A Study on Application of Fitness Inference Method to PC-IGA

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***Abstract*— This paper applies the fitness inference method to Interactive Genetic Algorithm based on Paired Comparison (PC-IGA). PC-IGA enables users to reduce the mental burden for evaluation by using paired comparison. Fitness inference method can decrease evaluation times on EC by using inferred fitness value instead of actual evaluation for candidate solutions based on the information of actually evaluated solutions in the past generations. However, PC-IGA does not give enough information to apply fitness inference method. This paper investigates effective application of the fitness inference method to PC-IGA through experiments with simulated evaluation. The experimental results show that fitness inference method can decrease the number of actual evaluation times by 40% comparing with the normal PC-IGA.**

I. Introduction

Recently, Interactive Evolutionary Computation (IEC) has been reported as one of the most effective method for optimization problems based on human-sensitivity. The evaluation function of IEC is given by human. IEC can find a satisfied solution for a user by repeating the following processes.

(1) A user gives the fitness value for each candidate solution.
(2) Genetic operations are applied to the candidates with the fitness values and new generated candidate solutions are indicated to the user.

IEC has been applied to a lot of fields such as design of light/music/C.G./building, medical service, industries and so on, because IEC enables us to incorporate human-sensitivity into the system [1]–[7].

The most serious problem of IEC is that the user has to evaluate candidate solutions many times. A lot of researches have tried to decrease the evaluation times so far such as acceleration of evolution [8] and fitness inference method [9]. The studies to reduce the user's burden considering easiness for giving fitness values have also been done such as improvement of user interface [10] and the study of discrete level of fitness value [11]. However, most of these researches does not reach enough reduction of mental burden in the evaluation for users. This paper discusses the evaluation method itself in IEC.

IEC currently employs rating scale method as the evaluation. In the rating scale method, some ordered categories

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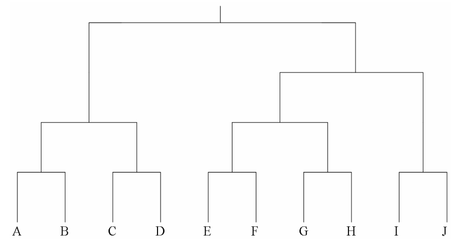

Fig. 1. Tournament Tree

("Good", "Normal", "Bad", etc.) are prepared and the user evaluates each object by selecting the category. IEC enables us to apply EC method based on the user's evaluation using quantified value by the selected categories as the fitness values of candidate solutions. However, the user has to evaluate the candidate solutions relatively comparing one another because it is difficult to evaluate them with absolute fitness values. "Giving the fitness values (selecting the categories) to candidate solutions" gives waver to a user in the decision and repeat of evaluation several times especially when the number of candidate solutions indicated by the system at once is large. Those impose a big mental burden on users.

On the other hand, paired comparison is widely known as an evaluation method which can measure slight difference of evaluation. In paired comparison, a user compares two objects and selects the better one for him/her. It is simple evaluation and easy for a user to select the better one in two objects. Then it is thought that using paired comparison for the evaluation in IEC can reduce the mental burden for users comparing with the rating scale method [12]. However in general, EC requires the order of all candidate solutions using their fitness values. If paired comparison is applied to IEC, the user would have to compare all combination of the candidate solutions. Therefore, it causes the increase of evaluation times and does not totally lead the reduction of mental burden in the evaluation for the users.

The authors have proposed Interactive Genetic Algorithm based on Paired Comparison (PC-IGA) [13]. PC-IGA enables us to apply the EC method with a small number of combination of paired comparison using tournament like Fig.1. PC-IGA realizes the genetic algorithm itself by using the characteristics of a tournament and creates some features explained in the section II suitable for IEC. PC-IGA enables a user to reduce the mental burden for evaluation on IEC.

This paper tries to apply a fitness inference method [9] to PC-IGA for more reduction of the mental burden for evaluation. Fitness inference method can decrease evaluation times on EC by using inferred fitness values instead of actual

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evaluation for candidate solutions based on the information of actually evaluated solutions in the past generations. It is expected that applying the fitness inference method to PC-IGA enables us to reduce the user's burden for evaluation mentally and physically. However, the fitness inference method needs the information of actual evaluated solutions and their fitness values. PC-IGA dose not have fitness values for solutions but only has the information of the winner in each comparison on tournament, which is not enough to infer the fitness values. This paper investigates how to apply the fitness inference method to PC-IGA through the experiment of simulated evaluation on hearing aid adjustment problem with IEC.

II. PC-IGA

This chapter explains the algorithm of PC-IGA. PC-IGA uses a tournament tree shown in Fig.1 which can keep the number of combination of paired comparison small. This paper calls vertical step "n-th round" (1, 2, 3 $\cdots N$) and horizontal one "m-th match" (1, 2, 3 $\cdots M$) in the same way with general tournament system. And the match to choose a winner is called "final". For example in the Fig.1, the most lower-left match of A with B is called "1st Round 1st Match".

The algorithm of PC-IGA is as follows.

(Step 1) Creating tournament tree depending on the number of candidate solutions.
(Step 2) Allocating each candidate on the tournament randomly.
(Step 3) Selecting the winner of each match based on paired comparison.
(Step 4) Two winners become parents and crossover is done.
(Step 5) Mutation is done to the child individuals generated in (Step 4) with the probability Pm to each locus and the losers are replaced with them.
(Step 6) Repeating (Step 3)$\sim$(Step 5) until the final.
(Step 7) (Step 2)$\sim$(Step 6) are defined as one generation. If the user is satisfied with the winner, the procedure is finished, otherwise go to (Step 2).

In PC-IGA, a tournament tree is created with the population size at first. And matches for paired comparison are selected randomly, though the candidates are allocated sequentially in Fig.1 for easy explanation. In addition, the "seed" such as the left of 3rd round and the right of 2nd round in Fig.1 is also allocated randomly not to be unbalanced when the tournament tree is created.

Next, the user selects the winner in each match by paired comparison from the 1st round 1st match to final. PC-IGA applies the genetic operations based on the result of wins and losses. The winner can be a parent of crossover, and the children generated by crossover replaced the losers after mutation is applied. These operations of crossover, mutation and selection are done until the final as one generation. The individual which has lost in final is replaced with that of the mutated winner.

Fig.2 shows an example of one generation. In the 1st round 1st match and 2nd match, the candidate solutions A and D

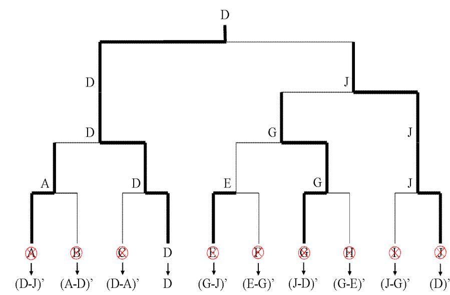

Fig. 2. 1 Generation

won. As the results, the losers B and C were replaced with the new candidate solutions generated by the crossover between A and D shown in Fig.2 as "A-D" and "D-A". In addition, ['] represents that mutation is applied to the individual. In Fig.2, for example, the candidate solution A lost in 2nd round by D, and it was replaced by one of the child individuals of winners in that round. The loser J in final was replaced by the winner D with mutation.

PC-IGA has the following features.

(1) **Evaluation by paired comparison**
It is expected to reduce the mental burden for evaluation.
(2) **Few number of genetic parameter**
PC-IGA requires only mutation rate for each locus as the genetic parameter.
(3) **Better individuals make more children**
In PC-IGA, the candidate solution reproduces its own parts of gene by crossover whenever it wins. That will be as effective as the selection/reproduction of genetic operation in general EC. Furthermore, the elite one is kept to next generation without genetic operations.
(4) **Early convergence but with diversity**
In PC-IGA, all candidate solutions except for the elite are selected accordingly. It turns out the convergence in early generation. However, the process of reproduction is not copy but crossover with mutation. It brings a certain diversity in addition to (5).
(5) **Chance for not good candidates to make children**
Each match in the tournament is created randomly, then it is possible not to lose even if it is not good enough. The effect is similar to roulette or tournament selection in general GA.

In IEC, it is too hard to tune the parameters for genetic operations because the candidate solutions are evaluated by user. Furthermore, it is desirable to converge in early generation considering user's burden, but genetic operation needs a certain diversity. Then, needless to mention the paired comparison, the features (2), (3) and (4) of PC-IGA are particularly suitable for IEC. The effectiveness of the feature (4) has been investigated through the comparison with standard GA in a preliminary experiment using benchmark function.

III. Experiment

In this section, PC-IGA is applied to hearing aid adjustment system with IEC and the effectiveness of PC-IGA is studied.

A. Hearing Aid Adjustment System

A hearing aid is widely used for hard of hearing people. It is important for hearing aids to adjust the parameters of amplification rates, which is called "fitting" and has to be done to each frequency and sound pressure. In general, the parameters are adjusted by the expert. However, the conventional fitting procedure is difficult to reflect individuality, then the fitting system with IEC which can adjust the parameter of hearing aid has been developed [14]. This paper applies PC-IGA to the IEC fitting system and investigates the effectiveness of this method comparing with the conventional one.

1) Conventional Fitting System: Fig.3 shows the interface of the conventional fitting system [9] [14]. The numbers from 1 to 20 mean the candidate solutions (sound). A user evaluates these sounds with five discrete level from bad to good. In this system, "bad" means that it is hard and/or unpleasant to hear, and "good" means easy and/or pleasure to hear. After the evaluation of twenty candidates, they are sorted according to their fitness values and the user reevaluates them one by one comparing with the next one to avoid fluctuation of his/her evaluation. These procedures are defined as one generation in this system. The user repeats these procedures until a satisfied solution for the user has been found out. The genetic parameters of this system are that cross-over rate is 80% and mutation rate is 2% [14].

2) Fitting System with PC-IGA: Fig.4 shows the interface of the PC-IGA fitting system. The buttons of "Left" and "Right" correspond to the candidate solution in each match of tournament. The user selects the better one in the two candidates. The user repeats this paired comparison until a satisfied solution for the user has been found out. The compensatory processing section (amplification process of input sound) and simulated hard hearing processing section explained in III-B were the same with the conventional system. Furthermore, the operation such as crossover (ex. one-point crossover) and mutation were also as similar as possible to the conventional one [9] [14].

B. Overview of Experiment

This paper compares PC-IGA with the conventional system described in the previous section. In this experiment, 9 normal 20's subjects are employed. This paper employs simulated hard-hearing system for the experiment, which deteriorate normal sounds through degradation filter imitation the sounds for hard of hearing people. The system gives these deteriorated but amplified sounds to subjects. The heavy degree of the degradation filter [14] is employed.

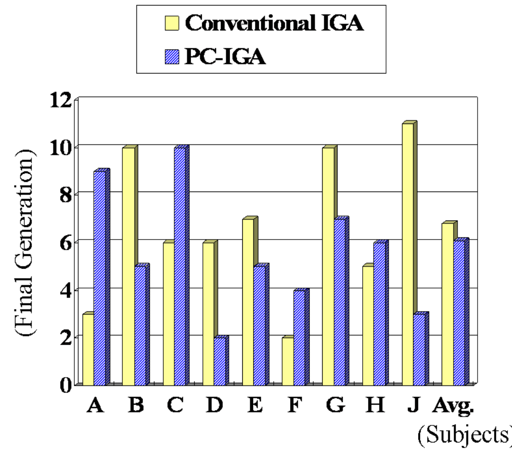

Fig. 5. Number of Final Generations

C. Result of Experiment

This paper asked the subjects which they had less burden on each generation and whole fitting between the conventional system and the proposed system. Table I shows the result of the interview. Most of the subjects said that the proposed method was less burden than the conventional one on each and total generation. The subjects answered the reason as follows:

- Easy and sure evaluation could be done because of simple comparison.
- It was little mental burden because it was not necessary to consider the other candidate solutions.
- "As the matches advance, candidate solutions improve" reduced the mental burden.
- In total burden, the conventional one was better because it had a satisfied solution at the 1st generation. (Subject A)

Fig.5 shows the number of final generations. In this experiment, it can not be said statically because the number of subjects was not many. However, there was at least no tendency that PC-IGA worsened the search performance even if it could be regarded that the rate of selection and crossover was fixed. Furthermore, subject C/F/H answered that PC-IGA was better even though the number of final generation in PC-IGA was bigger. The result shows the effectiveness of the proposed method to reduce the user's mental burden for evaluation.

On the other hand, the subjects also answered the bad points of the proposed method as follows:

- It was difficult to compare similar candidate solutions.
- It gave the feeling of inequality that bad candidate solutions went upper round when bad ones gathered.
- It was not needed that the matches between clearly bad candidates.

It is thought that the second and third answers were mainly affected by the matches between clearly bad candidate solu-

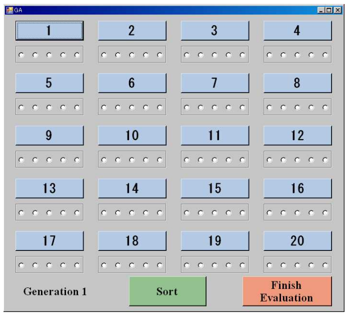

Fig. 3. Conventional IEC Fitting System

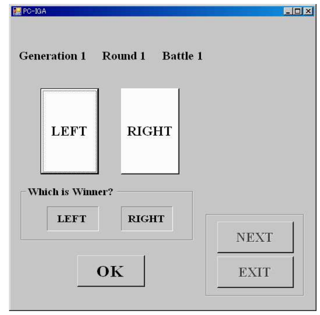

Fig. 4. Fitting System with PC-IGA

TABLE I
BURDEN FOR EVALUATION

	← Conventinal IGA			PC-IGA →	
	Very Easy	Easy	Same	Easy	Very Easy
Each Generation	0	0	0	**4**	**5**
Total	0	**1**	0	**4**	**4**

tions. The authors showed that it was possible to infer especially bad candidate solutions as bad with high probability when the fitness inference method was applied to IEC in [9]. As these results, it is expected that the user's burden for evaluation will be more reduced by applying fitness inference method to PC-IGA.

IV. APPLYING FITNESS INFERENCE METHOD

This section investigates the effectiveness of the application of fitness inference method to PC-IGA. This experiment employed simulated evaluation for the hearing aid adjustment problem with IEC. In the simulated evaluation, each candidate solution was evaluated using the similarity with a target solution of the parameter for hearing aid which was defined beforehand. In this experiment, each candidate is a contaminated normal distribution. Each candidate had a virtual fitness value based on the similarity. The similarity is defined as follows.

$$Similarity = \frac{\sum(min(f(x_i), g(x_i)) - MostMin)}{\sum(max(f(x_i), g(x_i)) - MostMin)} \quad (1)$$

In equation (1), "MostMin" means the smallest value in the two distributions. The fitness value was used just to judge which the winner was, and only the information of the number of advanced round were stored into the database for the fitness inference method. The size of database was fixed to every round and updated by new information and old one was deleted for each round. The number of individuals was 16 and the number of generation was 30 for one trial. This experiment shows the average value in 100 trials.

A. Investigation of Applied Round

This subsection investigates which round the fitness inference method should be applied to. First, it investigated the change of fitness value to the number of actual evaluation times. Two cases were compared with normal PC-IGA; the inference method was applied to (1) the matches at first round of PC-IGA, (2) that at first and second rounds. The hearing aid adjustment system with PC-IGA finds out a solution satisfied for the user usually in around 10th generation (the number of evaluation is 150 times) when the fitness inference method is not applied. Then the comparison in this experiment uses the fitness value 0.81 as a standard of end condition which is the value of the normal PC-IGA acquired at 150th evaluation times (Fig.6).

In Fig.6, "(1) 1st Round" means the transition of fitness value in the case that the winner in every match of 1st round is selected based on the inferred fitness value and actual fitness values are used for the matches after 2nd round. "(2) 2nd Round" means that the inference is done until 2nd round. The number of evaluation times on "1 Round" was decreased by 30% comparing with the normal PC-IGA. On the other hand, "(2) 2nd Round" does not have many actual evaluation times and it could not reach the fitness value 0.81 within 30 generations. However, the figure shows the saturation of fitness value of "(2) 2nd Round", and it is not expected that it can reach the fitness value 0.81 within 150 evaluation times.

Table II shows the number of losses for the actual elite candidates by the fitness inference method, and Table III shows the ratio of inference error (actual winner candidate was inferred as the loser) in all inference. In both the tables, the inference method until 2nd round shows worse performance. In addition, it can be also the reason that too much inference prevented the database from updating. From these results, when it applies the fitness inference method to PC-IGA, it is thought that the application to 1st round is the most effective.

Fig.7 shows the inference accuracy for the every difference of actual/inferred fitness values in "1st Round". In Fig.7,

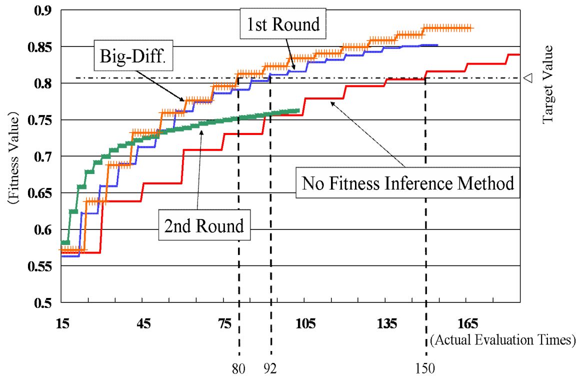

Fig. 6. Fitness Value to Evaluation Times

TABLE II
NUMBER OF LOSSES FOR ACTUAL ELITE

	1st Round	2nd Round	Big-Dif.
Error Times	6.20	12.9	3.44

the difference of inferred value was normalized on each generation. Fig.7 shows the fitness inference method could infer with high precision that the difference of fitness value was big/small. Furthermore, there is a tendency that the difference of fitness values is bigger, the inference accuracy becomes higher. As the results, it will be more effective to apply the fitness inference method to the match inferred that the difference of fitness value is big.

B. Investigation of Applied Match

This subsection investigates the inference method described above. In this paper, the inference method for big difference match is called "Big-Dif.". In this experiment, "big difference" of inferred fitness value is defined as follows:

$$Difference > \sigma \quad (2)$$

σ is the standard deviation of inferred fitness values at the generation. Furthermore, the actual fitness value is used for every final no matter how much the difference of inferred fitness values is.

Fig.6 shows that the number of evaluation times was decreased by 40% comparing with normal PC-IGA. Table II and Table III also show the higher performance of Big-Dif. method. In addition, Big-Dif. can be combined with the other method shown in the previous subsection, for example, the inference method is applied to all matches on 1st round and to the matches that the difference of fitness values is big after 2nd round. It will be also effective to change the threshold of equ.(2) in proportion to the rounds.

V. CONCLUSIONS

This paper introduced the effectiveness of Interactive Genetic Algorithm based on Paired Comparison (PC-IGA). This paper applied the fitness inference method to PC-IGA and investigated the effectiveness through the experiment with simulated evaluation. The experimental results showed that the fitness inference method could decrease the number of actual evaluation times by 40% comparing with the normal PC-IGA. As the future work, the experiment by subjects will be done for more investigation.

TABLE III
RATE OF INFERENCE ERROR

	1st Round	2nd Round	Big-Dif.
Error Rate	21%	28%	12.9%

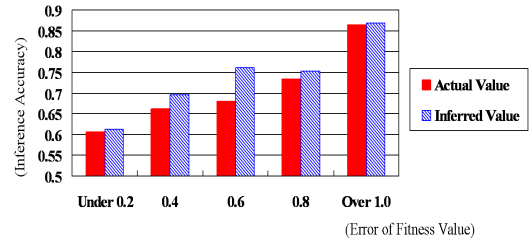

Fig. 7. Inference Accuracy for Every Difference of Fitness Value on Each Match

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