GENERATIVE DESIGN EXPLORATION FRAMEWORK BASED ON SUBJECTIVE EVALUATION

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Abstract: Application of evolutionary computation in design, supporting artificial intelligence and design inspiration, requires a good understanding of design process. However, obtaining a creative design solution with subjective evaluation is the barrier of traditional evolutionary mechanisms. In this paper, a novel aesthetic evaluation model connecting subjective and objective space is introduced, and an exploration algorithm combining human cognition and preference is presented, which can support design exploration to generate new design solutions more effectivelly and intelligently.

1 INTRODUCTION

In AI in Design community, it is considered that complex human intelligent activities being reduced to manageable computing task (Poon and Maher, 1997) became the dominant thinking with the development of CAD tools (Computer-Aided Design). Evolutionary computation is concered with avoiding the evolving of large numbers of unsatisfactory solutions. In order to do so, a subjective evaluation method is needed, but it is hard to define. In this paper, a preliminary attempt on evolutionary exploration based on subjective evaluation is presented. Our aim is to build connections between a logical system and subjective space of design. A novel aesthetic evaluation model embedded in generative design exploration framework is introduced, and an Embroidery Design System is built to prove the validation of this theory.

2 DESIGN EXPLORATION

For the purpose of creative design, especially in the art domain, traditional evolutionary method does not solve these ill-defined issues very well, which have many uncertainties, imprecise descriptions and subjective assessment criteria (Antonsson and Sebastian, 2005). In this section, we introduce a novel aesthetic evaluation model to build a bridge between subjective and physical evaluation aspects,

and a heuristic exploration algorithm is presented for evolutionary computation.

2.1 Aesthetic Evaluation Model

Comparing the traditional evolutionary fitness functions which are mainly focused on searching for optimization process or constraining satisfaction process, exploration is more suitable for design domain in order to satisfy designers' potential requirements guided by the vague assessing criteria. Therefore, a multi-dimensional evaluation model is introduced here. There are two kinds of evaluation dimension: One is subjective dimension to express different feeling and preferences in a designer's mind; another is the physical dimension to evaluate the concrete design features.

The physical dimensions are linear in Cartesian Coordinate, which start from origin and their absolute values are increased with the amount from their distances to the origin (equation 1). However, the subjective dimension (equation 2) is quite different. The value of a subjective dimension is non-linear without the global extremum, but several local extremums. In other words, the value of subjective dimension is unstable which fluctuates around a relative statistic point. So, there is no absolute value but many relative values.

There is a multi-to-multi map between the two kinds of dimension. The subjective dimension is fluctuated and data-sensitive. Small changes from physical dimension can bring big alternations in the

subjective one, and vice versa (equation 3).

$Dimension_{subjective} = E_{subjective};$
$Dimension_1, Dimension_2,…, Dimension_m = E_1, E_2, …, E_m,$ which m>0;

$$E_i = \gamma * x_i + \eta, \text{ which } m>0, \gamma, \eta \in R; \quad (1)$$

$$E_{subjective} = \Phi + \alpha * \sin(\beta * x + q), \text{which} \Phi, \alpha, \beta, q \in R; \quad (2)$$

$$E_{subjective} = \begin{vmatrix} E_1 \\ E_2 \\ … \\ E_m \end{vmatrix} * \begin{vmatrix} a_1 & a_2 & … & a_n \\ b_1 & b_2 & … & b_n \\ … & … & … & … \\ m_1 & m_2 & … & m_n \end{vmatrix} * \Psi, \quad (3)$$

which m, n $\in R^+$;

In equation (3), Ψ is a fluctuated factor used to control the sensitive trend; when Ψ is larger than 1, a small change in the physical dimension will cause big fluctuated changes in the subjective dimension; When Ψ is smaller than 1, a small change in subjective dimension will bring huge value changes in the physical dimensions.

The matrix of $\begin{vmatrix} a_1 & a_2 & … & a_n \\ b_1 & b_2 & … & b_n \\ … & … & … & … \\ m_1 & m_2 & … & m_n \end{vmatrix}$ is the feature matrix which can be specified by a designer for pending or ongoing generating process.

2.2 Exploration Algorithm

The exploration process is an application incorporating a human designer's interference and computational operation. For every generation, designers need specify an evaluationary value based on their subjective assessments. Then, the evolutionary computational mechanism calculates (3) to get every fitness value of every physical dimension for changing the evolutionary step in the next generation. Through this algorithm, we could trace the influence of subjective fitness value to physical fitness value for future research.

The algorithm is presented as follow:

Exploration Algorithm
Begin
1. To create the design generation based on random possibility model;
2. To evaluate the generation by user and specify the value of $E_{subjective}$;
3. To calculate every fitness value of every physical dimension E_i of equation (3);
4. To decide whether change the feature matrix of equation (3);
5. To compare the last evaluation with the current one. If the last is larger than the current, then change the

developmental direction of the parameters, otherwise, keep the same developmental direction;
6. To calculate the change pace by E_i;
7. To get the new parameters based on E_i and feature matrix;
8. Io generate new results based on the new parameters;
9. If the result is satisfactory, then end the process, or, go backto step 2.
END

3 EMBRODERY DESIGN SYSTEM

Embroideries of Zhuang ethinic has long history and folkoric tradition in Chinese Yunnan Province. The design patterns have strong cultural characters on shape and color, pursuing the simple and decorative beauty with impressionistic and abstractive aesthetics. In this section, a generative framework, Embroidery Design System, makes use of generative productive abilities and design exploration algorithm to generate novel design solutions.

3.1 System Structure

There are three main parts in the system: **User part**, **Application part**, and **Evolution part**. The **User part** concentrates on the interactive function with users, including the information input, information output and visual interface; The **Application part** is an aggregation of data reservoir and visualization generator; The **Evolution part** focuses on the evolutionary computation and design exploration.

In this system, users can type the data information to specify their preferences through valuing the parameters, as well as, operate instructions to draw their favorite petal patterns using a visual interface. Consequently, the patterns and parameters are preserved in a Pattern Database and an Infor Database, of which the Control.Info is sent to next component by the message system and the data is sent to Visualization Unit for visual generating.

3.2 Result Analysis

The Embroidery Design System is programmed by Visual Studio C++ 2003 and ACIS in Window XP system. The interface technique is implemented by XTreme ToolketPro 2008.

For the exploration algorithm, we extract the feature matrix as follows:

$$\begin{vmatrix} 0.9 & 0.7 & 0.5 & 0.2 & 0 & 0 & 0.1 & 0 & 0.2 & 0.1 & 0.1 & 0.2 \\ 0.1 & 0.1 & 0 & 0.1 & 0 & 0 & 0.3 & 0 & 0.6 & 0.7 & 0.7 & 0.5 \\ 0 & 0.2 & 0.5 & 0.7 & 0 & 0 & 0.6 & 0 & 0.2 & 0.2 & 0.2 & 0.3 \end{vmatrix}$$

In the subjective dimension of Aesthetic Evaluation Model, the subjective criteria can be subdivided into balance, redundancy and harmony according to the view of romanticist of aesthetics (Reich, 1993). So, (3) they can be translated into equations (4)-(15), in which the groups of {a1, a2, … , a12}, {b1, b2, … , b12}, {c1, c2, … , c12} come from the feature matrix.

$$E_{category} = a_1 * E_{balance} + b_1 * E_{redundancy} + c_1 * E_{harmony} \tag{4}$$

$$E_{partproportion} = a_2 * E_{balance} + b_2 * E_{redundancy} + c_2 * E_{harmony} \tag{5}$$

$$E_{symmetry} = a_3 * E_{balance} + b_3 * E_{redundancy} + c_3 * E_{harmony} \tag{6}$$

$$E_{relationship} = a_4 * E_{balance} + b_4 * E_{redundancy} + c_4 * E_{harmony} \tag{7}$$

$$E_{petalstyle} = a_5 * E_{balance} + b_5 * E_{redundancy} + c_5 * E_{harmony} \tag{8}$$

$$E_{petalcolor} = a_6 * E_{balance} + b_6 * E_{redundancy} + c_6 * E_{harmony} \tag{9}$$

$$E_{stemstyle} = a_7 * E_{balance} + b_7 * E_{redundancy} + c_7 * E_{harmony} \tag{10}$$

$$E_{stemcolor} = a_8 * E_{balance} + b_8 * E_{redundancy} + c_8 * E_{harmony} \tag{11}$$

$$E_{petalnum} = a_9 * E_{balance} + b_9 * E_{redundancy} + c_9 * E_{harmony} \tag{12}$$

$$E_{patternheight} = a_{10} * E_{balance} + b_{10} * E_{redundancy} + c_{10} * E_{harmony} \tag{13}$$

$$E_{patternwidth} = a_{11} * E_{balance} + b_{11} * E_{redundancy} + c_{11} * E_{harmony} \tag{14}$$

$$E_{partnumber} = a_{12} * E_{balance} + b_{12} * E_{redundancy} + c_{12} * E_{harmony} \tag{15}$$

During the generation process, a user can only specify these three subjective evaluation parameters from the visual interface (Figure 1). There is no need to interpret the meaning of the subjective criteria ('balance', 'redundancy' and 'harmony'), as different users with different design preferences must have different understanding about them. So, these three subjective values are just as the standards to weight the physical fitness value for the next generation.
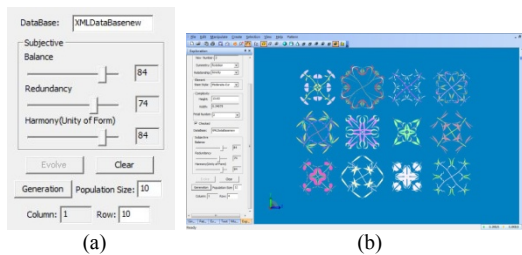

Figure 1: The snapshot of interface. (a) The system panel, (b) The visual interface.

In the system, users can use the digital system to explore their favorite embroidery patterns using the exploration algorithm mentioned in section 2.2, the collecting data is in Figure 2.
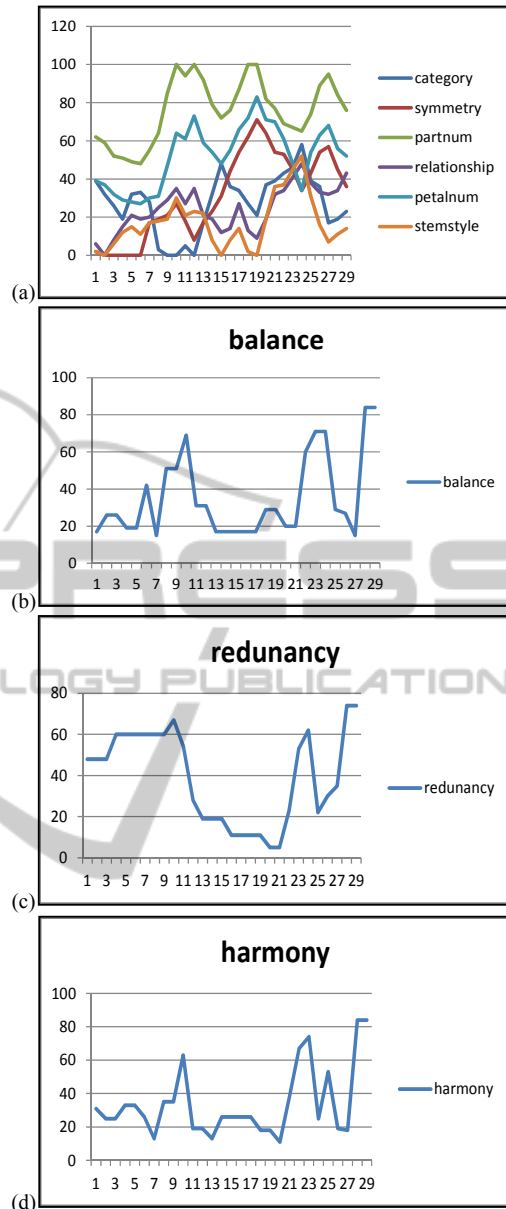

Figure 2: The fitness value in evolutionary process.

In Figure 2, we can see that at the generation 8 and generation 23, the values (Figure2.a) are comparatively centralized, and they can become emanative after that. Meanwhile, the values of three subjective criteria are all above 50 and then sharply down below 20. It indicates that during the two phrases, the results from evolution generations are onverging to a fixed style, and the fitness values of subjective dimentions are reaching at local maximum during the evolutionary process, whilst these are no user's favorite designs. As a result the values of subjective evaluation dimensions are not

kept at a relative high level. This situation of gradual changes in the physical dimensions bringing the sharp changes in the subjective dimension shows the fluctuated and data-sensitive characters of the subjective dimension evaluation method.

After generation 27, the three subjective fitness values are all higher than 70 and are kept at this level, whilst and the physical fitness values become concentrated. It means that, in this case, the user finds his/her favorite design patterns at the end of evolutionary process.

It is noticed that through the exploration algorithm, the user interactive operation is quite different from the traditional IEA approaches. In our system, every generation is created by the users' fitness value from subjective dimension and the computational fitness value from the physical dimension. By analyzing the collected data, it is found that there are some interrelationships between the subjective space and the logical mechanism, and this validates the feasibility of our aesthetic evaluation model trying to connect the subjective and objective world. There are some novel designs generated from Embroidery Desigy system, in Figure 3.
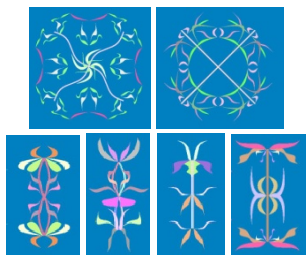

Figure 3: Some samples of creative design by EDS.

4 CONCLUSIONS

In this paper, The novel aesthetic evaluation model and design exploration algorithm can represent the subjective feeling and physical features of designers. Through experiment, we can trace the process of subjective and objective evolutionary evaluation and analyze the feature of the relationship between them. This is considered as an advanced interactive evolutionary computation objective for the research on AI in Design but so far little is tested with real design examples.

However, at this preliminary state of our research, some disadvantages need to be improved in the future. Firstly, although the aesthetic evaluation model can express the fitness value of design objectively, but how to specify a feature

matrix in a dynamic way is our next destination of the research. Secondly, based on the evaluation in physical dimension, involvement of heuristic a searching method for deciding the evolutionary development is needed but would require more studies, for achieveing more efficient and effective exploration of design solutions.

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