Collaborative Design Support System Based on Interactive Genetic Algorithm (IGA)

Yasufumi Inoue¹, Takashi Inoue¹, and Masataka Tokumaru²

¹ Graduate School of Kansai University

3-3-35 Yamate-cho, Suita-shi, Osaka 564-8680, Japan

² Kansai University, 3-3-35 Yamate-cho, Suita-shi, Osaka 564-8680, Japan

{k863806,k008376,toku}@kansai-u.ac.jp

Abstract. In this paper, we propose a system that facilitates collaborative design by multiple users of on the basis of Interactive Evolutionary Computation (IEC). Further, we conduct numerical simulations in order to analyze the optimized performance of the proposed system. In the simulations, multiple evaluation agents with bit strings are used to evaluate the design plans, instead of real users. The simulation results confirm that the proposed system provides satisfactory optimized performance in order to create a collaborative design.

1 Introduction

Recent years have witnessed growing opportunities for collaborative work in product development processes such as design creation. In other words, there are more opportunities for argument and discussion. However, it is not easy to summarize people's opinions and to arrive at a consensus. A previous study had investigated collaborative design support systems [1]; however, such systems facilitate only one-on-one interaction between a user and the system.

In this paper, we propose a system that facilitates collaborative design by multiple users. The proposed system consists of a server and some clients, where multiple users interact through each client. Our objective is to achieve collaborative design via interactions between multiple users and the clients. The server communicates with the clients and modifies the design for each of them. We implement these novel mechanisms using Interactive Evolutionary Computation (IEC) [2]. Thus, the proposed system can create a design that reflects the opinions of all users. Moreover, it can be potentially employed in various fields as a collaborative design support system based on human computer interaction involving multiple users. Finally, we conduct numerical simulations in order to analyze the optimized performance of the proposed system.

2 Proposed System

Figure 1 shows an overview of the proposed system; specifically, it shows the situation in which a user designs running shoes using the proposed system. The

Fig. 1. Overview of the proposed system

proposed system consists of a server and some clients. Each client conducts a one-on-one interaction with each user, while the server summarizes the design plans from each client . In other words, each client creates design plans automatically and proposes them to the user. The users may evaluate the proposed design plans and sort them according to their preferences. Then, the client creates new design plans based on the users' evaluation. In other words, the users evaluate the design plans, and accordingly, the client evolves the designs using a Genetic Algorithm (GA) [3]. Then, each user feeds his/her favorite design plan to the server. The server modifies the design plans such that they reflect the opinions of all the users and feeds them back to each client.

In design creation using IEC, the system expresses a design using bit strings. In other words, the system creates various designs by changing the values of the bit strings. Therefore, such a system can be employed to process various things, such as images and sounds.

3 Design Example

In this section, we present a design example, i.e., a design running shoes. Figure 2 shows the gene coding of the running shoes design. This design consists of five parts: sole, base, toe, line, and shoelace. Further, each part has eight designs that are expressed using a 3 bit gray code. Therefore, the gene length is 15 bits. This design can generate 32,768 ($= 2^{15}$) patterns. The running shoes designs are generated by combining the shoe parts.

4 Simulation

4.1 Summary of Simulation

We conducted some numerical simulations in order to analyze the optimized performance of the proposed system; multiple evaluation agents with bit strings

Fig. 2. Design example

were used to evaluate the design plans, instead of real users. The bit string patterns express the evaluation agents' preferences; each evaluation agent has a particular preference.

Accordingly, all evaluation agents were built such that the Hamming distance between any two evaluation agents is 40% of the bit string length. We used five evaluation agents in this simulation. An evaluation agent sorts the design plans and gives an absolute evaluation value by comparing the Hamming distance of the design plans. In other words, the absolute evaluation value expresses the design satisfaction of the evaluation agent.

Whenever each agent feeds a design plan to the sever, the server's new design plans are evaluated by all the evaluation agents. When the total of the absolute grading values from each evaluation agent is maximum, its design plan is assumed to be unanimously agreed upon. Equation (1) represents the absolute grading value fitness of each evaluation agent.

$$fitness = \frac{L - l}{L/10} \quad (1)$$

Here, L denotes the gene length of the design plans and l denotes the Hamming distance between the evaluation agent and the design plans that are evaluated. The absolute grading value of the simulation result is the average of the absolute grading values of all the evaluation agents for consensus. Moreover, each evaluation agent's highest absolute grading value is 10, and the highest average of the absolute grading values of all the evaluation agents for consensus is 7.5.

In the simulation, we analyzed the optimized performance of the design plans provided by the proposed system by varying the influence quantity from 10% to 50% (simulation 1) and the number of design plans from 2 to 10 (simulation 2). The influence quantity is a ratio that reflects the opinion of the evaluation agent.

4.2 Result of Simulation 1

Table 1 lists the parameters used in this simulation. Figure 3 shows the results of simulation 1. The results indicate that the initial convergence of the absolute

Table 1. Simulation 1 Parameters

Evaluation agent	5
Influence quantity	10, 20, 30, 40, 50
Feed	100
Design plans	10
Generation	5
Gene length	20 bits
Selection	Roulette selection + Elite preservation
Crossover	Uniform crossover
Mutation rate	1

Fig. 3. Result of simulation 1

evaluation value improved as the influence quantity increased. However, the final converged absolute evaluation value degraded, even when the influence quantity was high. We assume an effective influence quantity of 30% to achieve a trade-off between the evolution performance and the initial convergence characteristics of the design plans.

4.3 Result of Simulation 2

Table 2 lists the parameters used in this simulation. Figure 4 shows the results of simulation 2. The results show the absolute evaluation value increased with the number of design plans. However, the evaluation load of real users can increase with the number of design plans. We assume an effective number of design plans for a system operated by real users to be 6.

5 Conclusion

In this paper, we proposed a system that facilitates collaborative design by multiple users, and we investigated its effectiveness via numerical simulations. The simulation results confirmed that the proposed system provides satisfactory optimized performance in order to create a collaborative design.

Table 2. Simulation 2 Parameters

Evaluation agent	5
Influence quantity	30
Feed	100
Design plans	4, 6, 8, 10
Generation	5
Gene length	20 bits
Selection	Roulette selection + Elite preservation
Crossover	Uniform crossover
Mutation rate	1

Fig. 4. Result of simulation 2

In the future, we plan to further enhance the proposed system. In addition, we plan to analyze the proposed system with real users and verify its effectiveness in real-life applications.

Acknowledgement. This work was supported by MEXT.KAKENHI (24500264).

References

- 1. Kubota, F., Inamori, Y., Nakano, M., Mitsuyuki, K., Yura, Y.: Navigation of Collaborative Manufacturing System Design Based on Dpio-Model. Journal of the Society of Project Management 9(6), 28–33 (2007)
- 2. Takenouchi, H., Tokumaru, M., Muranaka, N.: Tournament Evaluation System Considering Multiple People’s Kansei Evaluation. Journal of Kansei Engineering International 9(2), 43–50 (2010)
- 3. Miki, M., Orita, H., Hiroyasu, T.: Design of Sign Sounds using Interactive Genetic Algorithm. In: Proc. IEEE Int. Conf. on Systems, Man, and Cybernetics, pp. 93–98 (2006)