Design Support System with Consensus Building of Multiple Participants by Interactive Evolutionary Computation

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Abstract. This study proposes the design support system with consensus building for multiple participants by using Interactive Genetic Algorithm. Two kinds of steps such as evaluation phase 1 and 2 are introduced in the system in order to acquire smoothly aggregation of individual affective image to the participants' common satisfied designs. From the experimental results by the prototype system for female's high school uniform, the effectiveness of the proposed methodology is confirmed. These results not only extends feasibility of Interactive EC, but also opens brand new way of collaborative design methodology.

Keywords: Human Centered System, Interactive Genetic Algorithm, Affective Design

1 Introduction

In the actual field of designing products, not only the design by designer oneself, but also design by several number of designers are ordinarily performed. There are many merits in the cooperation among designing products in order aiming at fine/outstanding products. For example, the products can be reflected many design ideas from the others, which does not come in mind if the designer is only by him/herself, or, the balance of designs from many points of view by many designers are considered and reflected toward products. On the other hand, the disagreement/conflict among designers may sometimes arise by the divergence of design policy. Therefore, it is not a small problem that how we can smoothly build the consensus among multiple participants for final designing.

The Interactive Evolutionally Computation is introduced in the field of generation products such as art, products shape designing, music composition, and so on [1]. EC is the meta-heuristic methodology, which searches and optimizes combination of attributes of solution, by simulating selection and evolution of genome information of lives. The Interactive EC introduces users' subjective affective evaluation for fitness evaluation of solution candidates. Until present day, the Interactive EC approach was assumed to acquire solutions, which reflect the single user's affective image toward candidates. In most case, the number of user of the systems was premised to be one.
However, nowadays there are some studies such that the introduction of IEC for multiple users. Sakai et al. proposed a support system to find coordinate of apparels by multiple people [2]. The system suggests potency of making consensus of solution by using votes of participants as subjective evaluation. However, currently, the same kind of attempts are not so many [3][4].

Based on the backgrounds, this paper argues consensus building among participants in the Interactive EC approach, with proposing an interactive design support system with several number of participants/designers.

2 System Requirements by Decision Making and Consensus Building

In general, human have different sense of values and sometimes they conflict interests. If some designers are participate in a certain ground of product design, they have to concord different kinds of opinions and aggregate many design candidates toward one. In order to accomplish it, the “consensus building” among participants is needed. From the Noguchi’s studies [5], the consensus building is divided into 3 types of relationship between the subject and object among participants.

• Type 1) WIN-LOSE relationship: The subject wins (chooses win), and the others lose. One of the most typical cases is the majority decision by voting. This type is effective in the case the participants have limited time. However, this does not really build consensus.
• Type 2) LOSE-WIN relationship: The subject loses (chooses lose), and the others win. This type is called concession or compromise. This type is not a really consensus building either, because even if a subjects' opinion can be fine, it will be abandoned by the other opinions.
• Type 3) WIN-WIN relationship: Both subject and objects bring good opinions to the others, and agree each other. This type of consensus building is the most ideal.

Nowadays, the word “Facilitation” is noticed as the ability of consensus building in some meetings [5]. In the meeting, there needs to exist a person “facilitator”, which has a role in order to take control and aggregate opinions quickly. He/she encourages participants by claiming many opinions, and appropriately arrangements and disclosures opinions to the participants for consensus. Therefore, the most expected ability for the facilitator is to finish meeting with the consensus type 3, the WIN-WIN relationship.

By the way, the decision-making by designers is important for a fine products designing. In the case if the designers are many, we have to consider how they make decision by themselves among many others’ opinions or design candidates. In order to acquire satisfied results among all of the participants, it is important to appropriately assign the timing of each decision making in each participants. For instance, if the time is spent too much for a specific small objective, investigation of larger objective may
not be put effort. Therefore, we made it importance for consensus building by considering appropriate execution cycle between small decision-making and information aggregation and disclosures.

Based on these considerations, the purpose of this study is to propose design support system, which acts a role of good facilitator in the plural number of designers’ participants. In order to realize this, the system requires are proposed as the following items.

- All participants can smoothly express their intentions through the interaction, without any interruptions.
- Participants can also receive tendencies of all other participants' opinions quickly and easily to understand, and can react their opinions.
- If possible, participants can add definite reasons why they made such decisions, and the reasons are used for better aggregation of opinions.

Moreover, we consider the development of information communication technology with handheld consoles such as smartphones. Therefore, the proposed system needs to perform design with essential and simple interaction among participants, even if they are not at a certain place but remote locations.

3 System Architecture

3.1 Overview of the System

Fig. 1 shows overview image of the proposed system. Participants/users of the system is assumed to design beginners, and plural number of users can participate. They cooperate in order to acquire commonly satisfied design, which has an affective image they decided firstly. The system automatically generates design candidates, which correspond to individuals/chromosomes of the Interactive Genetic Algorithm, and each loci of the chromosome represents to attribute value information of each design candidate. Some kinds of design variation candidates are presented toward users, and users view them with their own handheld terminal devices such as smartphones. The users evaluate them and make decisions with placing “like” chips to vote liking candidates. Based on the evaluations, the system performs GA operators to the chromosomes, and presents newly generated candidates toward users again.

![Fig. 1. Outline of the Proposed System](image)
3.2 Detailed Flow of the System

Fig.2 shows the detailed flow of the proposed system. The participants/users start with common target/objective with affective image of the design, and perform the following procedures until they acquire design satisfying the objective. The evaluation phase 1 and 2 in the procedure are described in detail in the following sections 3.2.1 and 3.2.2, respectively.

- (a) The system automatically generates several kinds of design candidates by chromosomes of IGA.
- **Evaluation phase 1:**
  - (b) The system presents design candidates to all participants/users through each user interface such as smartphone application.
  - (c) Each user perform subjective evaluation toward candidates, based on his/her own affective impression and their designing purpose.
- **Evaluation phase 2:**
  - (d) The system shows each user's evaluation results toward each user.
  - (e) Each user see other users' evaluated candidates, and evaluates again.
- (f) After all of the users' evaluations, the system performs GA operators toward the candidates based on users' evaluation results.
- (g) New generation candidates are generated and presents to users again (go to phase (b)).
- (h) If users find a candidate, which satisfies the objective affective image, they can place “satisfied” chip to the candidate in the phase (c). If all users place the satisfied chip, the repetition is finished and candidate(s) placed many chips is (are) acquired as chosen design(s).
3.2.1 Evaluation Phase 1

The left side in the Fig.3 shows the image view of the user interface in the evaluation phase 1. Each user has some number of “like” chips. The users evaluate candidates and make decisions with placing chips to vote liking candidates. The evaluation phase 1 is considered as each user's representing intentions to the other users. Based on the references backgrounds, in this phase, we made it importance that users can no longer be interrupted their intentions by the others' opinions.

The “meta-proposal” system is proposed, considering effectively/successful aggregation of opinions to acquire designs rapidly, and for WIN-WIN type aggregation. The meta-proposals space is shown in the right side of the interface. The meta-proposals are freely inputted texts by users themselves. Users can add opinions that are more concrete or evaluation plans about why/how they evaluate candidates based on, such as “I like blue designs.”, “I want rounded designs”, and so on. Users can not only vote candidates, but also express why/how they evaluate so. Moreover, the users can also place “like” chips toward each meta-proposal by other users, to express agreement of the others' opinions.

![Fig. 3. Example of User Interface in Evaluation Phase 1 and 2](image)

3.2.2 Evaluation Phase 2

After all users' evaluations in the evaluation phase 1, the phase is moved to evaluation phase 2. The right side in the Fig.3 shows the image view of the user interface in the phase. All of the users' voted chips are shown through each user's display. The chips are also displayed the user number, showing which user voted. In the phase 2, users also have “like” chips and they can vote candidates or meta-proposals considering whether they agree others’ opinions.

3.2.3 Features of the Proposed Evaluation Methodology

The aggregation of opinions among multiple participants is not so easy in the actual social landscape. Therefore, this study proposed the methodology of division two evaluation phases for multiple participants for Interactive EC. The evaluation phase 2 is specifically divided from the evaluation phase 1. By dividing evaluation phases into two, users can evaluate candidates without interruption by the others, and smoothly express their opinions to the others without dissatisfaction. This kind of natural human
consultation based evaluation methodology is rather new feature in the field of Interactive EC. Moreover, the “meta-proposal” system is proposed to expect more effective attainment of WIN-WIN type aggregation of opinions.

4 Evaluation Experiments

4.1 Prototype System

We implemented a prototype system by using the proposed methodology to confirm the effectiveness of proposed system. Design subject is set as female high school uniform in Japan. Table 1 shows the settings. The design genotype and phenotype have the categories of design such as 1) outer wear, 2) inner shirt, 3) necktie, and 4) skirt as shown in Fig.4. Each category also have several kinds of attributes, and each locus are assigned an integer value representing design varieties. The combination size is 17,280. In the prototype system, we constructed the system by PC as shown in Fig.5. In the evaluation phase 1, participants are evaluated candidates through interface one by one (with no seeing the others’ results). In the evaluation phase 2, we allow participants that they directly talk each other about why they evaluated candidates in the phase 1, which is the alternative experiment of omitting the meta-proposals.

Table 1. Settings of a Prototype System for Experiments

<table>
<thead>
<tr>
<th>Name</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Subject</td>
<td>High School Uniform (Female)</td>
</tr>
<tr>
<td>Design Objectives /Situation</td>
<td>“Uniform for School in Snowy Country” (Group A, C), “Uniform for Technical High School” (Group B, D)</td>
</tr>
<tr>
<td>Num. of Candidates in each gen.</td>
<td>12</td>
</tr>
<tr>
<td>Num. of Chromosomes in Pool</td>
<td>120</td>
</tr>
<tr>
<td>Crossover</td>
<td>One-point Crossover (80%)</td>
</tr>
<tr>
<td>Mutation</td>
<td>Replacement 1 Locus (10%)</td>
</tr>
<tr>
<td>Termination Condition</td>
<td>10th Generation</td>
</tr>
<tr>
<td>Setting in Evaluation Phase 1</td>
<td>Subjects Choose 1-3 Candidates</td>
</tr>
<tr>
<td>Setting in Evaluation Phase 2</td>
<td>Subjects Choose 1-5 Candidates</td>
</tr>
</tbody>
</table>

![Table 1. Settings of a Prototype System for Experiments](image)

**Fig. 4.** Genotype and Phenotype of the Prototype System
4.2 GA Operators

The prototype system executes the following GA operators: (a) Ranking selection: each chip has score \( s \), and \( s \times \text{number of voted chip} \) are copied as parent chromosomes. Score \( s \) is assumed to be different between the evaluation phase 1 and 2, such that the influence of chips in phase 2 are larger than phase 1. (b) One-point crossover: randomly chosen parent chromosomes crossover by a point. (c) Mutation: randomly chosen parent chromosomes are chosen and a value in 1 locus is replaced to a new value.

4.3 Experiments

Subjects are chosen from college students in department of engineering (10 male, 6 female, age 21-25), and divided into 4 groups. Members in group A and D knows each other well, and members in group B and C don’t know each other. Each group perform experiments in order to design that fills the design objectives as shown in Table 1, which are considered situation of why they design uniforms. After interaction and consultations by using system, subjects answered questionnaires as shown in Table 2, and answered comments by free text.

<table>
<thead>
<tr>
<th>Questionnaire</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>Answer your evaluation policies among experiments, such as focusing attributes including types and colors in the candidates. (text)</td>
</tr>
<tr>
<td>Q2</td>
<td>Do you feel your evaluations reflect candidates as the generation progresses? (5:good – 1:bad, and text)</td>
</tr>
<tr>
<td>Q3</td>
<td>Do the final chosen candidates have near images you imagined? (5:good – 1:bad, and text)</td>
</tr>
<tr>
<td>Q4</td>
<td>Did the final chosen candidates satisfy you? (5:good – 1:bad, and text)</td>
</tr>
<tr>
<td>Q5</td>
<td>Answer your impression and suggestions through experiments. (text)</td>
</tr>
</tbody>
</table>

Fig. 5. User Interface of the Prototype System
4.4 Results and Discussions

Fig. 6 shows generated best 3 designs in each group at the generation 10 and results of the questionnaires. In the questionnaire 2, 3 and 4, the answers average are 4.44, 3.94, and 4.19, respectively. These good results are also recognized in subjects' free comments such as “The number of designs reflecting objective are increased as the generation passes.”, “I felt the designs become near the objectives by our evaluation.”, “My primal evaluation attributes in the design are reflected to candidates.”, and so on. From these results, the proposed system can generate designs both aggregating and satisfying subjects' own affective images. However, there are some not satisfied answers such as “There are not so many candidates reflecting objectives if I view from each component in the design.”, “I found better candidates in the latter generation, but we did not choose them.” and so on. Those answers suggest that the GA operators such as crossover methodologies have to re-consider.

We also compared results between group A+D (members know each other well), and B+C (do not know well). In the interactions of evaluation phase 2, the results of group B+C are slightly less values than group A+D, but the difference is not significant. From the result, the proposed methodology of aggregation opinions are effective, in both of the situation such as the participants know each other well, or do not well.

There are some opinions we have to discuss from free answers such as “I wanted to evaluate part of attributes in detail.”, “I wanted to know why other participants choose candidates more detail.” and so on. These opinions suggests meta-proposals system needs to implement, and way of betting chips needs more to be considered.

![Fig. 6. Best Designs and Results of Questionnaires](image-url)
5 Conclusion

This study proposed the design support system with consensus building of multiple participants by using Interactive EC approach. Two kinds of steps such as evaluation phase 1 and 2 are introduced in the system in order to acquire smoothly aggregation of individual affective image to the participants' common satisfied designs. From the experimental results by the prototype system, the effectiveness of the proposed methodology is confirmed. These results not only extends feasibility of Interactive EC, but also opens brand new way of collaborative design methodology. In the future study, we intend to implement meta-proposals system and re-consider of parameters of some GA operators. Moreover, we have to investigate if the number of participants is increased more, which the situation may become more complex.

6 References

3. H. Furuta, S. Kameda, S. Tanaka, "Consensus Building Support System for Bridge Design by Using Interactive Multi Objective GA", 60th annual conference of Japan Society of Civil Engineering, 4-060, 2005