the biggest problem with the interactive EC. Several trials have been proposed to reduce fatigue and have been evaluated through psychological tests.

One of these, the discrete fitness value input method, was shown to significantly reduce human fatigue [67, 68, 69, 71, 74, 50, 51].

On-line human evaluation was incorporated by GenJam [11]. Normally, music individuals must be displayed time-sequentially. One evaluation value for an entire melody is time-consuming and causes human fatigue. GenJam allows the user to perform evaluations as the jazz melody is created rather than after the entire melody is played.

Ease of human evaluation depends on the display order of individuals. If the interactive EC can predict human evaluation and display individuals based on that prediction, it may reduce human fatigue from comparison and evaluation. Predictions based on NN [72, 12, 74, 50, 52] or on Euclidian distance [46, 50, 52] were then proposed for the interactive EC.

Significant increase in EC convergence speed must reduce human fatigue. A new elitist method which approximates the searching surface using a convex curve was proposed [25] and applied to the interactive EC [74, 50].

The human operator's role in interactive EC is passive, involving the evaluation of the displayed individuals. This role may reduce human fatigue by introducing ways that directly embed the operator responses obtained during an EC search. SBART obtained from http://www.intlab.soka.ac.jp/˜unemi allows a human operator to directly modify GP trees manually during its search [81, 82, 83].

In general, human evaluation requires much more time than computer speed. Pipe-line GA uses the waiting time for other GA searches and for image retrieval [32, 33].

A similar method to tune the parameters of a fitness function with reinforcement learning was proposed to combine normal GA search and the interactive EC [27, 79].

5 Conclusion

We have described the technical features of the interactive EC and overviewed a wide variety of its research. We hope this survey and list of references interest and motivate readers so that this practical technique becomes widely used.

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