Global Asynchronous Distributed Interactive Genetic Algorithm

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Abstract— **We have already proposed Parallel Distributed Interactive Genetic Algorithm(PDIGA) that enables Interactive Genetic Algorithm(IGA) to be done at the same time by two or more people. In PDIGA, the synchronization of the generations is necessary among the subpopulations or users. Therefore, PDIGA is not appropriate for the situation with a large number of people in separate areas. In this paper, we propose Global Asynchronous Distributed Interactive Genetic Algorithm(GADIGA) as an algorithm for creating better design solutions with many people without synchronization. It is found that the asynchronous evolution is effective for making satisfying design solutions with the use of a database of elite individuals. Moreover, it is found that the users can generate more excellent design solutions by repeating the design process because better elite solutions are accumulated in the elite database. For two groups with different sensibilities, it is found that the exchange of design solutions between the groups is less than the one in the groups, but the exchange between the groups plays an important role. From the experimental results, GADIGA is found to be effective for creating better design solutions with many people in separate areas.**

I. INTRODUCTION

In recent years we have seen in such areas as product design the increasing importance of the level of sensibility that enhances such added values as design onto engineering scale. In sync with this, the engineering research with sensibility has drawn attention. In similar cases analytical methods would often be conventionally employed to integrate the modeling of the human evaluation system. However, such modeling of evaluation is extremely difficult as it depends heavily on personal preferences. To this end, a method that integrates human evaluation into the optimization system and allows computer optimization based on personal evaluations is then devised.

In this way, as an optimization method that is based on the interaction between human and computer, and subjective human evaluation, the Evolutionary Computing (EC) becomes Interactive Evolutionary Computing (IEC). One technique of the IEC method is the Interactive Genetic Algorithm (IGA)[1], and utilizes Genetic Algorithm (GA) [2] in EC technology. The authors have previously proposed the use of the Parallel Distributed Interactive Genetic Algorithm (PDIGA) that would allow a number of people to carry out this IGA [3]. It is found that by allowing several people to use PDIGA users are affected by the sensibility of other users, leading to the support of users' individual ideas.

With PDIGA users are able to promote individual advancement while keeping synchronicity within each generation. However, in the event that the number of users exceeds the set value, it is difficult for users to obtain synchronicity. For instance, if 1000 people utilize PDIGA, the time lag necessary for synchronicity between users will increase dramatically. In addition, it is equally difficult to obtain synchronicity even if the users are in physically separated places. While the effectiveness of PDIGA that implements multi-user collaboration has already been shown [4], due to the aforementioned limitations, PDIGA is rendered inapt for multi-person and wide-area use.

This research proposes the Global Asynchronous Distributed Interactive Genetic Algorithm (GADIGA) as a method for solving time and spatial limitations in PDIGA and stimulating ideas among a large number of users over a wide area without users being conscious of synchronicity. Also this research verifies its effectiveness. With GADIGA each user's Elite Individual (the unit with the highest user evaluation) is kept in the database, and by appending that to the candidate of other users' parent individuals, it is possible to implement asynchronous idea support among the users. Furthermore, the structure of the proposed system makes it possible to distribute servers and reduce the load, making it possible for multi-user participation.

Although there have been a number of proposals for a collaboration system within an asynchronous distribution environment, they mainly focused on the communication between specialists remote from each other [5]. As a result, these researches were not meant for use by a large number of average users. As IGA is used in GADIGA, it is possible for a large number of average users without specialist knowledge to collaborate within an asynchronous distribution environment.

II. PARALLEL DISTRIBUTED INTERACTIVE GENETIC ALGORITHM

A. With Interactive Genetic Algorithm

With Interactive Genetic Algorithm (IGA), both genetic operation in GA and human evaluation as artificial judgment are used to search for solutions. In other words, the evaluation in the GA process is done by human.

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B. Parallel Distributed Interactive Genetic Algorithm

Parallel Distributed Interactive Genetic Algorithm (PDIGA) is a method that extends IGA into the parallel distribution model [3]. With PDIGA it is possible to integrate design solutions into IGA processing by allowing communication of elite individuals per generation between computers. This exchange of design solutions is known as migration. With this migration operation a user can get to know other users' elite individuals with different sensibility. Through this the sensibility of users is stimulated and concepts are supported. Furthermore, since it is possible to reflect in solution search the sensibility of a number of people with PDIGA, there are possibilities for the creation of new ideas. It is considered that with PDIGA using computers connected via a network, it is viable to draw out the sensibility of a number of users.

C. The Limitations of PDIGA

As mentioned in II-B, by utilizing PDIGA the design solution of other users has an idea-supporting effect for users [6]. However, there are given limitations of PDIGA as follows.

- Time limitation
  When creating design solutions with PDIGA, users communicate synchronously. As a result, the increase of the number of users means longer time lag necessary for synchronization. If we consider the stress of the users, then utilization of PDIGA by a number of users exceeding the limited number would not be easy.
- Spatial limitation
  For synchronization with PDIGA it is necessary for users to communicate with each other from their locations and for all users to confirm with each other the end of the evaluation of the unity in that generation. As a result, when a number of users are in separate locations, the amount of time for synchronization will become significantly longer.

Ways of solving the above limitations of PDIGA were examined. By solving the limitations, we can anticipate more idea-supporting effects and thereby expect further advancement in the optimization of solutions.

III. Global Asynchronous Distributed Interactive Genetic Algorithm

As mentioned in II-C, as with PDIGA synchronization is necessary between users, multi-user utilization is not easy. To solve this problem, it is then necessary to implement IGA to exchange solutions with a number of users by utilizing the database.

In order to distribute the load as shown in Fig.1, the topology of inter-user asynchronous distribution model was devised. In addition, due to the characteristics of users made possible through connection with several servers, it is also possible to create particular characteristics for each server.

In order to realize the topology such as the one shown in Fig.1, in this research we are proposing the Global Asynchronous Distributed Interactive Genetic Algorithm (GADIGA) as a method extending IGA into the global asynchronous distribution model.

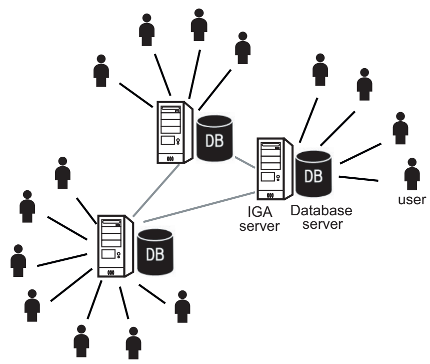

Fig. 1. Diagram of Global Collaboration Concept for the User Asynchronous Distribution Model

GADIGA saves the elite individuals (the unit with the highest user evaluation) of participation users in the database server. In this research the gathering of elite individual information shall be called the elite pool. In addition, the appending of elite individuals of other users in the elite pool to a parent individual candidate of the population that implements its own genetic operation shall be referred to as the migration within GADIGA.

Through communicating between servers and renewing the information of each elite pool, GADIGA makes it possible to realize asynchronous solution search among users. Therefore GADIGA is capable of multi-user collaboration.

The flowchart of GADIGA is shown in Fig.2. Initialization, Selection, Crossover and Mutation are the same as for the GA. The characteristic processes of the GADIGA algorithm are Read elite individuals, Display individuals, Evaluation and Write elite individuals. These will be shown below.

- Read elite individuals
  In this process several units of the elite individuals of other users are obtained through random selection from the elite pool. The inclusion of such units obtained from the elite pool as genetic operation targets is called the migration. Consequently, the units obtained from the elite pool shall be called the migration candidate units.
- Display individuals
  This process presents the units obtained from the elite pool and the subunits of the next generation. For the 1st generation, however, it presents the units obtained from the elite pool and the units generated from initialization.
- Evaluation
  This process is where users evaluate the subunits and the migration candidate units. Evaluated units will become targets of genetic operations (Selection, Crossover, and Mutation).
- Write elite individuals
  This process saves the elite individuals selected through the evaluation process in the elite pool.

Once the users assess that after the repetition of these

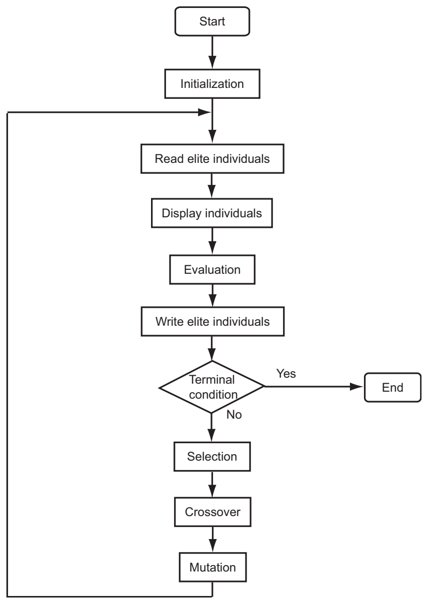

Fig. 2. Flowchart of GADIGA

processes a satisfactory design can finally be made, the operation will terminate.

IV. Experimental Design System

A. Problems used in the experiments

As a problem using GADIGA, the 'Tricolor Flag Design Problem' was devised for this research. As shown in Fig.3, this problem is concerned with the coloration of the top, middle and bottom parts of the flag. For each color the HSB color system is employed to show the 3 elements Hue, Saturation and Brightness [7].

The purpose of this problem is to create a final design by evaluating each of the designs presented by users based on a given concept.

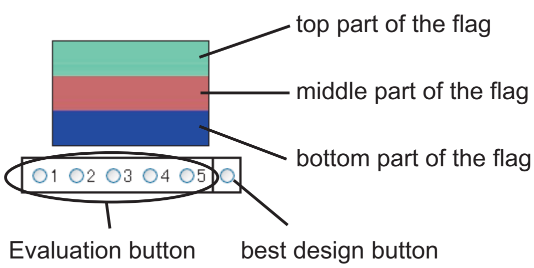

Fig. 3. Presentation of a Unit in the Tricolor Flag Design Problem

For the experiment the concept 'Flag of an Island Nation in the Mediterranean' was set. By adjusting to see how the elements in this concept would fit, each participant was to create a final design after having given evaluations of all the designs in 5 stages.

B. Interface of Presentation

The number of units presented at once was set to 16. The interface of the tricolor flag design system is shown in Fig.4. The top 4 units shown in Fig.4 are the elites of other users obtained from the elite pool and are the migration candidate units. The remaining 12 units are subunits generated by the genetic operation. The initial units are randomly created with random numbers.

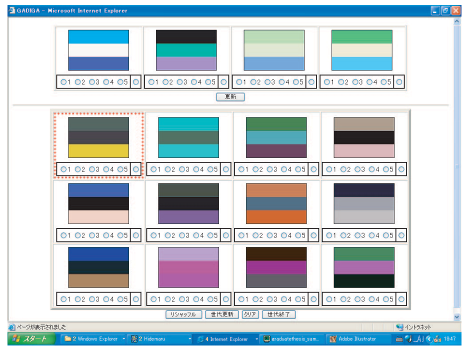

Fig. 4. Presentation Interface of GADIGA

V. Verification Experiment

An experiment was conducted to verify the validity of GADIGA as a method to stimulate the creation of concepts among users globally without being conscious of synchronicity.

A. Outline of the Experiment

For the experiments 46 people were asked to participate and they each had to create a tricolor flag by operating the GADIGA applied tricolor flag design system. Users were asked to decide on the final design when reaching the 20th generation. Of the 46 participants 23 were male students from the Department of Knowledge Engineering and Computer Science at Doshisha University (hereafter referred to as male students), and 23 were female students from the Department of Information and Media at Doshisha Women's College (hereafter referred to as female students). These 2 groups were asked to connect to two different servers and the experiments were carried out as follows.

1) Friday, June 17, 2005
   Each participant independently carried out IGA once. The designs created with this preparatory experiment were decided as the initial solution of the elite pool using GADIGA.
2) Saturday, June 18, 2005 - Wednesday, June 22, 2005
   The participants were each asked to conduct GADIGA twice independently at any time during the 5-day experiment period. During this period the exchange of elite individuals was done within the groups, but not between the male and female student groups. The two experiments during this period are chronologically listed as L1 (Local-1) and L2 (Local-2) respectively.
3) Friday, June 24, 2005 - Tuesday, June 28, 2005
   Participants were again asked to conduct GADIGA twice independently at any time during the 5-day experiment period. As the experiment was conducted

with communication between two servers, during this period the exchange of the elite individuals from the male and female student groups was simultaneously conducted with the exchange of the elite individuals within the groups. The two experiments during this period are chronologically listed as G1 (Global-1) and G2 (Global-2) respectively.

B. Result of the Experiments

1) The level of satisfaction of design creation: After the final design was made the participants were asked to give their satisfaction ratings using a 5-level scale. Fig.5 shows the mean value of satisfaction of the designs created by each group. 5 denotes the highest level of satisfaction, while 1 denotes the lowest level of satisfaction. As can be seen, there was a tendency of higher rating of satisfaction.

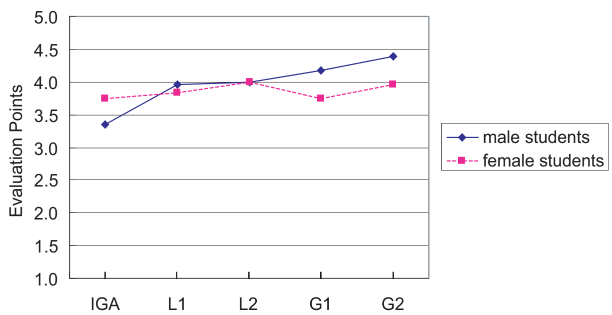

Fig. 5. User Satisfaction Level

2) Evaluation of the final designs: After the termination of the 5 experiments, the participants were asked to give their evaluation of the final designs. They were asked to give preference to the designs made during the 5 experiments, with 5 being the highest point and 1 the lowest. Fig.6 shows the average of all participants. It is clear that the more experiments were conducted so did the evaluation increase for the designs made using GADIGA.

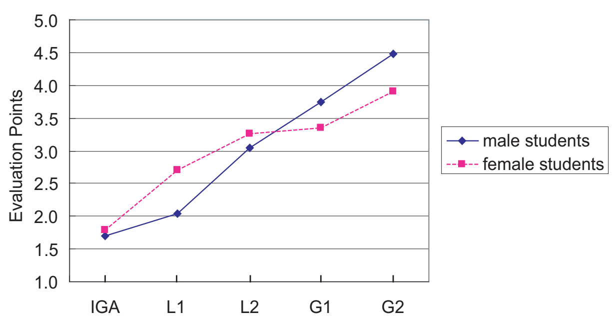

Fig. 6. User Evaluation for the Best Design

3) Frequency of Idea Integration: Here, giving their highest ratings for the elite solution of other users during the experiments, in other words, evaluating other users' solutions as the best one was defined as "idea integration". Table I shows the frequency of idea integration obtained during the experiments. The number is divided largely into the male students group and the female students group. Furthermore, under both groups are two more categorizations of the frequency: the frequency of idea integration within the group, and the frequency of idea integration with the other group. For L1 and L2 as there was no exchange of solutions with the other group, the number is non-applicable.

TABLE I
FREQUENCY OF IDEA INTEGRATION

	Male Students		Female Students	
	Own Group	Other Group	Own Group	Other Group
L1, L2	97	-	128	-
G1, G2	48	41	65	27

With this it is clear that for G1 and G2 the frequency of female students selecting the elite solutions of the male students, which was 27, was much less than that of the male students selection of the elite solutions of the female students, which was 41.

4) The transition of Idea Integration: Fig.7, 8, 9, and 10 indicate the final designs by all users within L1, L2, G1 and G2. From the final designs we were able to confirm designs that supported the concept of the majority of participants. Of the 5 experiments, the final design, the orange/white/blue-colored tricolor flag which made the most characteristic migration, is marked ◯. The designs of L2 were influenced by the idea integration of this design made in L1 and it is clear that it spread among the male students and among the female students of G1. In addition, this design evolved in G2 to become a yellow/white/blue-colored tricolor flag, and spread among both male and female students.

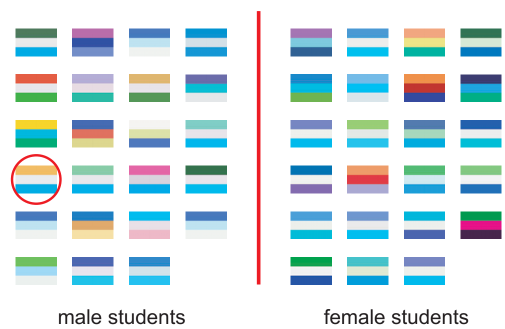

Fig. 7. Final Designs of All Users in L1

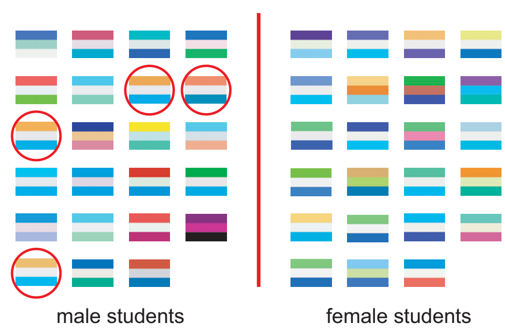

Fig. 8. Final Designs of All Users in L2

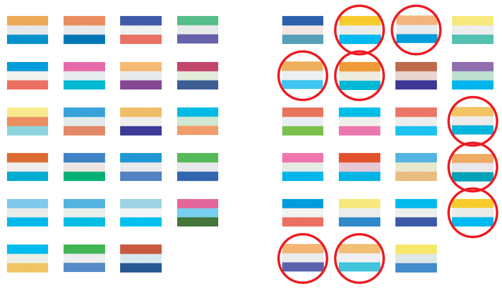

Fig. 9. Final Designs of All Users in G1

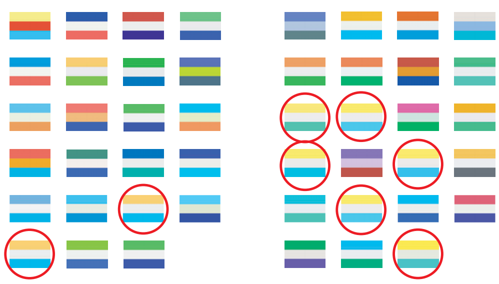

Fig. 10. Final Designs of All Users in G2

C. Discussion

1) The level of satisfaction of design creation: From Fig.5 we can see that there was a relatively higher tendency of satisfaction and we can determine that by using this system we can create satisfactory tricolor flag designs. Through this it was clear that the asynchronous evolution within a number of sub populations can create satisfactory design solutions.

2) Evaluation of the final designs: From Fig.6 we can see that as the number of experiments using GADIGA increased so did the level of evaluation. While this can be attributed to the familiarity with the use of the system and the creation method of designs, it is likely that it is due to the fact that as the number of experiments increased, excellent elite solutions were being saved in the elite Pool. In this way, it is clear that as the elite solutions of many users are stored, it is possible to create better design solutions by repeating the design creation process.

3) Frequency of Idea Integration: We can see in Table I that compared with the frequency of the selection of the elite solutions of female students by male students the reverse was much less. In other words, while many male students may like the designs created by their female counterparts, it was not so the other way. That is to say, there was a discrepancy in the sensibility of the two groups; hence we can see that, compared with the female students' idea support for male students, it was less the other way.

4) The transition of Idea Integration: In Table I we can also see that idea integration was frequent within the groups. Meanwhile, in Fig.7 and 8, we were able to confirm the idea integration of the orange/white/blue tricolor flag made in L1. With this we can say that by using GADIGA it is possible for collaboration among groups of relatively similar sensibility.

Although it became clear with section V-C.3 that the sensibility of the two groups was rather different and that there was little idea integration from the male students group to the female students group, from what we can see in Fig.8 and 9, there were many designs in the G1 female students group that were greatly influenced by the male students group in L2. This can be attributed to the shift of one female student, having received the idea integration from male students, onto other female students. In other words, when solution exchange with a group having less sensibility were carried out, if a solution exchange were done once then it will spread among the users of the group that has carried out the solution change. In G2 the yellow/white/blue tricolor flag design evolved and spread among both male and female students. Following this, the evolution continued and further solution exchange was implemented. From these results we know that utilization of GADIGA makes the collaboration among groups of different sensibility valid.

VI. Conclusion

In this research, the Global Asynchronous Distributed Interactive Genetic Algorithm (GADIGA) is proposed as a way to stimulate concepts among a number of users globally without being conscious of synchronicity, as well as verifying its validity. The results of the experiments show that the asynchronous evolution among several sub populations can create satisfactory design solutions. Furthermore, as the elite solutions of many users are stored, by repeating the design creation process it is possible to create much better design solutions. In the case where there may be a group with a different sensibility among the users, in addition to the frequent solution exchanges within the group, the exchange of solutions among different groups would also occur to a certain extent, thus making it valid for creating excellent solutions. From these points we can say that GADIGA is valid as a method for stimulating concept among users globally without being aware of the synchronicity.

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