INTERACTIVE SKETCH DESIGN RECOGNITION SYSTEM USING EVOLUTIONARY TECHNIQUES

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Abstract: In this study, a methodology that hybridizes a sketch design recognition approach with an interactive genetic algorithm is proposed to help laypersons get clothes reflecting their preference. The sketch design recognition approach consists of a composite description model, a sketch recognition method and a database. First, a composite description model based on the knowledge of fashion design is developed to describe the characteristics of a skirt. Second, a sketch recognition method is used to help laypersons get satisfied clothes. Third, a database contains general elements about skirts. Moreover, an interactive genetic algorithm (IGA) is used to accelerate the sketch recognition process. The subjective experiments results demonstrate that the proposed method outperforms the existing fashion design systems.

1 INTRODUCTION

Holland (1975) first proposed genetic algorithms (GA) in 1975 as computer programs that mimic Darwinian's evolutionary processes in nature. Genetic algorithms (**GA**s) are stochastic search algorithms based on the mechanism of natural selection and natural genetics (Goldberg, 1989). Since GAs lack the capability to utilize human intuition and emotion appropriately, it is hard to implement them in creative applications such as architecture, art, music, and design. In addition, it is difficult to evaluate the fitness due to no clear measure. In order to overcome its drawback, it is necessary to introduce an approach called interactive genetic algorithm (IGA) (Takagi, 2001). A review of research efforts related to IGA was summarized by Takagi (2001). It provides two advantages over GA: the first one is that it performs optimization with human evaluation, and the second one is that it reflects personal preference. Therefore, IGA is a good solution in fashion design.

Although IGA has some advantages, developing a fashion design system based on the techniques of IGA is a complex task. As a result, only a few attempts to develop garment style design system using IGA were reported in the literature. For instance, Inui (1996) constructed an apparel design system, in which combined genetic algorithm with apparel computer aided design system to produce apparel design that the system users prefer. Nakanishi (1996) developed a fashion design aid system using genetic programming, which evolved each dress design according to the user's selection. However, most of its productions were impractical designs because they did not consider domain-specific knowledge. To solve this problem, Kim and Cho (2000) proposed an effective human-oriented evolutionary system based on the knowledge of fashion design to encode genotype with OpenGL design models in order to produce more realistic and reasonable design. Unlike traditional approaches that attempt to model the dress design by several spline curves, Kim and Cho (2000) provided a new encoding scheme to describe a dress with three parts: neck and body, sleeve, and skirt. Cho (2002) also used a new encoding scheme to fashion design system. Sugahara, Miki and Hiroyasu (2008) proposed a yukata design system that adopts IGA to create a yukata that accommodates user's taste. Ogata and Onisawa (2008) designed a cloth design support system based on IGA considering the factors including shape, color and material in order to help laypersons design clothes reflecting their Kansei and help them get unexpected design candidates by only evaluating candidates.

In this study, we develop a new sketch design recognition system which consists of a sketch recognition approach and an interactive evolutionary

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strategy. This system needs to be not only easy for a layperson to use, but also needs to fast converges to the target. The remainder of the paper is organized as follows. Firstly, a brief description of the sketch design recognition problems is given in section 1, and a new methodology is outlined in section 2. Secondly, a sketch recognition approach is presented in detail in section 3. Thirdly, in section 4, an interactive evolutionary strategy is used to accelerate the sketch recognition process. Fourthly, the effectiveness of the proposed methodology is illustrated in section 5. Finally, conclusions are summarized in section 6.

2 METHODOLOGY

In this paper, as shown in Figure 1, a general methodology which combines a sketch design recognition approach and an interactive genetic algorithm is proposed to help laypersons design clothes reflecting their preference. Furthermore, we use skirts (Independent clothes covering the lower half of one's body, or a part of clothes under waistline) (Kim and Cho, 2000) as an example to illustrate the proposed sketch design recognition system. The sketch design recognition approach consists of a composite description model, a sketch recognition method and a database. A composite description model based on the knowledge of fashion design is developed to describe the characteristics of a skirt. A sketch recognition method is used to help laypersons get satisfied clothes. A database shown in Table 1 contains general elements about skirts. Moreover, an interactive genetic algorithm (IGA) is used to accelerate the sketch recognition process. The outline of this sketch design recognition system is as follows:

1) The system generates the skirt candidates by combining style elements in the database in accordance with the composite skirt model and decoding of the skirt style information, and then the skirt candidates are generated and displayed on screen for users by using the sketch recognition method.
2) A user subjectively evaluates the skirt candidates and chooses the more favourite ones.
3) The system modifies skirts according to users' evaluations by using genetic operations of crossover and mutation, and the modified skirt candidates are displayed on screen for users again.
4) The system iteratively implements procedures (2) and (3) to produce skirt candidates that can satisfy a user. If a user is satisfied with some designed skirts, the system can terminate the design process.

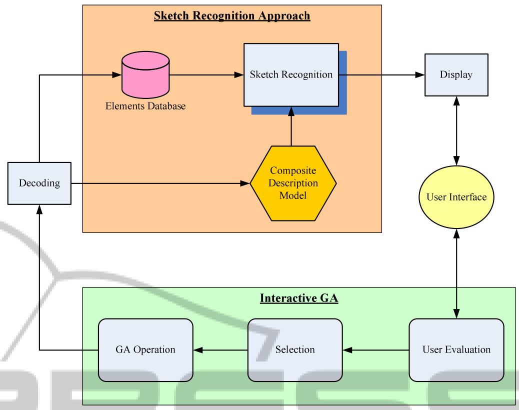
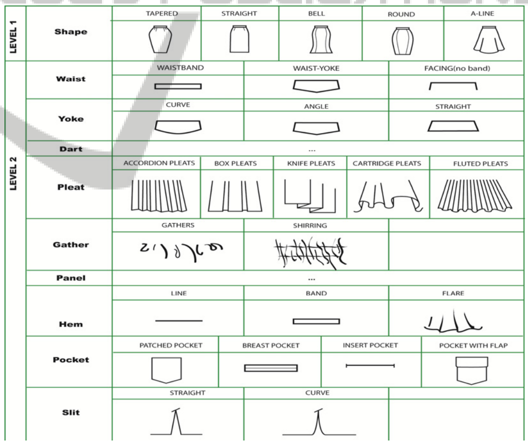


Figure 1: System architecture.

Table 1: Skirts classification.



3 SKETCH RECOGNITION APPROACH

3.1 Composite Description Model

The composite skirt model based on the knowledge of fashion design is composed of three portions: the general factors, style features and detail factors. The general factors provide information about the outline silhouette, the ratio of the length and width, the waist level, the symmetry of a skirt, waist band and hem. The style features include dart, pleat, panel, and york. The detail factors contain pocket, gather, and slit. In general, dart feature can be classified into three classes: straight dart, curve dart and tuck dart.

The position of a dart feature on a skirt can be represented by using the coordinates (d_{x1}, d_{y1}) and (d_{x2}, d_{y2}). There are three panel features: vertical panel, horizontal panel and sidelong panel. All of them can be further classified into three sub-classes: straight, curve and angle. The position of a panel feature on a skirt can be decided by the coordinates (pa_{x1}, pa_{y1}) and (pa_{x2}, pa_{y2}). For the york feature, there are three classes: straight, curve and angle, moreover, the york feature can be placed on a skirt by using the points y_{y1} and y_{y2}. For the pleat feature, there are five classes, and the pleat feature can be placed on a skirt by using the point p_y

3.2 Elements Database

A database of general elements about skirts is shown in Table 1. First, at the first level, the outline silhouette of skirts is categorized into five classes. Next, at the second level, waist band, hem, four style features and three detail factors are further classified into classes, respectively.

3.3 Sketch Recognition

The procedure of the sketch recognition method is considered as a two-stage process. In the first stage, general factors are generated. Then in the second stage, one style element is selected.

Stage 1: Generate General Factors

1) Assume that the origin of the created skirt style is represented by (ox, oy).
2) Obtain the skirt style information about outline silhouette of the created skirt style in accordance with decoding of the skirt style information,
3) Calculate the enclosing rectangle (i.e., m) of outline silhouette of the created skirt style,
4) The origin (ox, oy) of the created skirt style becomes:

   ox = m_left+(m_right-m_left)*0.5
   oy = m_top

   where m_left, m_right, and m_top are the left coordinate, the right coordinate and the top coordinate, for the enclosing rectangle of the created skirt style, respectively.
5) Obtain the length ratio of the skirt style in accordance with decoding of the skirt style information,
6) Decide the waist level of the skirt style in accordance with decoding of the skirt style information and designers' experiences , then

   oy = oy-Y_waist if above waistline
   oy = oy+Y_waist if below waistline

   where Y_waist is the distance between the waistline and the top of the waist band
7) Decide the style type of the waist band feature in accordance with decoding of the skirt style information, then place the waist band at the position (i.e., WB_Y) as below:

   WB_Y = oy if no waistband
   WB_Y = oy-WB_height if waistband
   WB_Y = oy-WB_height if waist-yoke

   where WB_height is the height of the waistband feature.
8) Decide the style type of the hem feature in accordance with decoding of the skirt style information, then place the hem at the position (i.e., H_Y) as below:

   H_Y = m_bottom if hemline
   H_Y = m_bottom+ hem_width if hemband
   H_Y = m_bottom if hemflare

   where hem_width is the height of the hem feature, and m_bottom is the bottom coordinate for the enclosing rectangle of the created skirt style.

Stage 2: Select Style Element

1) According to decoding of the skirt style information, choose only one style element among style features and detail factors.
2) According to decoding of the skirt style information, if the dart feature is included in the created skirt style, then place the dart at the position (i.e., LDart_X, LDart_Y, RDart_X, RDart_Y) as follows:

   LDart_X = ox-0.5*(d_{x2}-d_{x1})
   LDart_Y = oy
   RDart_X = ox+0.5*(d_{x2}-d_{x1})
   RDart_Y = oy
3) According to decoding of the skirt style information, if the pleat feature is included in the created skirt style, then place the pleat at the position (i.e., Pleat_Y) as Pleat_Y = oy
4) According to decoding of the skirt style information, if the panel feature is included in the created skirt style, then place the panel at the position (i.e., LPanel_X, LPanel_Y, RPanel_X, RPanel_Y) as follows:

(a) For vertical panel

   LPanel_X =ox-0.5*(pa_{x2}-pa_{x1})
   LPanel_Y =oy
   RPanel_X=ox+0.5*(pa_{x2}-pa_{x1})
   RPanel_Y =oy

(b) For horizontal panel and sidelong panel

LPanel_X=pa_{x1}
LPanel_Y=pa_{y1}
RPanel_X=pa_{x2}
LPanel_Y=pa_{y2}

5) According to decoding of the skirt style information, if the york feature is included in the created skirt style, then place the yoke at the position (i.e., Yoke_Y) as Yoke_Y=oy.
6) According to decoding of the skirt style information, if the gather feature is included in the created skirt style, then place the gather at the position (i.e., Gather_Y) as Gather_Y=oy.
7) According to decoding of the skirt style information, if the pocket feature is included in the created skirt style, then the pocket position (i.e., Pocket_X, Pocket_Y) is decided by the user.
8) According to decoding of the skirt style information, if the slit feature is included in the created skirt style, then the slit position (i.e., Slit_X, Slit_Y) is decided by the user.

4 INTERACTIVE GENETIC ALGORITHM

Assuming that the current generation is *t* and the current population is represented by **X(t)**. Here, a small population of 9 individuals in order to ensure a good compromise between convergence speed and usability.

Step 1: Set *t* = 0, generate an initial population of 9 individuals randomly, then present these individuals to the user.

Step 2: If the user is satisfied with the individuals, then terminate the search process.

Step 3: Select individuals by the user, and then perform crossover and mutation
Firstly, if one individual is selected, then the selected individual will be cloned eight times. These eight individuals will be placed into a mating pool where the mutation operation is performed. Secondly, if two individuals are selected, then one individual is randomly selected within the two selected individuals to generate three selected individuals, then these three individuals will be placed into a mating pool where the genetic operations of mutation and crossover are performed. Thirdly, if three individuals from **X(t)** which are selected by the user, then these three selected individuals will be performed crossover and mutation operations in the mating pool.

Step 4: Create a new population for the next generation
All the newly generated individuals are then collected to form the new population known as **X(t+1)**, which will replace **X(t)** and serve as the population of individuals for the next generation t+1. Unlike the elitist strategy (De Jong, 1975) of genetic algorithms, in which the single best individual with the highest fitness value in parent population is reserved and is copied directly into the new population; in this study, all the individuals in each generation are reserved.

Step 5: Check the pre-specified stopping condition. In this case, the pre-specified stopping condition is satisfied when the user is satisfied with the created individuals. If it is satisfied, terminate the search process, and return to the best solution as the final solution. Otherwise, increase *t* by 1 and go to *Step 3*.

4.1 Structure of the Individuals

Although there are many different representations to implement interactive genetic algorithm, the most natural representation for the skirts design problem is the value encoding representation. (Chen and Hou, 2006) In this study, the information contained in an individual is used to construct a feasible solution which corresponds to a unique skirt. In this research, each chromosome as shown in Figure 2 consists of three portions: a set of bits in the first portion of the string that is a set of real numbers to indicate the general factors of skirts. A set of bits in the second portion of the string comprises four substrings: dart substring, pleat substring, panel substring, and yoke substring, which is a set of real numbers to represent the style features such as dart, pleat, panel, and yoke. And a set of bits in the third portion of the string that is a set of integer numbers contains the information about pocket, gather, and slit.

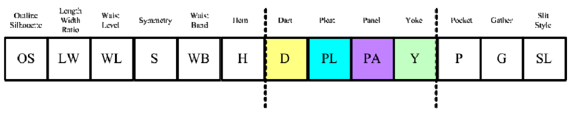


Figure 2: Chromosome encoding.

4.2 Crossover Operation

In this study, for the first portion of the chromosome, no crossover operator is employed before the "S" bit (i.e., symmetry of a skirt). For the bits of the chromosome after the "S" bit, one-point crossover operator is applied to recombine the individuals. The procedure of the crossover operator is presented below:

Step 1. Select two parents randomly from the mating pool.

Step 2. Select a crossing-site along the parent individuals. This crossing-site is used as a cutting point to swap the bits among the strings. There are no crossing-sites within each substring.

Step 3. Generate the offspring individuals by cutting the parent individuals at the crossing-site and swapping the bits after the cut.

4.3 Mutation Operation

When the crossover process is completed, the mutation operator will be used to guarantee population diversity. The mutation rate should not be very high; otherwise, the individual will be disrupted, and the genetic search bears no difference from a random search. In this research, for the bits before the "S" bit (i.e., symmetry of a skirt) in the first portion of the chromosome, the mutation operation is not performed; for the remaining portions of the chromosome, three kinds of mutation operators are employed.

Firstly, for the four bits such as d_m, p_m, pa_m, y_m in the second portion of the chromosome, traditional gene-alter mutation operator (Goldberg, 1989) is used. For instance, if an offspring individual is encoded by using the value encoding representation, (0 1 1 0), then four random numbers ranging from 0.00 to 1.00 are drawn: (0.653, 0.231, **0.007**, 0.014). If the mutation rate is 0.01, one random number in the above array has its value smaller than the mutation rate. This number will trigger the mutation operation to take place in the third bit of the string. The mutation operator will cause the bits to change from 1 to 0 or from 0 to 1 whenever the mutation operations are triggered. The resulting individual will become (0 1 **0** 0).

Secondly, for the four bits (i.e., d_{sc}, p_{sc}, pa_{sc}, y_{sc}) in the second portion of the chromosome to represent the subclass marks of the features for the created style, the following mutation operation is adopted. If the feature mark (i.e., d_m, p_m, pa_m, y_m) of the created style is equal to one and the mutation operation is implemented, then generate a random integer ω within a range of [1, *l*] (*l* is dependent on the created style features) to determine the subclass mark of the feature for the created skirt style; otherwise, ω=0

Thirdly, for the five bits such as WB and H in the first portion of the chromosome, P, G, SL in the third portion of the chromosome, the following mutation operation is adopted. If the mutation operation is implemented, then generate a random integer θ within a range of [0, *w*] (*w* is dependent on the created style features) to determine the feature of the created skirt style; otherwise, θ=0

Finally, for the remaining bits in the second portion of the chromosome, let T denote a random integer number within a range of [-1, 1], and τ denote a uniform random number in the range [0, 1]. D_k denotes the value to be mutated, and the notation D_k' denotes the value after mutation, which is given as follows:

$$D_k' = D_k + (D_{kmax} - D_k)(1-\tau^c) \text{ if } T=1,$$
$$D_k' = D_k - (D_k - D_{kmin})(1-\tau^c) \text{ if } T=-1,$$

where D_{kmax} and D_{kmin} are the maximum and minimum values of D_k, respectively, and c is a constant.

5 SUBJECTIVE EXPERIMENTAL RESULTS

In this section, subjective experiments are performed to verify whether the proposed methodology can help laypersons design clothes reflecting laypersons' preference or not. In this study, ten subjects are requested to find good-looking design by using this system, In all the experiments, the genetic parameters adopted for the interactive genetic algorithm after testing are Population size = 9, Crossover rate = 0.7, Mutation rate = 0.01, Maximum number of generations = 10. At each run, subjects are asked to design skirts and evaluate the skirts with 5-point scale (i.e., -2 to +2). Figure 3 presents some examples of generated skirts after ten generations. It reveals that various skirts are obtained after ten generations even if the same initial individuals at the beginning. In addition, in Figure 4, the average of satisfaction degrees among subjects is plotted against the generation number. It indicates that the satisfaction degree becomes high as generation progress. As the previous presentation, it can be noted that the proposed methodology is useful for non-professional users without knowledge on clothes design to design and obtain skirts reflecting their preference.

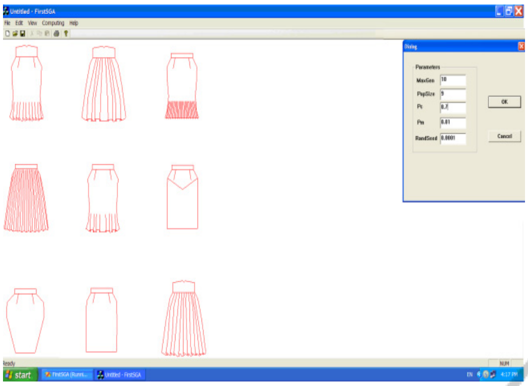


Figure 3: Some examples of skirts.

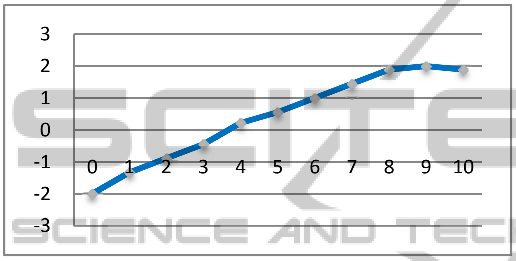


Figure 4: Average of satisfaction degrees.

6 CONCLUSIONS

In this study, a sketch recognition approach and an interactive evolutionary strategy has been proposed to establish an effective methodology for laypersons to design clothes reflecting their preference. This system possesses several advantages over the existing fashion design systems. Firstly, a composite description model based on the knowledge of fashion design is developed to create various skirts and to overcome the impractical designs. Secondly, with interactive genetic algorithm, it can reflect personal preference in fashion design directly rather than setting a standard of “goodness of design”. Finally, a two-stage sketch recognition method is developed to help laypersons achieve satisfied clothes without compromising the computational effort and expense. The subjective experiments results have shown that the proposed methodology has provided an effective means to help laypersons get satisfied clothes according to the laypersons’ preference.

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