1. INTRODUCTION

We use and enjoy media content in our daily life. The use of media content suited to each user’s preference and our common feelings is very important for enriching our life. The development of information technologies and algorithms limitedly enable us to provide media content suited to our preference and Kansei.

Interactive Evolutionary Computation (IEC) [1] is an efficient method reflecting the user’s subjective preference and Kansei on the contents. IEC employs the user’s subjective evaluation instead of mathematical function of Evolutionary Computation which adjusts the impression of the warning alert by using a set of sound effectors. The target of the search is the appropriate parameters of the effectors on the Earthquake Early Warning alert. Differential Evolution (DE) is used as an evolutionary algorithm, and the efficiency of the Interactive DE for adjusting the impression was investigated through a listening experiment. In the search step, the subjects compared two alerts and selected a better one repeatedly. In the evaluation step, the subjects evaluated the created alerts and the original alert. The results showed a significant increase in fitness by the proposed Interactive DE and effective search processes.

**Keywords:** Interactive evolutionary computation, Differential evolution, Warning alert, Effector, Sound eXchange
Earthquake Early Warning alerts, thus the method is the Interactive Differential Evolution (IDE). In detail, this study employs the paired comparison-based IDE [24] where the user evaluates the solution candidates by selecting the better one from the pair, which are pair of the alerts in this study (Fig. 1).

The remainder of this paper is as follows. The next section describes the proposed IDE optimizing the parameters of the effectors for the warning alert. Section 3 shows the experimental method. Section 4 shows the experimental results. Based on the results, discussion and conclusion are performed in Sections 5 and 6, respectively.

2. PROPOSED METHOD CHANGING IMPRESSION OF SIGN SOUND USING INTERACTIVE DIFFERENTIAL EVOLUTION

This section explains the proposed IDE for adjusting the warning alert after describing DE algorithm and paired comparison-based IDE with a flow chart.

2.1 Differential Evolution

DE is known as a relatively recent evolutionary algorithm having a simple scheme, and it has been being improved by previous researches [25]. The present study employs a DE/rand/1/bin scheme, which is one of the fundamental DES [23]. DE starts its search with a population containing Np target vectors which are solution candidates in the current generation. The search is progressed by creating a new solution candidate, trial vector, for each target vector by using a differential vector between some of the target vectors. By their fitness for a certain problem, the target and the trial vectors are compared, and the winner retains as the target vector of the next generation (Fig. 2).

The paired comparison-based IDE [24] became the basic scheme of IDE, because the paired comparison of target and trial vectors is easy for a user to evaluate them without large mental fatigue. For example, it is difficult to precisely score each of the several sounds because they are a kind of time-sequential media. Furthermore, the paired comparison is directly related to the evolutionary process in IDE. Paired comparison also employed in

\[
P_{\text{rand}}(i, g) = (x_{i, g})\]
\[
u_{i, g} = (u_{i, g})
\]

The index, \(g\), indicates the generation, and \(g_{\text{max}}\) indicates the maximum generation. In the initialization, \(g=0\), values of the target vectors are randomly determined between the lower and the upper limits.

2) Mutation and Crossover: Once initialized, DE mutates randomly chosen vectors to produce an intermediate mutant for providing the trial vector. Each target vector in the current population is recombined with a mutant vector to produce \(N_p\) trial vectors, \(u_{i, g}\):

\[
P_{\text{rand}}(i, g), i = 0, 1, \ldots, N_p - 1, g = 0, 1, \ldots, g_{\text{max}}
\]
\[
u_{i, g} = (u_{j, g}), j = 0, 1, \ldots, D - 1.
\]

Uniform crossover builds the trial vectors by crossing each target vector with a mutant combining three different target vectors:

\[
u_{j, g} = \begin{cases} x_{i, g} + F (x_{j, g} - x_{r_0, g}) & \text{if } (\text{rand}_j(0,1) < C_{\text{rand}}) \\ x_{j, g} & \text{otherwise} \end{cases}
\]

The scale factor, \(F\), is a positive real number and is defined lower than 1.0. The vector indices, \(r_0, r_1,\) and \(r_2\), are randomly chosen and are all different from one another and \(i\). The generator, \(\text{rand}_j(0,1)\), returns a uniformly distributed random number within the range [0, 1]. The crossover probability, \(C_{\text{rand}}\), controls the fraction of values that are copied from the mutant. The randomly chosen index, \(j\), takes a parameter of the mutant to the trial vector.

3) Selection: If the trial vector, \(u_{i, g}\), has an equal or a better fitness value than that of its target vector, \(x_{i, g}\), it is replaced with the trial vector in the next generation: this means an update of the solution candidate. Otherwise, the target vector retains.

2.2 Interactive Differential Evolution

As described above, the evolutionary process of DE is repetitive comparisons of the vectors which are the solution candidates. IDE is an interactive type of DE where a human user evaluates the vectors instead of mathematical functions. In other words, the selection process shown in Fig. 2 including the paired comparison based on the fitness for both vectors is performed by the user.

The paired comparison-based IDE [24] became the basic scheme of IDE, because the paired comparison of target and trial vectors is easy for a user to evaluate them without large mental fatigue. For example, it is difficult to precisely score each of the several sounds because they are a kind of time-sequential media. Furthermore, the paired comparison is directly related to the evolutionary process in IDE. Paired comparison also employed in
Adjusting Impression of Warning Alert by Optimizing Sound Effectors Using Interactive Differential Evolution

2.3 The Proposed IDE Searching Optimal Set of Effectors for Warning Alert and Construction of the System

While many previous IECs dealt with sound and music as the target of optimization, the novel point of the proposed IDE is to search the optimal set of effectors for the warning alert based on the user’s subjective feelings. D-dimension of the problem means the number of the sound effectors, and the value of each dimension corresponds to the parameter of each effector, e.g., frequency of the low-pass filter. All these effectors are applied to the original warning alert. The proposed IDE is expected to change the user’s impression on the warning alert to milder. The important point of the proposed IDE is to create the warning alert that affords a milder impression to a user with transmitting an alert impression.

To construct a concrete system based on the proposed IDE, Sound eXchange [28] was used. This tool is a kind of sound platform enables the user to use various sound effectors, and it was used for audio signal processing in a previous study [29]. In this study, five effectors were picked up from many kinds of effectors. They are often used in acoustical engineering and desktop music, etc. Table 1 describes the five effectors and their ranges with upper and lower limits. The set of these parameters is the target of optimization in the proposed IDE, and the values were in real number. Some previous studies in musicology investigated psychological effect of some of the effectors. However, we cannot explain the effect of each of the five effectors employed in this study, because the melody of the alert is very short as music piece. The original sound is the Earthquake Early Warning alert officially used in Japan. This alert is composed by music melody containing dissonance (un-harmonic) keys [30]. In the IDE system, the melody was input with the piano sound of Musical Instrument Digital Interface format, and it was transformed to WAVE format.

3. EXPERIMENTAL METHOD

To investigate the efficiency of the proposed IDE, the listening experiment was conducted with search and evaluation steps. The target was the set of effectors that make the alert to be preferred. The performance of the proposed IDE was mainly evaluated by change in fitness value from the initial to the final generations. Ten Japanese subjects participated in the experiment individually and listened to the warning alerts from the IDE system via headphones. Before the listening experiment, the subjects were confirmed that they knew the Earthquake Early Warning alert used in Japan. They were not told the precise goal of our research that creates the appropriate warning alert with IEC.

3.1 Search Step

In the search step, the subjects repeatedly listened to two alerts played from the IDE system described in Subsection 2.3. The two alerts corresponded to target and trial vectors respectively, and the subjects could listen to the alerts repeatedly. After deciding the preferred one, they input the decision by themselves. The maximum number of generations, \( g_{\text{max}} \), was 14, and 8 target vectors were included in each generation. Thus, each subject compared pair of alerts 120 times. As the parameters of DE, \( C_r \) was set as 0.6, and Scale Factor \( F \) was set as 0.9.

| Effector  | Range           | Role                                        |
|-----------|-----------------|---------------------------------------------|
| Pitch     | -2000 - 2000 cent | Adjusting pitch (key) without changing tempo |
| Tempo     | 0.5 - 1.5 time  | Adjusting tempo without changing pitch       |
| Highpass  | 0 - 3000 Hz     | High-pass filter                            |
| Lowpass   | 0 - 10000 Hz    | Low-pass filter                             |
| Tremolo   | 0 - 5 step      | Sinusoidal volume modulation                 |
### 3.2 Evaluation Step

To investigate the efficiency of the proposed IDE, the evaluation step was conducted by using the created target vectors in the search step. In the evaluation step, the subjects listened to 17 alerts mainly created with the set of effectors obtained in their own search step. 8 of them were target vectors in the 0th generation, and other 8 of them were target vectors in the 15th generation: note that after finishing the evaluation process of the 14th generation, the target vectors of the 15th generation were already obtained. Comparing the fitness values of the 0th and the 15th generations show the search performance. The last one was the original alert, which was used as a reference. The sequence of them were randomized and counter-balanced. The subjects scored them with Semantic Differential method in 7-point scale (1: extremely dislike - 4: neither - 7: extremely like).

### 4. EXPERIMENTAL RESULTS

#### 4.1 Results of Search Step

Figures 3 (a)-(e) show progresses of parameters in accordance with generation. These graphs show the parameters of each of the 10 subjects from a to j: the parameters were included in the best target vector which had the maximum fitness value in the 15th generation in the evaluation step. In the result of High-pass and Low-pass filters, the trend of change in the parameters to a low value in accordance with

![Figure 3: Progress of the five parameters](image-url)
the generation. In contrast, in Tempo and Tremolo, the parameters were quite different between the subjects and were scattered into various values in the 15th generation. The parameter of Pitch had the intermediate trend which seems to gather to around 0.0.

The progress of the best target vector is important, however, it does not mean the progress of all target vectors. To show the search process of all target vectors, Fig. 4 shows a convergence of the search process which reflects the distance between the target vectors. In details, after normalizing each parameter by assuming the upper limit as 1.0 and the lower limit as 0.0, the total Euclidean distance of all pairs of the target vectors was obtained by

\[
(\text{Euclidean Distance}) = \sum_{i=0}^{7} \sqrt{(x_{ijk,d} - x_{ijd})^2}
\]  

(4)

where the Euclidean distances of the target vectors \( i \) and \( k \) were calculated. In the total Euclidean distance, a gradual decrease was observed. By comparing the 0th and the 15th generations, a smaller value in the 15th generation was observed in all subjects \((P<0.01)\).

From a different perspective, Fig. 5 shows the mean number of wins of the trial vectors: the number means updates of the vectors. In the 0th generation, the mean number of updates was almost 4.0 times, and it was a chance level because there were 8 vectors in each generation. In the 14th generation, a relatively smaller value of almost 3.0 was observed. By comparing the numbers between the 0th to the 14th generations, no significant difference was observed.

4.2 Result of Evaluation Step

As a result of the evaluation step, the mean values for the three conditions, the original alert, 8 target vectors in the 0th generation, and 8 target vectors in the 15th generation, were calculated in each subject: they were treated as the representative values of each subject. Figure 6 shows the mean and standard deviation of fitness values of the three conditions between the subjects. The highest fitness was obtained in the 15th generation, and the lowest fitness was obtained in the 0th generation. The original alert was evaluated as an intermediate level. With the multiple comparisons and Wilcoxon-test, a significant difference was observed between the 0th and the 15th generations \((P<0.05)\). There was no significant difference between conditions of the original alert and the 15th generation.

5. DISCUSSION

By observing the result of the evaluation step, the proposed IDE worked well as the search method for the warning alert, because the significant increase in the fitness value was observed from the 0th to the 15th generations. In addition, in the analyses of the total Euclidean distance and the update of the vectors, the convergence of the search area was also observed: these trends were often observed in the successful results of previous IDE studies [14, 15]. By combining the meaningful increase in the fitness and the search processes, the proposed IDE is a useful search method to create the appropriate set of the sound effectors of the Earthquake Early Warning alert.
The trends in the progress of five parameters were different between the sound effectors. In the two parameters of High-pass and Low-pass filters, the common trend of change in the parameters to relatively low values were observed. Originally, IEC is the optimization method for personal user, however, common trends and results between the subjects must be useful information. Some previous studies proposed the use of IEC on awareness from search result [31], and from this perspective, the common trend of these parameters mean that high frequency component in the alert might cause people’s dislike: the property is useful to making effector on the alert which is used in the public spaces. The common trend of the parameters should be defined by a listening experiment with participants of a wide range of ages because a previous study clarified the different audibility between ages [32]. In detail, older listeners need a higher tone level to attain a certain level of audibility when a pure tone is 2000 Hz or higher. In the other three parameters, relatively various values were observed in the 15th generation. For these parameters, the subjects’ preferences are considered to be different. The previous IDE study creating sound by using music melody showed that IDE well reflects the subjects’ individual differences [14]. Thus, the obtained set of parameters might be useful to produce the alert for personal use with mobile phones.

Although the successful search with the increase in the fitness and common trend in the progress of parameters were observed, improvements of the IDE and its system are needed, because the mean fitness value for the 15th generation was just over 4-point and was not significantly different to the original alert. To obtain a better set of effectors as a vector of the IDE, further search experiment with longer generations is needed: according to the search process shown in Figs. 4 and 5, the search was not enough and should be continued. As a problem of the IDE system, sometimes the created set of effectors produce alerts with small volume which might be caused by a narrow range of band path filter composed of similar value of High- and Low-pass filters: this problem might be related to the slow search performance and lower fitness for the 0th generation where the vectors were composed of random values. This matter was related to the fitness values of the 15th generation and the original alert, because these fitness values were relative values in the evaluation step. Meanwhile, according to the largest standard deviation of the original alert, it was obvious that some of the subjects evaluated it as 5-point or higher. This fact partly contradicts the precondition of this study based on the poor evaluations on the original alert [11, 12]. The impressions on the alert may be different in situations. Whether the original alert is evaluated higher or not, obtaining the better alert will dedicate to reduce anxiety from the alert and enrich our life. Therefore, the set of parameters used in the IDE system should be argued, especially the lower limit of the Low-pass filter.

This study aims to propose the IEC adjusting impression on the Earthquake Early Warning alert that is well-known in Japan by using the sound effectors. Too much uncomfortableness of the alert was the motivation of this study, therefore, we employed the effectors as the target of optimization and focused on changing the impression on the alert to be preferred by people. However, changing the impression to be preferred might reduce urgent feeling of the alert, although Japanese people know it as the sound of urgency by the earthquake. Therefore, in the creation of the ideal alert, we need to consider both of urgent feeling and preference. As a future study, further experiments with two fitness values of urgency and preference might be conducted: with these evaluation scales, a different trend of change in the parameters from the result of the present study will be observed because the target of the present study was creating the preferred alert using the effectors.

6. CONCLUSION

This study proposed the IDE adjusting set of the sound effectors for changing the listener’s impression on the warning alert. In the proposed IDE, the user listens to two alerts corresponded to the target and trial vectors and selects preferred one. To investigate the efficiency of the proposed IDE, the listening experiment was conducted. As the result, different trends in the progress of parameters were observed. Additionally, the fitness increased significantly from the 0th to the 15th generations. By combining the increase in the fitness and convergence of the search space, the proposed IDE has the ability to search the appropriate set of the effectors applied to the Earthquake Early Warning alert.

However, the fitness value in the 15th generation was not different to the original alert significantly. The further experiment is needed after improving the IDE and its system, especially in the parameter settings. In the further experiment, sound speaker will be used with a consideration of the real environment.

NOTES

1. This study is the extended version of a previous paper [33] which was presented in ISIS2019 & ICBAKE 2019.
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