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Fashion set design with an emphasis on fabric composition using the interactive genetic algorithm

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Abstract

Today, with increasing development of digital technologies and their use to promote and accelerate artistic production trends as well as decreasing utilization of manual and traditional methods, the use of computers has had a special place in fashion design. The present research seeks to design a fashion system utilizing a set of fabric patterns through the interactive genetic algorithm to produce artistic creativity and a set of clothes designs. First, clothes components, including top, crown, skirt, blouse, sleeve and shoes, and fabric patterns proportionate to each clothes component are designed and coded separately. This system combines clothes components and fabric pattern set, using the interactive genetic algorithm and laws based on fashion design. Then, fitness of the designs created is determined by the user and next generations are produced by this fitness and evolution principles so fashion design trend is performed by the user's opinion. The results of evolutions indicate system efficiency in fashion set design using a fabric pattern set at the least cost and shortest time according to user tastes.

Keywords: Fashion set design, Fabric composition, Fashion system, Interactive genetic algorithm

Introduction

Clothing industry is important as one of representations of human civilization for long and always seeks to compete with other industries, using modern technologies. The dressing type of people in a society is directly related with their social culture. Research indicates that the dressing type of individuals is highly effective to create self-confidence and personality credibility (Callis 1982). Individuals in a society use clothing as a tool of confirming or displaying their social situation (Zarenejad et al. 2014). At the present, with respect to the importance of clothing in communities and increased competition in market, application of perfect methods in fashion design, clothing production and sales is very vital. Since fashion design is affected by fabric design industry, fabric pattern sets can be used to design homogenous, and also various, clothes to attract customers of different groups. These fabric patterns produced by different combinations of forms, colors, pictures and other visual elements can satisfy different needs of different groups

of customers including the fulfilling of personal taste, the creating of psychological influence on individual personality, the covering of physical defects, the strengthening of representation of specific body characteristics, the creating of aesthetic representations in clothes etc. Without the use of different cuttings and or expensive and time-consuming decorations. To emphasize a beautiful part of the body, for example, large pattern fabrics or bright colors can be used. While relatively dark colors or those in harmony with the environment should be used to cover physical defects. In general, the use of different visual elements for producing patterns of a fabric set allows you to create different visual effects to communicate customer-friendly concepts; there is no need for extreme cuttings and decorations. So, it takes less time and costs less to design and sew clothes. Due to the fact that the clothes set designed and produced has a variety of sizes, colors, densities and pattern forms, customers can have more free choices. In addition, the use of different representations of a fabric set, instead various cuttings and decorations, results in decreased production costs and increased product sales; before producing a design, mass producers and purchasers can survey the clothes design and color from their customers using digital technologies and employ their opinions in the design process. Today, the use of computer aided design software in clothing, especially in fashion design, has attracted much attention. The genetic algorithm is among algorithms used in fashion design, which many people have used it in computer aided design systems to promote design (Barari et al. 2010a, b, 2011; Payvandy 2005, 2007; Zamani et al. 2009).

Literature review

The genetic algorithm is an optimization technique inspired by the nature of living organisms, which is also referred to as the evolutionary algorithm; it is used to optimize problems in various industries (Fesahat and Payvandy 2013). In fact, The genetic algorithm is a spanning probabilistic search method which follows natural biological evolution process. The genetic algorithm acts upon a population of potential solutions, and employs the principles of struggle for survival to produce better and better approximations to the solution to a problem. In every generation, a new set of approximations is built by the process of selection of the best member based on their fitness degree within the range of the problem and by reproduction via operators derived from natural genetics. This process, finally, ends up in population evolution of members having a better adaption to environment than the initial generation that is, in fact, their parents (Beasley et al. 1993).

The fitness degree of members in every generation within the genetic algorithm is performed by the fitness function; however, there are problems that are impossible and or difficult to be evaluated because the evaluation of some problems is only made by human mind and there is no scale to measure them quantitatively. To solve this problem, the interactive genetic algorithm was devised, in which the fitness function is replaced by human's evaluation. An interaction is created between human and computer, which has partly solved problems with the genetic algorithm in the respect. The advantage of the method is that human is not required to be aware of details, and he is only concerned with output evaluation. The interactive genetic algorithm is like the genetic algorithm, except the difference in the expression method of the fitness degree. For this reason, the interactive genetic algorithm can be used to solve problems like art and design which are

not solved by the genetic algorithm easily (Zamani et al. 2009). Figure 1 shows the difference between the genetic algorithm and interactive genetic algorithm.

The subject was raised by Charles Darwin in the principles of species survival first. The basic principles of the genetic algorithm (GA) were raised by John Holland in 1975 (Beasley et al. 1993). Following some researchers, Kim and Cho (2000) presented a computer aided fashion design system, based on the genetic algorithm. In this system, clothes designs are divided into three parts trunk, collar and sleeve, based on a new method of coding. Lee et al. (2001) allowed the user to directly manipulate in order to prevent generations from worsening. Sano and Yamamoto (2001) presented a three-dimensional computer aided fashion design system which could measure the body form of a customer and simulate Japanese Yukata clothes. To prevent user fatigue, as well as apply her personal opinion, during generation production, direct manipulation can be used (Honolulu 2002). With efforts of Volino et al. (2005) a framework and details, which are matched with requirements of clothing industry, were obtained to design virtual clothes and modeling with focus on interactive design, simulation, and visualization features. In fact, this is an evolutionary tool of productivity and quality in the process of fashion modeling ad design, which is effective in mechanical simulation and animation. Gong et al. (2007) have presented a new algorithm based on a multi-population method and mutation strategy, which can create diversity within population, improve the capability of exploitation and exploration, prevent from eliminating the fittest generation, and reduce user fatigue. Ogata and Onisawa (2007) have presented a fashion design support system, using the interactive genetic algorithm, which allows applying users' opinions. After producing designs, the system shows some models to the user, and then according to evaluation and application of the operators of the genetic algorithm (selection, crossover and mutation), produces better designs. Gong et al. (2008a, b) determine its evolutionary path based on differences of individuals' fitness among genes to reduce two errors stemmed from random visual systems and customer taste mechanism and increase the efficiency of the interactive genetic algorithm. Results indicate the effect of the presented strategies in reduced errors and improved algorithm. Yuan and Gong

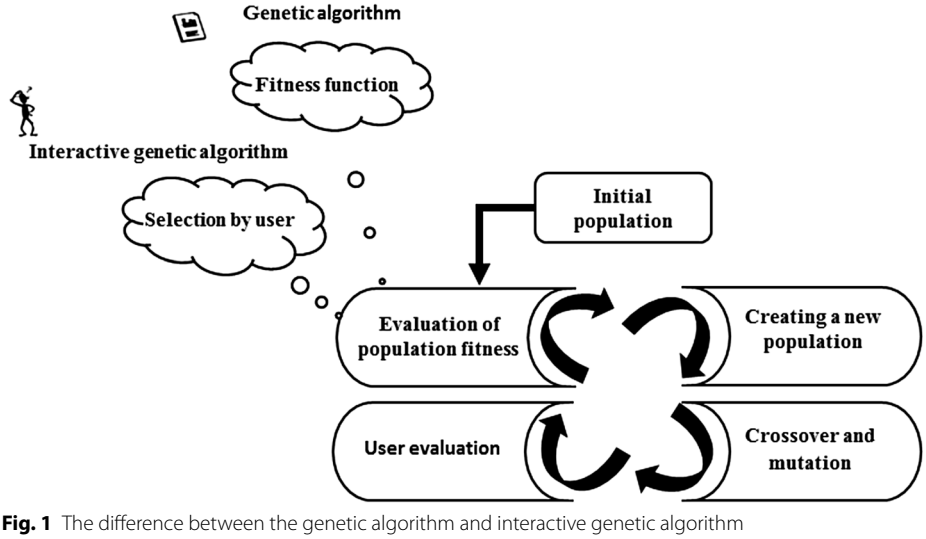


Fig. 1 The difference between the genetic algorithm and interactive genetic algorithm

(2008) presented an interactive genetic algorithm of a large group with individuals' fitness not assigned by the user. Population is divided into some groups, and the majority of the group is changeable through expansion and population distribution. In this algorithm, the user evaluates just one sample placed in the center of population, and accordingly other members' fitness is calculated automatically. Experiments and studies represent the advantage of the algorithm to traditional interactive genetic algorithms. Instead of determining fitness, Gong et al. (2008a, b) selected and recorded a sample of population, with respect to sensitivities, as the user's satisfactory sample or unacceptable sample to solve the problem of user fatigue in the interactive genetic algorithm, its fitness is calculated automatically by transfer from time space to fitness space, and the genetic operators are applied on it. Tseng et al. (2009) have utilized computer vision for recognizing clothes features in a variety of applications including customer taste recognition and suggestion of similar clothes. Because of the importance of the customer's opinion on clothes fitness after the element of quality, Barari et al. (2010a, b) have employed the interactive genetic algorithm to produce Iranian dress designs. First, the designs obtained in the initial step are given to the user and the user determines their fitness degree. Then, fitness of other designs is obtained by their similarity degree to the initial designs. Results indicate user-friendly design productions after certain numbers of algorithm replication. Using the interactive genetic algorithm, Mok et al. (2012) have presented a fashion sketch design system to accelerate the design process: (1) a design model based on design knowledge to describe the features of the fashion product using developed parameters; (2) a database based on suggesting a fashion design method to define the elements of a general style; and a multi-stage sketch design motor. Empirical results indicate that the proposed method is effective to help ordinary people achieve fashion sketch design. Mok et al. (2013) have presented a customized fashion design system for nonprofessional users and customers, which includes a design, combination method, model designed by the interactive genetic algorithm, and graphical interface evaluated by the user. Empirical results indicate that the proposed system is effective to create user-friendly fashion sketch designs. Zeng et al. (2013) presented an intelligent recommender system to support personal fashion design. In the system, two models specifying the relationships between body measurements and individual's inference of body shape are introduced; it allows an evaluation of a series of new design styles for a special customer and special content. In this approach, intelligent methods such as decision tree, cognitive maps and fuzzy relation calculations are used. In studying customer behavior in the process of clothing purchase, factors such as design, size, color and quality are important, but clothes design is most important Zarenejad et al. (2014). So, if a set of similar clothes designs with various and attractive details is existed in market, they will attract attention of different groups of customers. The research, therefore, tries to present a computer aided fashion design system, which can employ various types of fabrics designed as a set by using the interactive genetic algorithm and considering consumer's taste in fashion set design.

Methods

The present research utilizes the interactive genetic algorithm to promote fashion design level, increase productivity of fashion products, and create confidence in mass producers and purchasers, which its steps are presented in Fig. 2.

Preparation of database

Data used in the research is two types: clothes designs and fabric patterns. First, clothes components including seven parts top, collar, skirt, belt, blouse, sleeve and shoe are designed by consultation with fashion designers and using the CorelDRAW software each in 10 different designs. Next, fabric patterns, which are designed in 80 various patterns as a set, are divided into seven groups based on their proportion degree for use in each clothes component in order to be utilized in clothes composition, which the number of their designs is variable. It is worth to mention that in the research, fit among fabric patterns is determined by their fineness and largeness, i.e. their cutting, in sewing step to be used in each clothes component. The number of clothes components, the number of fabric patterns, and their totals are presented in Tables 1 and 2.

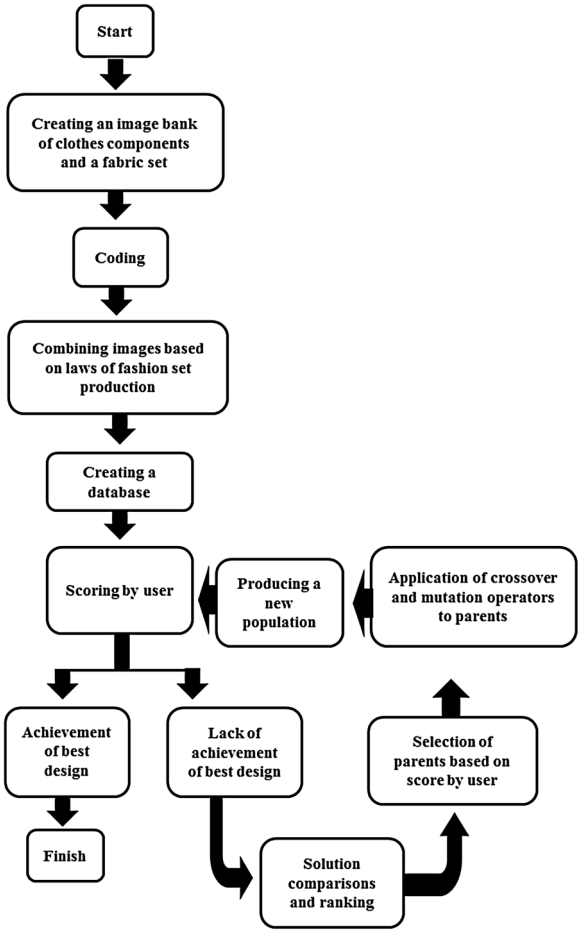


Fig. 2 Implementation trend of the interactive genetic algorithm in fashion design

Table 1 The number of clothes components, the number of fabric patterns proportionate to each component, and their totals

Clothes components	Number of each clothes component	Number of fabric patterns proportionate to each component	Total of each component, and of fabric proportionate to it
Top	10	65	650
Collar	10	28	280
Skirt	10	77	770
Belt	10	77	770
Blouse	10	80	800
Sleeve	10	77	770
Shoe	10	10	100
Total of number of clothes components and fabric patterns			~10^8 designs

An example of a garment (chromosome) and two groups of genes (clothes components and fabric patterns) is shown in Fig. 2.

Coding (conversion of a problem to genes and chromosomes)

To solve a problem through the interactive genetic algorithm, the genes in the problem must be coded so that they can be understood. In the research, each clothes design is coded as chromosomes, and clothes components and fabric patterns are coded as genes in the problem through the value coding method, as seen in Fig. 3. In the research, chromosomes have two parts, and consist of 14 genes. The first part as clothes components includes top, collar, skirt, belt, blouse, sleeve and shoe, and the second part is fabric patterns proportionate to each clothes component (according to its feature of scissoring).

According to Fig. 3, the procedure is that in step 1, fabric patterns and clothes components along with a model are called. In step 2, clothes components and desired fabrics for each of them are chosen by sliding controls. In step 3 and 4, laws related to clothes component compositions and fabric pattern compositions are formulated, respectively. Step 5 is to store and exit the program.

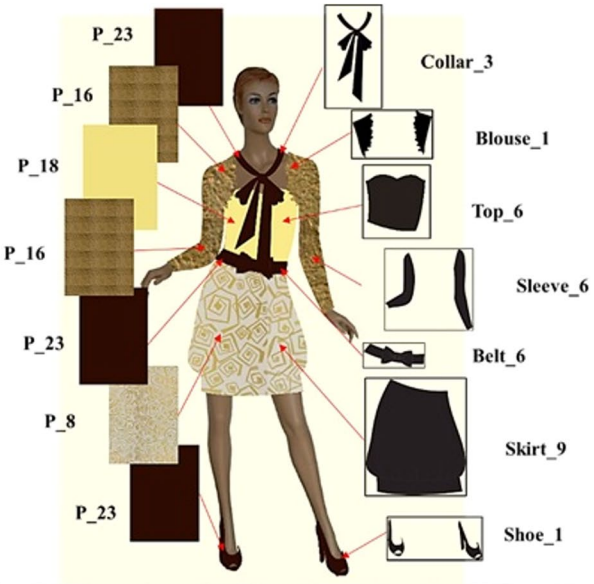
Formulating laws based on principles of fashion design

First, the fitness degree of each pattern of the fabric pattern set is examined to use in designing clothes components (based on pattern fineness and largeness and the prevention of their breakage when cutting fabrics in final production step) and, then, a chromosome consisted of clothes components and patterns proportionate to each clothes component are given to the software as coded ones.

In the genetic algorithm, the initial population is randomly selected from a combination of the parts in Table 1, column II and 80 designs. Considering that the number of the initial population is restricted to eight designs, it is more likely that there will be designs considered as being defective based on the initial principles, resulting in its decreased efficiency. In order to prevent the production of defective designs, laws are applied. For example, if the fabric pattern of the blouse is fine, the fabric pattern of the sleeve should not be fine. To be visual, a visual system was prepared when formulating the laws, where the software designer creates different compositions of clothes components and fabric

Table 2 Clothing and textile designs and the total number of components

The number of components clothing							The number of fabrics can be used in any part of the dress							The total number of projects
Top	Collar	Skirt	Belt	Blouse	Sleeve	Shoe	Top pattern	Collar pattern	Skirt pattern	Belt pattern	Blouse pattern	Sleeve pattern	Shoe pattern	
10	10	10	10	10	10	10	65	28	77	77	80	77	10	$\sim 3 \times 10^{15}$



Top	Collar	Skirt	Belt	Blouse	Sleeve	Shoe	Top Pattern	Collar Pattern	Skirt Pattern	Belt Pattern	Blouse Pattern	Sleeve Pattern	Shoe Pattern	Chromosome
6	3	9	6	1	6	1	18	23	8	23	16	16	23	

Fig. 3 An example of a garment (chromosome) and its components

designs, and records proper compositions as a law. In the genetic algorithm all designs created are adapted to the laws at all stages of design production. If they comply with 80 % of the design laws, designs will be chosen. In fact, genes forming each chromosome are crossed over, based on these laws, to produce initial generation. So, eight clothes designs are produced as initial generation. Figure 4a shows steps of formulating laws based on principles of fashion design for designing a set.

According to Fig. 4a, the procedure is that in step 1, fabric patterns and clothes components along with a model are called. In step 2, clothes components and desired fabrics for each of them are chosen by sliding controls. In step 3 and 4, laws related to clothes component compositions and fabric pattern compositions are formulated, respectively. Step 5 is to store and exit the program.

First generation

In the present research, according to laws based on the investigator's principles of fashion design accounted for the purpose of fashion set design using a fabric set, genes in the problem (clothes components and fabric patterns) are crossed over. The said laws are formulated by professional experiences in the field selected from university professors. Considering that these professionals have adequate experience in and knowledge of fabric pattern compositions in fashion design, they can present default laws to the fashion design system and guide the interactive genetic algorithm to reach proportionate clothes designs. Because applying these laws in fashion design makes it easy to be used by non-professional users (no having knowledge of fashion design). An example of first generation designs is presented in Fig. 4b. Given that one of main aims of a fashion design system to reduce time in design, it worth to note that production and representation of

Fig. 4 **a** Steps of formulating laws based on principles of fashion design for designing a fashion set. **b** First generation. **c** Presentation of some designs to the user for evaluation. **d** Selection of parents by the Roulette wheel

every eight designs in the system are less than one second, which is less in comparison with manual design. Because time required for design evaluation in each generation by users varies, the final use of the system is extremely varied. In the research, four generations are created to prevent user fatigue, which are constant in algorithm iterations. Generation evolution in the algorithm is made by evaluating clothes designs by the user and by applying her opinions as fitness function to select parents in order to produce future generations.

Presentation of designs to the user for evaluation

After having produced the first generation based on principles of fashion design, clothes designs are presented by a page called graphical interface to the user for survey. Figure 4c shows graphical interface related to the user's evaluation. The interactive genetic algorithm used in the paper has two dimensions. The first dimension is to technically discuss gene compositions within chromosome framework, performed by laws of fashion design art and by a software designer (using the genetic algorithm); the second is to use the customer's opinions to increase the productivity of clothes designed before producing and supplying them to market, using the interactive genetic algorithm. To show designs to the user for evaluating means that designs produced by the genetic algorithm in the initial population are shown by graphical interface pages to seek customer opinions, and the customer rates designs from 1 to 10. These points are stored as design value in the system. Each design obtained a higher point by the customer has a higher chance of

being chosen. The customer survey is performed several times, which makes the IGA-based fashion design system process and customer opinions consistent.

Selection of parents

In the present research, selection of a clothes design (chromosome) is made by a rotating wheel called Roulette wheel and based on maximum fitness. The Roulette wheel functions as following. It produces a random number between 0 and 1 to select a clothes design; a clothes design corresponding to the number within an interval is selected. Of course, it is implemented as following. A circle is considered and divided into parts equal to clothes designs such that each part is related to the fitness degree of a clothes design. The wheel is rotated and everywhere is stopped, on looks at the wheel index and selects a clothes design related to the part. Therefore, every member having more fitness will have more chance. With each rotation of the wheel, a design is selected and is affected by the crossover and or mutation operators to produce next generation as parents. Selection of parents by the Roulette wheel is shown in Fig. 4d.

Operators of the genetic algorithm

The genetic algorithm requires methods derived from the principles of biological evolution to produce a new generation from the initial generation. These methods are operators that affect the members of the initial generation and evolve them for evolution of next generations. The operators used in the research include crossover and mutation operators. They will briefly explain.

Crossover operator

In the crossover operator, two chromosomes selected as parents are subject to two-point crossover, that is, two points of chromosomes are selected randomly and jointly between the two and both of the points are cut. Next, divided parts of chromosomes are exchanged, generating children. Two-point crossover is shown in Fig. 5a. It is worth to note that because of using two types of genes (clothes components and fabric patterns) forming chromosomes in the research, two-point cutting is performed on two types of genes; however, the cutting points of clothes components and of fabric patterns necessarily are not common. As seen in Fig. 5b, the cutting points of part of chromosomes associated with clothes components are before belt and after blouse while part of chromosomes associated with fabric patterns are cut from points before collar and after belt.

Mutation operator

In the research, 20 % of chromosomes will be mutated. First, a gene is selected randomly and mutated. Next, the resulting chromosome is compared with the chromosomes proposed by the designer in the formulated laws, and is replaced by the chromosome having the least similarity to it. This type of mutation is made because it proposes ideas to the user, which do not exist in the chromosomes produced by the crossover operator. The comparison of the mutated chromosome with laws based on principles of fashion design is made due to the prevention of producing imperfect and defective (according to principles of fashion design). So, different compositions of fabric genes are proposed to the

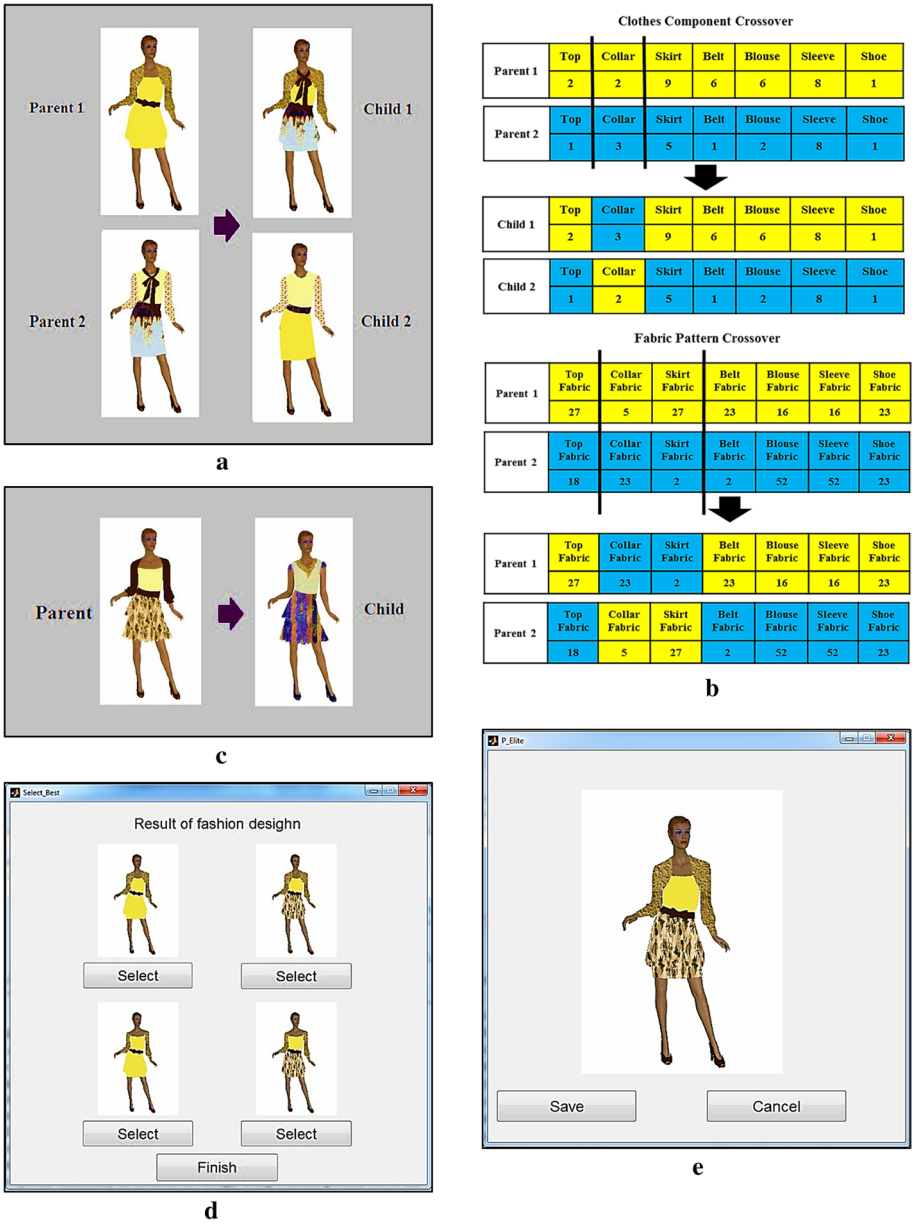


Fig. 5 **a** The *graphical* representation of the function of the two-point crossover operator. **b** The function of the two-point crossover operator as coded one. **c** The function of the mutation operator. **d** The representation of four elite clothes designs. **e** The representation of the best clothes design

user so that the user has more choice through creating diversity in options. In Fig. 5c, an example of mutation is presented.

Representation of the elite of each generation to the user for selecting the final design

In this stage of design, the best designs of generations selected by user opinions are four elite designs of four generations of the algorithm, which are represented by graphical interface to the user to select one design as the best design. Graphical interface associated with the stage is shown in Fig. 5d.

The representation of the best clothes design

After the final evaluation of the four generations of the algorithm by the user, a design is selected as the nearest one to the user's opinion and as the best produced design through the interaction with the user, which its output can be stored as an image. An example of the representation of the best clothes design in the system is shown in Fig. 5e.

An examination of convergence

After creating clothes designs in first generation, the system continues the number of generation productions, which is three generations (considering first generation, four generations) here, and members of each generation are evaluated by the user. This is done by the system to converge the user's taste and fashion design trend. At the end, the best member of each generation is presented to the user to create the possibility of selection of the best design among the elite. By selecting one of options, the best design is resulted from implementing the interactive genetic algorithm one time. Examples of the results from designing via the software are presented in Fig. 6.

Results and discussion

In the research, the interactive genetic algorithm becomes optimum, using laws based on fashion design, for designing a clothes set through fabric patterns. Given that the user's opinion plays a fundamental role in the fashion design process as fitness function, a questionnaire was designed to qualitatively examine the efficiency of the fashion design system, and given to 38 people In the questionnaire, at first, users' personal information shown in Table 3 and Fig. 7 was asked.

To conduct this survey, first, we described its use to people, and then asked them to make fashion design through it. After they communicated with the system in practice and evaluated clothes designs produced, people expressed their opinions in written and by answering multiple-choice questions. The items related to the survey and the answers to them are presented in Table 4 and Fig. 8, respectively.

The results from the questionnaire shown in Fig. 8 indicate, in the order of items, that 73 % users are satisfied with communicability of the system with the user. Given

Fig. 6 Examples of clothes designs produced by the system

Table 3 Users' personal information

	Answer 1	Answer 2
Age	20–35	35–50
Education	BA	MA
Course	Fashion design	Other
Marital status	Married	Single

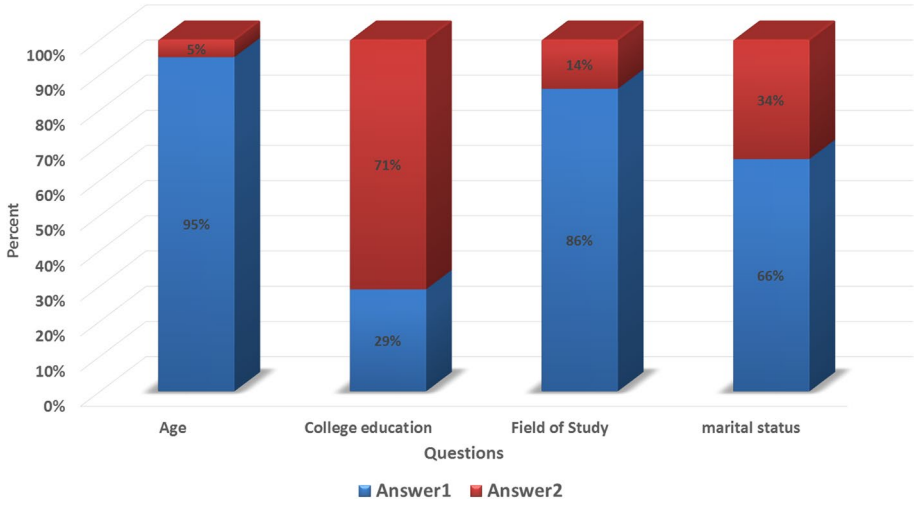


Fig. 7 Users' personal information

Table 4 The fashion system efficiency evaluation questionnaire

No.	Questions	1	2	3	4
1	How is communicability of the fashion system with the user?				
2	To what extent were principles of set design observed in produced designs?				
3	How is the efficiency of the fashion system in designing various designs?				
4	How do you evaluate the speed of fashion design by the system?				
5	How is the efficiency of the system in terms of cost-efficiency and time-efficiency?				
6	To what extent will produced designs help you select a desired clothes design?				
7	How is the effect of users' tastes in fashion design trend by the system?				
8	In your opinion, how is the effect of the system in attracting customers?				

Offers 4 point evaluation scale: *1* perfect, *2* good, *3* medium, *4* week

that manual design is difficult and time-consuming, 76 % of users prefer fashion design through the system to manual design, and 68 % say that the system can design various designs. The speed of fashion design by the system is confirmed by 89 % of users, and 92 % of users believe that the use of the system will result in saving in time and cost. The results show that 52 % have achieved their desired designs, and the high effect of users' tastes in the fashion design process is confirmed by 60 % of users. Also, 73 % say that the system can be successful at attracting customer satisfaction. As to the two final items, 71 % of users say that the designed system is effective to promote fabric and fashion

Fig. 8 The statistical results from the survey

design field, and 84 % believe that the system presented in the paper can be used as an effective educational aid in fashion design using a consistent fabric set.

After they answered the items, people made suggestions to qualitatively promote the system, including (1) adding different types of clothes components and selecting clothes components by specific users, (2) allowing it to offer custom fabric patterns for specific customers, (3) three-dimensional display of clothes on models, (4) displaying the back of clothes for better use of produced designs by the user, (5) display of sewing and cutting details, and (6) presenting designs on the Internet for virtual selection and order.

After evaluating the fashion design system, it can be said conclusively that fashion companies can use it in industry by surveying different people in society (including specific customers or the general public) to find popular clothes designs and models produced by the system, and then start producing fabrics, modeling and sewing clothes with minimum risk. Fashion companies can offer sets of fabric patterns to the system designers to add to the system data bank. Considering that fabric patterns and clothes components are presented to the system to design a fashion set, models produced and evaluated are consistently associated and can be introduced into market as a set.

Conclusion

In the modern world, with respect to the inefficiency of manual and traditional fashion design because of reduced speed and precision, and increased cost and trial and error, as well as increased competition in fashion industry, the necessity of reduces in costs, and the fulfilling of various demands by consumers, the utilization of digital technologies can develop this industry. In the present research, a system is presented in which clothes designs are developed by the interactive genetic algorithm and principles based on laws of fashion design of set design, and by presenting them to the user, design trend is led to consumer taste. First, a number of clothes designs are crossed over by a combination of clothes components and fabric patterns, based on the said laws, and then are presented to the user for giving their opinions. The results obtained represent users' 73 % with the proposed system. The use of a set of products is effective to attract audiences' tastes;

to give their pre-representation to the user, before production and supply in market, results in corrections in design process through consumer evaluation and artisans' confidence in mass production of these designs. The system, therefore, can be used to design a clothes set, and consumer opinions are also applied in their design before production and supply in market. Furthermore it can seek more customers' opinions online and customers can choose and order their considered designs in the internet store. However the presented method have some limitation like as small population number, design details and 2D design illustration which will be mentioned in future work.

Authors' contributions

PP designed the study. MK prepared the manuscript under guidance of PP. SJD gave encouragement and some advise. All authors read and approved the final manuscript.

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Competing interest

On behalf of all authors, the corresponding author states that there is no competing interest.

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