Interactive genetic algorithm based on typical style for clothing customization

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Abstract

Companies find it extremely difficult to predict consumers’ needs and requirements, since the spiritual significance of clothing is getting more and more attention. However, most current clothing customization platforms only allow customers to retrieve previous design components from the database and recombine them together, ignoring the customer’s personalized design requirements. In view of the above issues, an intelligent design approach of personalized customized clothing based on typical style and interactive genetic algorithm is proposed in this article. It could generate new fashion styles according to simple customer evolution. The binary coding scheme of suit coat style is presented. And an automatic suit coat design system based on interactive genetic algorithm is developed, in which 10 typical suit coats are selected as the initial population. The experimental results show that the system can alleviate customers’ fatigue and speed up convergence compared with the classic interactive genetic algorithm design, and the designed styles can better meet customers’ preferences.

Keywords

Customized clothing design, interactive genetic algorithm, typical style, automatic suit coat design system

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Introduction

Twenty-first century technologies are defining a new era of customized and mass-customized clothing. Worldwide, apparel firms are experimenting with economic strategies that individualize clothing for each customer by offering a variety of design and fit options. Fashion customization platform such as China’s Red Collar develops vigorously. Customers are allowed to rearrange and design the clothing style elements; select design element such as collar, sleeve, pocket, and back style; choose available colors, fabric, and accessories; and come up with their own personalized suit style via platform.1 A collaborative garment design using the three-dimensional-to-two-dimensional (3D-to-2D) virtual draping design method is proposed.2 By following the cycle of Design–Display–Evaluation–Adjustment, the garment collaborative design process focusing on fitting enables interactions between designers, shoppers, and consumers for generating a relevant design solution meeting their requirements. However, that sort of design can only choose from the limited styles provided by apparel firms. It cannot generate new styles. Therefore, it could not satisfy the customer’s needs to participate in fashion design. Usually customers have their own personalized preference

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for clothing. Simply, recombination of clothing component could not fully meet the needs of customers. How to provide customers with convenient and easy-to-use design tools so that they can design personalized preference clothing via concise interface and deliver a complete design scheme is still one of the urgent issues to be solved.

The purpose of this article is to research and develop intelligent design method and tool for clothing customization. In order to serve customers, the proposed clothing customized platform must fulfill a number of requirements. First, customers may not be familiar with pattern making, and the proposed system should have intelligence to create feasible and practical designs. Second, general customers, unlike designers, may not be good at design drawing; therefore, the system must be easy to operate without complex parameters and measurement input. Third, the system should have the ability to design, that is, generating new styles not just retrieving previous designs from a database. Finally, the system outputs (i.e. the generated designs) must be easy to understand. The best way to present designs is by visualizing as design sketches.

Interactive genetic algorithm (IGA) has been used to study on product innovation design. IGA differs from traditional evolutionary algorithms in the fitness evaluation method. Unlike calculating the fitness value of each individual by a defined fitness function, in IGA, users subjectively evaluate and decide the fitness value for each individual. Chioou and Wang describe an effective compound genetic algorithm for the museum’s cultural and creative products design. An automatic mapping mechanism of color scheme from plane image to produce 3D product model is studied which IGA is used to seek for the optimal scheme to realize the automatic extraction of color scheme, mapping, and design optimization. In the field of fashion design, the collars, sleeves, pockets, and other clothing components of the body are randomly combined to form the overall clothing. Then, the rating is conducted by user interaction, and the clothing that users are satisfied with is finally obtained through genetic manipulation. DunWei et al. present a system based on an encoding scheme that practically describes a dress with three parts: body and neck, sleeve, and skirt. By incorporating the domain-specific knowledge into the genotype, a more realistic design and system for women’s dress is developed. Hee-Su and Sung-Bae design a data structure of 3D garment parts suitable for genetic manipulation and construct a typical 3D garment parts database by means of parametric modeling. And a genetic algorithm coding method based on component pointer is proposed to make it suitable for the genetic operation of 3D components. However, above mentioned methods based on clothing component does not generate new styles essentially, it just retrieves previous designs component from the database, and recombine them together. Therefore, its innovation in design is limited. The car profile is decomposed into multiple splines, and the locations of feature control points of the spline curves are changed via IGA to get customer favored style. However, the scheme simply takes the key points of spline function of product contour as the modeling parameters and does not consider uniform design and subsequent manufacturing parameters.

The competition of product is not only quality, price, and function but also in the users’ emotional and personalized needs today. The emotional factors of products are becoming more and more important. Research shows that there is a mapping relationship between product style parameters and emotional elements corresponding to product expression. Style is an expression of taste, thus shaping the set of socially acceptable elements that are available to individuals at one point in time and space. Product style represents the comprehensive needs of users.

Based on the above analysis, an intelligent design approach of personalized customized clothing based on typical style and IGA is presented in this article by taking suit coat as an example. Here, the word “coat” refers to the “suit coat” in the following statements of this article. It enables customer to complete the innovative clothing design through less human–computer interaction, provides theoretical and methodological support for customer to participate in personalized customized clothing design, and improves the design participation and satisfaction of customized customers. This article is organized as follows: in section “The coat typical styles and binary gene coding,” the typical styles of coat are given. The main shape structure parameters of coat are defined and the binary gene coding scheme for coat style is designed. The flowchart of automatic design of typical style based on IGA (TS-IGA) is provided in section “Typical style based on IGA.” The Coat Style Design System based on TS-IGA is introduced and the test results are given in section “Validation tests.” The final two sections discuss the results and findings from this study and draw the conclusion.

The coat typical styles and binary gene coding

The coat typical style

Style is defined as a durable, recognizable pattern of aesthetic choices. To understand fashion, one has to understand style, because in essence, fashion is about the diffusion of styles rather than the diffusion of clothes. The fashion style represents the connotation meanings outside of apparel which denote the feelings, thoughts, beliefs, and desires of clothes based on mental concepts. For instance, a peak lapel with a wider shape and higher position of gorge can create a muscular chest look. Chan collected consumer’s preference rates of all related design elements to men’s coat. The representative vocabularies were selected via scientific analysis and processing to guide the
work of fashion perceptual design. Here, 10 semantic words relating to perceptual feelings (to express style genres) and their corresponding style pictures are chosen to label typical coat styles. They are elegant, rough, playful, mature, classic, trendy, casual, professional, feminine, and manly, respectively.

A total of 627 pictures of men’s coats on shows within 4 years were collected as research subjects and also act as sample set for single factor range value experiment, from which maximum and minimum value of shape structure parameters such as the depth of collar, the angle, and position of the notch could be obtained. Typical styles can also be selected via experimental tests. For example, the elegant style can be seen in Figure 1(a), the rough style picture can be seen in Figure 1(b).

The main shape structure parameters of coats

The main shape structure parameters of coat are shown in Figure 2, which includes collar parameters such as depth of the collar c angle and position of the notch e and b of the lapel d, depth of the notch L, angle between the roll line and notch \( \theta \), width of the upper notch h, width of the front edge f. Other parameters include the shape of hem, pocket, waistline type, and so on.

Binary gene coding of coat style

The binary gene coding scheme for coat style can be seen in Table 1. The maximum and minimum values corresponding to coat shape structure parameters are studied and listed in the second and first columns of Table 1. For example, the variation range of the depth of suit collar is 27–57 cm. This range is represented by a 4-bit binary code, which is from 0000 to 1111. There are 15 binary values in this range. The decimal unit of change for each adjacent binary value is 2 cm. For a specific style, its 11 parameters in the first column correspond to a 34-bit binary string. The code position of the depth of collar in this 34-bit binary code is at 31–34 bits.

Through the coding scheme in Table 1, the binary coding string corresponding to the specific coat style can be obtained. For example, Table 2 lists the shape structure parameters value of mature coat style in the second column. We can get its corresponding binary code from Table 1. Combining these binary numbers into 34-bit binary strings according to the position relationship listed in the fifth column of Table 1, the gene code of mature coat typical style is obtained, which is 11001000001001100110000100001010.

The genetic algorithm in the IGA keeps the population iteratively evolving by coding the feasible solution and applying genetic operations such as selection, crossover, and mutation to the individual coding. When the generation design is finished and the satisfactory solution is obtained, the corresponding phenotype of the solution can be obtained by the inverse operation of the coding method.

Figure 1. (a) Elegant style versus (b) rough style.

Figure 2. The main shape structure parameters of coat.

Typical style based on IGA

As a kind of evolutionary and optimized method, IGA treats a human’s subjective evaluation as individual fitness. It differs from the traditional genetic algorithm which counts individual fitness according to fitness function. The number of populations affects the algorithms’ performance to some degree. Hence, it is important to determine appropriate population numbers. In general, the number of populations is determined by optimized
The implementation steps of TS-IGA are as follows:

Step 1. At the beginning, setting parameters such as the number of population, mutation rate, and crossover rate. The number of population is set to equal the number of typical styles. We get 10 typical coat styles in section “The coat typical styles and binary gene coding” and the parametric expression of these 10 various coat styles can be converted into binary gene code. Thus, the 10 typical coat styles are assigned to initial population.

Step 2. Displaying the individuals of the current population via graphical interface for customers to evaluate. The rating ranges are from 0 to 10. Zero means extremely dissatisfied, 10 means very satisfied. The value of the rating represents the degree of satisfaction. It is also the fitness value of IGA.

Step 3. If the user’s evaluation score for one of current fashion style is 10, then output the optimal evolutionary individual. The program is terminated. Or if the number of iterations has reached the per-set maximum threshold then go to Step 1. Else go to Step 4.

Step 4. Evolutionary stage: (1) selection: the system automatically calculates the fitness of all individuals, the sum of fitness values, and the proportion of individual fitness values in the population. Individuals with higher fitness values in the population are selected to breed into the next generation. (2) Crossover: for chromosome individuals with higher fitness, a cut-off point is randomly selected, and offspring are generated by interchange of chromosomes from the cut-off point. (3) Variation: randomly select one (or two) of the chromosomes to perform binary inverse operation. New offsprings are generated.

Step 5. The offspring binary codes are decoded into the coat style parameters. The offspring style pictures are drawn via the decoding algorithm. In the process of drawing, according to the decoding rules of coat style, the illogical schemes are eliminated. Go to Step 2.

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### Table 1. Binary gene coding scheme for suit shape.

| Shape structure parameters     | Variation range | Binary range | Unit change value | Binary coding location |
|--------------------------------|-----------------|--------------|-------------------|------------------------|
| Depth of collar                | 27–57 cm        | 0000–1111    | 2 cm              | 31–34                  |
| Position of notch              | 6–17 cm         | 0000–1100    | 1 cm              | 27–30                  |
| Width of lapel                 | 4.5–49.5 cm     | 0000–1111    | 1.5 cm            | 23–26                  |
| Depth of notch                 | 2.5–47.5 cm     | 0000–1111    | 1.5 cm            | 19–22                  |
| Angle between roll line and notch | 30°–90°    | 000–110      | 10°               | 16–19                  |
| Angle of notch                 | 0°–120°         | 0000–1100    | 10°               | 12–15                  |
| Width of upper notch           | 2–17 cm         | 0000–1111    | 0.5 cm            | 8–11                   |
| Width of front edge            | 1–31 cm         | 0000–1111    | 1 cm              | 4–7                    |
| Shape of hem                   | Smooth to curves| 0–1          |                   | 3                      |
| Pocket                         | No pocket to have pocket | 0–1          |                   | 2                      |
| Waist type                     | Standard to slender | 0–1          |                   | 1                      |

### Table 2. Coat style coding with mature style.

| Shape structure parameters        | Value    | Binary code |
|-----------------------------------|----------|-------------|
| Depth of the collar               | 51 cm    | 1100        |
| Position of the notch             | 10 cm    | 0100        |
| Width of the lapel                | 6 cm     | 0001        |
| Depth of the notch                | 7 cm     | 0011        |
| Angle between the roll line and notch | 60°      | 001        |
| Angle of the notch                | 80°      | 1000        |
| Width of the upper notch          | 4 cm     | 0100        |
| Width of the front edge           | 2 cm     | 0001        |
| Shape of the hem                  | Smooth   | 0           |
| Pocket                            | Have pocket | 1          |
| Waist line                        | Standard | 0           |

problems and it is different for different problems. On one hand, the larger the number of populations and the better the whole populations’ diversity are, the larger the possibility of the algorithms to find better solutions will be. On the other hand, the larger the number of populations is, the slower the speed of hierarchy will be. The research also shows that the initial population has a great influence on the efficiency and global convergence of genetic algorithm under certain genetic operators.17 Usually, the initial population is randomly generated in IGA (RG-IGA). The RG-IGA algorithm has two shortcomings: one is that the initial population number and selection of random distribution algorithm, which will lead to unreasonable initial value setting and reduce work efficiency, and the other is that the algorithm is easy to fall into local optimum in the later stage of execution.

The typical styles of products are representative of product groups, and they are evenly distributed in the total product population. Therefore, the number of population is set to equal the number of typical product styles and the typical styles are assigned to the initial population of IGA, which is called TS-IGA in this article. The flowchart of automatic design of coat style based on TS-IGA is shown in Figure 3.
Validation tests

On the basis of the above study, a Coat Style Design System based on TS-IGA is developed. The system parameter setting interface is shown in Figure 4, and the main user evaluation design interface is shown in Figures 5 and 6. Fifty male undergraduate and graduate students aged between 18 and 30 were selected for the test. When the users begin to test, the system gives 10 typical coat styles first, which allow them to select and rate initially as shown in Figure 5. They can choose from 10 styles that they are interested in and rate. The rating degree of each style’s satisfaction is an 11-point scale, from 0 to 10. Zero means extremely dissatisfied, 10 means very satisfied. After that, new styles will be generated according to the flowchart of Figure 3. With the iteration of user rating, the satisfaction style is finally obtained as shown in Figure 6.

Table 3 shows the contrast effect between the initial interesting selection style and the final satisfactory style of some test users. In the experiment, it was found that many male users did not have a clear understanding of what style they liked at first. Test results show that 82% of the users could gradually get their favorite style through systematic evaluation. Therefore, the system can effectively predict the user’s coat style demand.

In order to validate the performance of TS-IGA, we also conducted a comparative experiment between RG-IGA and TS-IGA to the same user. Figure 7 shows the comparison of the all test users’ mean value of maximum evaluation score in each generation between TS-IGA and RG-IGA, in which the Y axis represents the fitness of the evolutionary individual and the X axis represents the evolutionary generations of the population. It can be seen that users can get satisfactory design styles on the 11th generation in TS-IGA. By comparison, users can only get satisfactory design styles on the 14th generation in RG-IGA. On each generation, the rating of TS-IGA is always greater than that of RG-IGA.

Figure 8 shows the convergence generation compartment of 20 users between TS-IGA and RG-IGA, in which the Y axis represents the convergence generation, and the X axis represents different user. It can be seen that most TS-IGA cases can get satisfactory style one to six generations ahead of RG-IGA, except the eighth is same.

Discussion and future work

The classic IGA algorithm has two shortcomings: one is the initial population number and selection of random distribution algorithm, which will lead to unreasonable
initial value setting and reduce work efficiency, and the other is the algorithm which is easy to fall into local optimum in the later stage of execution. To overcome the above shortcomings, the TS-IGA is proposed, in which the number of population is set to equal the number of typical product styles and the typical styles are assigned to the initial population of IGA. Therefore, the initial values of the TS-IGA are set rationally and the initial points

**Figure 4.** The system parameter setting interface.

**Figure 5.** The main interfaces of evolutions.
are evenly distributed. These not only speed up the operation of the algorithm but also make the algorithm better and more robust. Experimental results have demonstrated

**Figure 6.** The interface with satisfactory style after eight generations evolution.

**Table 3.** The coat style comparison between some users’ initial interest and final satisfaction.

| Users  | The initial interesting selection | Final satisfactory style |
|--------|----------------------------------|-------------------------|
| User 1 | ![Image]                         | ![Image]                |
| User 2 | ![Image]                         | ![Image]                |
| User 3 | ![Image]                         | ![Image]                |
| User 4 | ![Image]                         | ![Image]                |

**Table 3.** (Continued)

| Users  | The initial interesting selection | Final satisfactory style |
|--------|----------------------------------|-------------------------|
| User 5 | ![Image]                         | ![Image]                |

**Figure 7.** The average fitness compartment between TS-IGA and RG-IGA.
that TS-IGA is effective in generating coat design sketches reflecting users’ preference as shown in Table 3 and Figure 7. Furthermore, TS-IGA can get satisfactory style three generations averagely ahead of the classic IGA as shown in Figure 7.

Clothing is a typical perceptual product. The collar is the most changeable and complex part in coat design and is also an important factor for aesthetic consideration. Therefore, our IGA binary coding scheme mainly focuses on the coat collar structural parameters. The intelligent design approach of personalized customized clothing based on typical style and IGA proposed in this article can generate new personalized coat styles based on user iterative evaluation. Our system is suitable for the scenario where users want to design new styles for themselves instead of retrieving previous designs from a database of apparel firms. Of course, there is still a long way to go from design sketches to garment production. The generation of individually fit basic garment pattern is one of the most important steps in the garment manufacturing process. Individualized pattern making means customized pattern making for individuals. In fact, our system records the corresponding shape structure parameters of the coat style while getting its sketches. There is a corresponding relationship between the shape structure parameters and the pattern design parameters. The individualized patterns can be obtained by transforming the base patterns based on the shape structure parameters. In 3D virtual environment, clothing model can be obtained by stitching clothing pieces to body. Then the clothing can be displayed in 3D virtual environment. In our previous paper, an interactive clothing design and a personalized virtual display with user’s own face are developed and presented in 3D virtual environment.\(^1\) Therefore, our future work plan includes developing individualized pattern generation algorithm, generating clothing 3D model, displaying clothing in virtual reality environment, and so on.

**Conclusion**

This article presents an intelligent design approach of personalized customized clothing based on typical style and IGA. A Coat Style Design System based on TS-IGA is developed. The experimental results show that the designed styles can better meet customers’ preferences. In addition to garment design, this method can be extended to other areas of product automation design. The main contribution of our work includes three aspects.

IGA provides a way for users to participate in product design. First, our approach has intelligence to create feasible and practical designs via simple customer evolution. Some genetic algorithms coding methods based on clothing component do not generate new styles essentially, but just retrieve previous design components from the database and recombine them together.\(^6\)\(^-\)\(^10\) By contrast, our binary coding scheme is shape structure parameter based and has the ability to generate new styles.

Second, whereas some approaches model dress designs in 2D sketches by several spline curves.\(^11\)\(^,\)\(^12\) However, the scheme takes the key points of spline functions of product contour as the modeling parameters, ignoring uniform design and subsequent manufacturing parameters. By analyzing the relationship between typical style and form parameters, we propose a binary coding method based on coat style parameters and apply it to IGA design. This will facilitate the subsequent individualized pattern generation.

Third, as well known, the key issue for IGA is that due to the need to guide the evolution direction of the system via user evaluation, frequent evaluation can easily lead to user fatigue. In this article, we propose a typical style based on IGA approach. Experimental results have shown that TS-IGA can converge earlier, has better performance, and can reduce users’ fatigue compared with classical IGA.

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