Interactive Design Support System by Customer Evaluation and Genetic Evolution: Application to Eye Glass Frame

Hideyoshi Yanagisawa[1] and Shuichi Fukuda[1]

[1] Tokyo Metropolitan Institute of Technology, 6-6, Asahigaoka, Hino, Tokyo, 191-0065, Japan.
{hide@exmgfkta, fukuda} .tmit.ac.jp

Abstract. To respond to the quickly changing and diversifying customer's requirements, a system for supporting an industrial design where a customer can personally participate in the design process is proposed. Our system uses *Interactive Evolutionary Computing (IEC)* technique where a customer can express his or her requirement such as a Kansei image by interacting with the system. To demonstrate the effectiveness of our system, we applied it to the design of an eyeglass frame shape. Harmony with the customer's face is an important key factor in the design of an eyeglass frame. In our system, the user evaluates some samples suggested by our system, and then gradually he or she comes to the design he or she likes. The systems' effectiveness was demonstrated through the experiments of user operations and questionnaires.

1 Introduction

Human evaluation, such as impression or preferences toward industrial design, depends on time situation and individuals. Generally it is difficult to quantify. With the rapid development of network technology, customer's demands have been changing and diversifying every moment. Those characteristics of human evaluation have become increasingly important due to this situation. In order to answer those demands, one of the solutions is an order made design where a designer listens to and understands each customer's demands and then determines a direction for design. But an order made design has a problem of cost and time. Therefore it is necessary to develop a design support system that can cope with the change and the diversification of customer's demand interactively.

In this paper, we introduced an industrial design support system where a customer can participate in the design process and express his or her requirement like a Kansei image by interacting with the computer. In our system, human subjective evaluation toward design samples is regarded as a fitting function and the system calculates suitable design parameters using Genetic Algorithm (GA). The proposed design samples consist of calculated parameters by GA. Through the interaction of generations of design samples and a customer's subjective evaluation, design samples evolve to the customer's required design. These interactive approaches using GA are called *Interactive Evolutional Computing (IEC)* [1]. IEC is applied to several fields such as design, art, computer graphics, music, etc. There are applications to a design support system [2]. However, most recent studies have been paying attention to the support for the designer. Our system helps the customer's requirements made clear.

We applied the system to the shape design of an eyeglass frame and developed an *Interactive Design support System for eye Glass Frames (IDS-GF)*. Eyeglass frames requires not only lens support function but also aesthetic value. For customers who are not designers, it is not easy to express his or her aesthetic image. As requirements of customers are diversifying, it is necessary to make clear the customer's requirement image. *IDS-GF* helps a customer to express and design his or her image. A user repeats the operation to evaluate design samples.

The *IDS-GF* and experiments of systems evaluation will be described. Effectiveness of the system is discussed through experimental results. We show the differences of characteristic of evaluation by operation process records and discuss about focus features.

2 Interactive Design Support system for Eye-glass Frame

The flow for developing the *IDS-GF* is shown in Fig.1. An image of the customer's face is taken with a digital camera and face parameters are measured using image processing. A parametric model for an eyeglass frame is generated from extracted face parameters. There are 10 design parameters. Those 10 parameters are coded to bit array. The bit array is called gene array. Values of the gene array are initialized at random and first generation design samples are generated. A customer evaluates and scores each generated design sample based on his or her degree of satisfaction. These scores are regarded as the fitness value of GA. The system calculates the next generation's gene arrays based on GA and scores and then design samples for the next generation are created. A user repeats these operations until he or her can receive a satisfied sample.

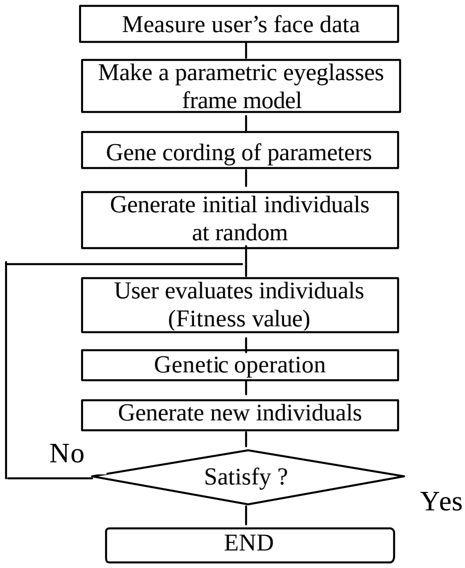

Fig. 1. Flow chart for developed system

2.1 A Parametric Model of Eye Glass Frame

A design parametric model is generated based on a customer's face measurements (Fig.2). The eyeglass frame model consists of a rim, a temple and a bridge. The shape of a rim is formed with the *Riesenfeld spline curve*. A rectangular area composed of lines $li(i=1,\ldots,4)$ is defined around user's eye as follows.

$$l_1 = e_x - \frac{R_w}{2},\;\; l_2 = e_x + \frac{R_w}{2},\; l_1 = e_x - \frac{R_w}{2},\;\; l_2 = e_x + \frac{R_w}{2} \qquad (\mathbf{1})$$

Where, R_w is the area width, R_h is the area height and ey_w is the central position of an eye. Spline control points from p1 to p8 are put on the rim area. The rim curve is obtained as follows.

$$x(t) = \sum_{i}^{8} x_i B_{i-2,4}^{c}(t),\quad y(t) = \sum_{i}^{8} y_i B_{i-2,4}^{c}(t) \qquad (\mathbf{2})$$

Where, x_i and y_i are the coordinates of the spline control points and is a closed spline function. The bridge is formed on the 2nd order curve and the temple is formed with a straight line.

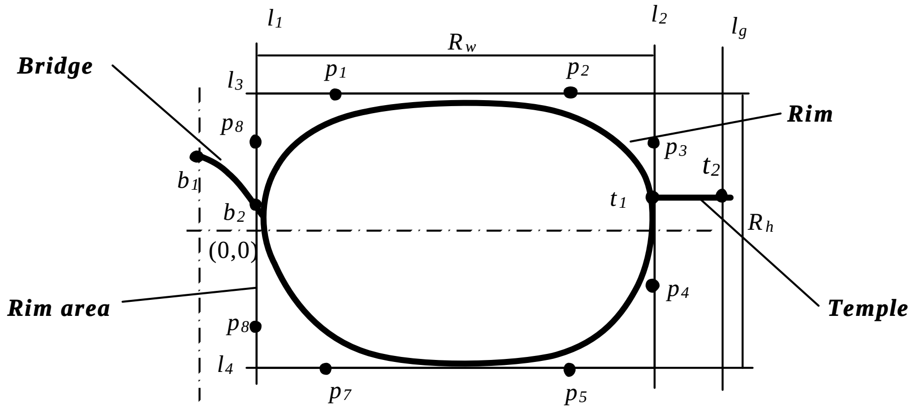

Fig. 2. Eyeglass frame model parameters

2.2 Gene Coding

The parametric model consists of 10 parameters that are coordinates of the spline control points p_i (i = 1,2,…,8), the width of the rim R_w and the height of the rim R_h. Vector of coordinates of the spline control points P are obtained as follows.

$$P = L + QR \tag{3}$$

$$P=\begin{bmatrix} x_1 & y_1 \\ x_2 & y_2 \\ x_3 & y_3 \\ x_4 & y_4 \\ x_5 & y_5 \\ x_6 & y_6 \\ x_7 & y_7 \\ x_8 & y_8 \end{bmatrix} \quad L=\begin{bmatrix} l_1 & l_3 \\ l_2 & l_3 \\ l_2 & l_3 \\ l_2 & l_4 \\ l_2 & l_4 \\ l_1 & l_4 \\ l_1 & l_4 \\ l_1 & l_3 \end{bmatrix} \quad Q=\begin{bmatrix} q_1 & 0 \\ -q_2 & 0 \\ 0 & q_3 \\ 0 & -q_4 \\ -q_5 & 0 \\ q_6 & 0 \\ 0 & -q_7 \\ 0 & q_8 \end{bmatrix} \quad R=\begin{bmatrix} R_w & 0 \\ 0 & R_h \end{bmatrix}$$

Where, q_i(i=1,2,….,8) is the distance between each corners of the rim area and spline control points p_i and is normalized from 0 to 0.5. Each parameter is coded into a binary string. Each q_i is 6 bit and the width of the rim R_w and the height of the rim is 8 bit.

2.3 Individuals, Fitness Value and Genetic Operator

6 frames are generated in one generation. The customer evaluates each individual frame according to the five-grade scale based on his or her degree of satisfaction. The evaluation score is regarded as a fitness value of the genetic algorithm.

The genetic operation is roulette selection, uniform crossover, and mutation. A probability of mutation is 0.08.

3 Experiments

In order to verify the effectiveness of our developed system and to analyze tendencies of subjective evaluation, 2 experimentations were carried out as follows. In each experiment there are 8 subjects who are males in their twenties and beginners of industrial design.

3.1 Experiment One: Systems' Operation

In the first experiment, the effectiveness of developing the *IDS-GF* was examined from the stand point of satisfaction from results received through system operations. In order to analyze the convergence of solution and characteristics of subjective evaluation, the processes of operations were recorded. The procedures of this experiment are as follows.

1) Take the image of the subject's face by digital camera and save it as a picture file.
2) Measure facial parameters with the face measurement system, which uses image processing.
3) Ask subjects to describe 3 concept words that express their required image such as beautiful, elegant, smart, etc… in other to obtain a clear image for the subject.
4) Measure their intensity of image with a questionnaire according to the three-grade scale.
5) Practice system operation until the subject gets used to it.
6) Subjects operate *IDS-GF* 3 times about 3 concepts. Therefore, total trials are 9 times. The number of repetition is 10 times.
7) Evaluate degree of satisfaction of an obtained design sample with a questionnaire according to the five-grade scale at the end of each operational trial.
8) Send out free style questionnaires about the system's impression.

3.2 Experiment Two: Design Sample Evaluation

In order to examine the appropriate uses of the design result, a design samples and randomly made design samples was compared. This experiment was done one week after Experiment One. Thus, the purpose of this experiment is to evaluate temporal stability and objective appropriateness of the result. The process of Experiment Two is as follows.

1) Select three design samples that ware scored highest satisfaction in the design results. These design samples are called "satisfied samples".
2) Generate seven samples at random. These samples are called "random samples".
3) Compare in a pair wise manner random sample and satisfied sample according to the five-grade scale. To avoid the influence of order, these samples appear at random.

4 Experimental Results and Discussion

Result of experiment one: One of the results we expect from our developed system is whether a user could receive satisfied results through the interaction with the system. The result of questionnaires about the satisfaction was obtained by Experiment One. There is a dispersion of the distribution and the standard deviation of satisfaction's average is 0.72. In order to find a cause, we compared free style questionnaires of Subject 3, who scored the maximum average satisfaction of 4.9, and Subject 4, who scored minimum of 2.6. Subject 3 mentioned that he was evaluating each design sample generated by the system based on his clear image. However, Subject 4 mentioned that he did not have a clear image and it was not easy to evaluate each sample. This means that a user who has a clear image of his requirements is trying to create a solution that is near his or her image. A user who does not have a clear image looks for his or her required design from the program. In other words, there is a user's difference of convergence and divergence. The correlation between the intensity of imagination and the average of satisfaction is 0.86. Thus our system proves to be effective for a user who has a clear image, but if the user does not have a clear image, he or she may not obtain a satisfied design.

Result of experiment two: If obtained design results are appropriate, the results should be better than random sample.

Based on the values obtained through Experiment Two, by comparing in a pair wise manner, degree of importance is calculated for satisfied samples and random ones. Degree of Imp ortance is calculated with *AHP* [3].

The average of the number of satisfied samples ranked until 3rd is 2.6. The average degree of importance of random samples is 0.08 and the degree of importance of satisfied samples ranked until 3rd is 0.2. There is a statistical difference between satisfied and random sample by T test and the significant level is 0.5%. Therefore the appropriateness of our system is verified.

Convergence of the solution is one of the important indicators for the system optimization. In this study, the optimized system is a human physiological evaluation and convergence of a solution means to bring the solution closer to the satisfied image. If a solution converges on a user's image, individuals should be similar to each other in subsequent generations. Thus, we regarded variance of design parameters as an indicator of similarity. Summation of variance of design parameters in j^{th} generation, $Tvar_j$ is obtained as follows.

$$Tval_j = \sum_i Var(F_{ij}) \qquad (4)$$

Where, $Var(F_{ij})$ is variance of i^{th} individuals' design parameter in j^{th} generation. Fig.3 shows a distribution of average of $Tvar_j$ about subjects. Distribution is reduced gradually along with generations and the value does not remain the same. It means the solution gradually converges on a user's image without getting into a local minimum.

It is expected that there is small increase at the 8^{th} generation. The users might be able to obtain better designs, even if they already obtained satisfied results. Because, in a free style questionnaire, some subjects mentioned that even when they obtained a satisfied result, they marked a high evaluation score to a poorer design on purpose, in the hope to obtain a better design.

Therefore, a user not only evaluates a suggested alternative, but he or she is operating the system, using an abstract operator, i.e., evaluation.

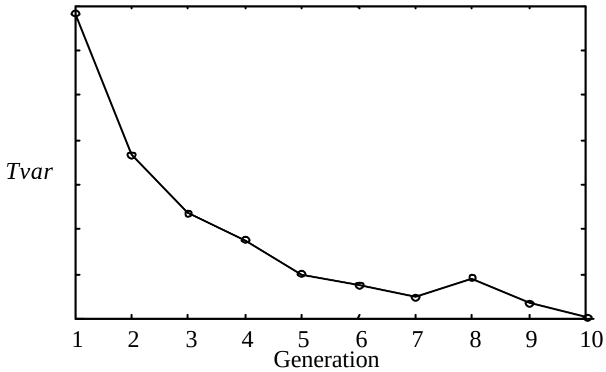

Fig. 3. Total variance of feature parameters

5. Conclusions

We developed an interactive industrial design support system for an eye glass frame, with a customer on mind, who would like to design an eye glass frame by him/herself by considering his or her taste. Our system uses Genetic operation and user's subjective evaluation as the fitness value in Genetic Algorithm. The following results are obtained from the experiments by non-designer subjects and the effectiveness of our system is demonstrated.
(1) Our developed system is demonstrated to be effective for a user who has a clear image about his or her taste in design, because there is a high correlation between the intensity of image and the degree of satisfaction of design results.
(2) The appropriateness of design results was verified by the experimental results which compared satisfied samples and random ones in a pair wise manner.
(3) Convergence of solution toward the final generation was confirmed except for a small divergence in near-final generation. The exception was considered due to user's expectation of a better result.

References

1. H. Takagi, Interactive Evolutionary Computing - Cooperation of computational intelligence and human KANSEI, In Proceeding of 5th International Conference on Soft Computing and Information/Intelligent System, (1998).
2. Stephen, N. S., David, R.W., Toward the Synthesis of Aesthetic Product Form, Proc. of DETC'00 ASME Computers and Information in Engineering Conf. Baltimore, (2000), 10-13.
3. Thomas, L. S., A Scaling Method for Priorities in Hierarchical Structures, Journal of mathematical psychology, 15 (1977), 234-281.