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RESEARCH

The simulation modeling to choose styles of torso dresses by fuzzy logic

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This study presents the use of the fuzzy logic technique in choosing Torso dresses for online shopping. Dress styles are established based on analyzing three factors that prioritize clothing selection using the Pareto chart. These factors include the dress's form, thickness, and color fabric of the dress. These are the three input variables of this model, and each of them has different membership functions. The first input variable is the form of the modeling, and has two membership functions. The second is the fabric type that can be used for dresses, and has five membership functions. The third input variable is the color of the fabric, and has three membership functions. The output is a type of outfit looked for so the actual survey method is conducted in the customers-interest-scale of clothing. The fuzzy If-Then rule and Sugeno controller are used in this modeling. There are 30 Torso dress styles coded for application to fuzzy logic modeling. Besides, the theoretical method is applied in a 2D flat pattern designing a basic Torso pattern and a fuzzy logic model. Additionally, albums of dress styles are created by the 3D simulation method as well as the model's feasibility is evaluated by the expert method.

Keywords: torso dresses, fuzzy logic, pareto, simulation, factor

1. Introduction

Up to now, internet technology has exploded and come into widespread use, and the number of customers shopping online is always increasing day by day (1). Companies and businesses always strive every day to satisfy consumer needs. Besides illustrators, introductory content, and product descriptions, there is also a great appearance of clothes to attract customers' attention (2, 3). Indeed, some authors have set up a dataset of more than one hundred thousand images labeled with brands, types, colors, materials, and prices so that customers can choose the right clothes when shopping online (4–7). Additionally, many businesses have seen the strong influence of the Internet potential on consumers, which leads them to create a lot of online shopping websites such as research (8–12). On such websites, customers will choose sizes and try on clothes through a virtual simulation program which helps them fit clothes in a short time. For customers who do not have experience in purchasing clothes online, there is also a supporting website through the advice of fashion experts such as studies (13, 14). For the product to meet the needs of customers, a research group has studied to find the factors that affect the buyers' decisions (15–17). Similarly, the method of comparing offline and online shopping behavior of buyers has been researched by some authors, and they have found out the motivating factors affecting customers' purchases online. These factors are the customer's favorite fashion style, and the combination of materials or colors as research results (18, 19). To create an additional direction for choosing clothes online, the content of this paper presents the use of the fuzzy logic simulation to choose Torso dress styles that match customer preferences in terms of form, color, and fabric.

2. Materials and methods

Basic Torso patterns use for draping dresses on avatars. There are five groups based on the fabrics' thickness, and this is set according to the database of the CLO3D software. The first group is very thin fabrics including chiffon, voile, and muslin. The second is the thin ones including silk fabric and brocade fabric. The third and fourth groups are medium-weight and thick fabrics, respectively. Cotton and linen fabrics belong to medium-weight fabrics, while denim and khaki fabric belong to the thick ones. The very thick fabrics are the final group including denim fabric and khaki fabric.

The 2D Torso patterns work is designed on the Gerber Accumark software, combined with the simulation on CLO3D software to create a dress collection. To choose a Torso dress style, the author designed a simulation program by using the fuzzy logic technique. In addition, the experimental content is conducted through customer behavior surveys, which are analyzed according to the Pareto chart. Finally, the simulation modeling results have checked the expert method's feasibility.

3. Results and discussion

3.1. Survey analysis based on customer behavior in choosing clothes

This is the first study that was conducted on 145 female customers' positions, who are 18 to 25°years old based on five factors: form, fabric, color, decoration, and price. The survey is analyzed by Pareto chart (**Figure 1**) and there are three factors mostly affecting clothes consumption on the customer service website: form, fabric, and color.

In terms of the dress fabric, there are 7 thickness factors: medium, thin, thick, very thin, very thick, lace, and knit that exert influence on buyers' selection. According to the chart, customers give priority to medium, thin, thick, very thin, and very thick fabrics (**Figure 2**).

There are also 4 features in the field of the dress form: fit, wide, very wide, and tight dress. As a result, female prefer to choose fit and wide dresses (**Figure 3**).

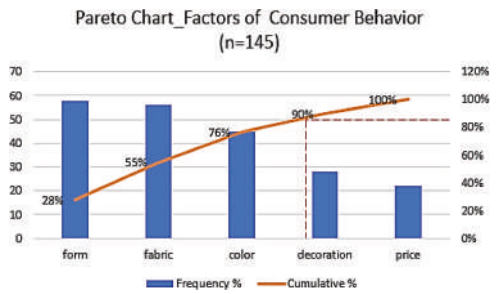

FIGURE 1 | The Pareto chart of factors affecting customer behavior.

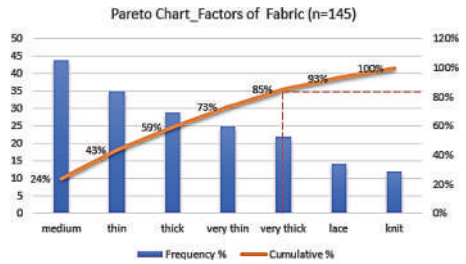

FIGURE 2 | The Pareto chart of factors affecting choice of dress fabric.

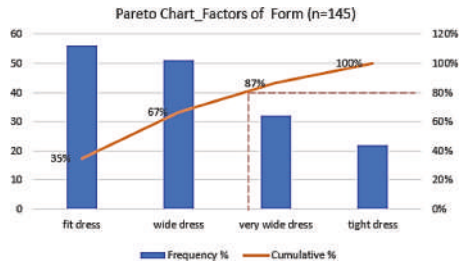

FIGURE 3 | The Pareto chart of factors affecting choice of dress form.

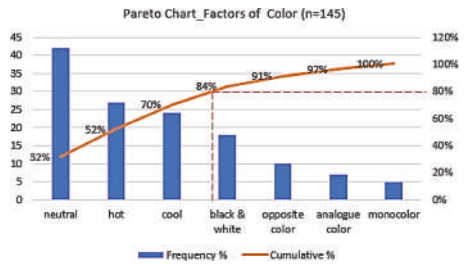

FIGURE 4 | The Pareto chart of factors affecting choice of dress color.

Moreover, the dress color include: neutral, hot, cool, black and white, opposite color, analog color, and mono-color. Neutral, hot, and cool are the favorite colors among the others (**Figure 4**).

Through the survey results, the fabric type, form, and color are three factors mostly affecting the customers' choice. These three factors are used as three input variables of the fuzzy logic simulation. Thereby, the total number of costume samples according to the fuzzy control modeling in the research is obtained by the following formula:

$$y = x_1 \times x_2 \times x_3 \quad (1)$$

where

y: samples

x_1: membership functions for the dress form

x_2: membership functions for the dress fabric

x_3: membership functions for the dress color

From formula (1), the total number of samples in the study can be calculated:

y = 2∗5∗3 = 30 (samples)

3.2. Coding dresses

The rules matrix of the simulation modeling is presented in Table 1. The numeric "0" doesn't combine between the dress form and the fabric. The numeric "1" combines between the dress form and the fabric.

Based on the presented three input variables, combining the number of modelings from (1) will have 30 samples of Torso dresses and perform sample coding as shown in Table 2.

3.3. Coding dresses

The Torso dress collection is obtained after simulating 30 Torso patterns according to three input variables in a fuzzy logic modeling with styles in Table 3. The figure number of each type corresponds to the encoding number of that type.

Torso patterns are designed by the 2D method of the formula system (20). Next, these patterns are draped on the avatar by CLO3D software. Measurements of body dimensions in the size chart are size 8 so the avatars sizing is edited to size 8 as well. Torso patterns include a front body, a back body, and a sleeve (Figure 35).

TABLE 1 | Rules matrix of sizes.

	Fabric					Color		
Dress form	**Very thin**	**Thin**	**Medium**	**Very thick**	**Thick**	**Hot**	**Cool**	**Neutral**
Fit form	1	0	0	0	0	1	0	0
	1	0	0	0	0	0	1	0
	1	0	0	0	0	0	0	1
	0	1	0	0	0	1	0	0
	0	1	0	0	0	0	1	0
	0	1	0	0	0	0	0	1
	0	0	1	0	0	1	0	0
	0	0	1	0	0	0	1	0
	0	0	1	0	0	0	0	1
	0	0	0	1	0	1	0	0
	0	0	0	1	0	0	1	0
	0	0	0	1	0	0	0	1
	0	0	0	0	1	1	0	0
	0	0	0	0	1	0	1	0
	0	0	0	0	1	0	0	0
Wide form	1	0	0	0	0	1	0	0
	1	0	0	0	0	0	1	0
	1	0	0	0	0	0	0	1
	0	1	0	0	0	1	0	0
	0	1	0	0	0	0	1	0
	0	1	0	0	0	0	0	1
	0	0	1	0	0	1	0	0
	0	0	1	0	0	0	1	0
	0	0	1	0	0	0	0	1
	0	0	0	1	0	1	0	0
	0	0	0	1	0	0	1	0
	0	0	0	1	0	0	0	1
	0	0	0	0	1	1	0	0
	0	0	0	0	1	0	1	0
	0	0	0	0	1	0	0	1

TABLE 2 | Rules matrix of sizes.

	Torso dresses	Figure	Coding number
1	Fit form, very thin fabric, hot color	(Figure 5)	1
2	Fit form, very thin fabric, cool color	(Figure 6)	2
3	Fit form, very thin fabric, neutral color	(Figure 7)	3
4	Fit form, thin fabric, hot color	(Figure 8)	4
5	Fit form, thin fabric, cool color	(Figure 9)	5
6	Fit form, thin fabric, neutral color	(Figure 10)	6
7	Fit form, very thick fabric, hot color	(Figure 11)	7
8	Fit form, very thick fabric, cool color	(Figure 12)	8
9	Fit form, very thick fabric, neutral color	(Figure 13)	9
10	Fit form, thick fabric, hot color	(Figure 14)	10
11	Fit form, thick fabric, cool color	(Figure 15)	11
12	Fit form, thick fabric, neutral color	(Figure 16)	12
13	Fit form, medium fabric, hot color	(Figure 17)	13
14	Fit dress, medium fabric, cool color	(Figure 18)	14
15	Fit form, medium fabric, neutral color	(Figure 19)	15
16	Wide form, very thin fabric, hot color	(Figure 20)	16
17	Wide form, very thin fabric, cool color	(Figure 21)	17
18	Wide form, very thin fabric, neutral color	(Figure 22)	18
19	Wide form, very thick fabric, hot color	(Figure 23)	19
20	Wide form, very thick fabric, cool color	(Figure 24)	20
21	Wide form, very thick fabric, neutral color	(Figure 25)	21
22	Wide form, thick fabric, hot color	(Figure 26)	22
23	Wide form, thick fabric, cool color	(Figure 27)	23
24	Wide form, thick fabric, neutral color	(Figure 28)	24
25	Wide form, thin fabric, hot color	(Figure 29)	25
26	Wide form, thin fabric, cool color	(Figure 30)	26
27	Wide form, thin fabric, neutral color	(Figure 31)	27
28	Wide form, medium fabric, hot color	(Figure 32)	28
29	Wide form, medium fabric, cool color	(Figure 33)	29
30	Wide form, medium fabric, neutral color	(Figure 34)	30

3.4. Fuzzy rules

Sugeno fuzzy control modeling is used for the study. Fuzzy rules are established from membership functions in three input variables and one output result (Figure 36). The first input variable is the form of the modeling. The second is the fabric type that can be used for dress, and the color of the fabric is the final variable.

There are two, five, and three membership functions for the first, second, and third input variables, respectively, (**Figure 37**). There are also 15 samples for the fit form showing from 1 to 15, and the same quantities are used for the wide form showing from 16 to 30. Every fabric group has 6 samples as well as every color has 10 samples. The first variable is the dress form in which its membership functions are the medium-dressed range [0.5 2 3 5], and the wide-dressed range [4 7 8 10]. The second variable is the fabric thickness with five membership functions representing five levels of it. Very thin and thin fabrics are [−1 0.5 1.5 3] and [2 3.5 5], respectively. Medium fabric is [4 5.5 7]. Thick and

TABLE 3 | Figures of Torso dresses.

Fabric	Hot color	Cool color	Natural color
Fit form, very thin fabric	 **Figure 5** | The style of sample 1.	 **Figure 6** | The style of sample 2.	 **Figure 7** | The style of sample 3.
Fit form, thin fabric	 **Figure 8** | The style of sample 4.	 **Figure 9** | The style of sample 5.	 **Figure 10** | The style of sample 6.
Fit form, very thick fabric	 **Figure 11** | The style of sample 7.	 **Figure 12** | The style of sample 8.	 **Figure 13** | The style of sample 9.
Fit form, thick fabric	 **Figure 14** | The style of sample 10.	 **Figure 15** | The style of sample 11.	 **Figure 16** | The style of sample 12.
Fit form, medium fabric	 **Figure 17** | The style of sample 13.	 **Figure 18** | The style of sample 14.	 **Figure 19** | The style of sample 15.

(Continued)

TABLE 3 | (Continued)

Fabric	Hot color	Cool color	Natural color
Wide form, very thin fabric	 **Figure 20** | The style of sample 16.	 **Figure 21** | The style of sample 17.	 **Figure 22** | The style of sample 18.
Wide form, very thick fabric	 **Figure 23** | The style of sample 19.	 **Figure 24** | The style of sample 20.	 **Figure 25** | The style of sample 21.
Wide form, thick fabric	 **Figure 26** | The style of sample 22.	 **Figure 27** | The style of sample 23.	 **Figure 28** | The style of sample 24.
Wide form, thin fabric	 **Figure 29** | The style of sample 25.	 **Figure 30** | The style of sample 26.	 **Figure 31** | The style of sample 27.
Wide-form, medium fabric	 **Figure 32** | The style of sample 28.	 **Figure 33** | The style of sample 29.	 **Figure 34** | The style of sample 30.

very thick fabrics are [6 7.5 9] for the former and [8 9.5 10.5 12] for the latter. The third variable is the fabric color. The range of the hot color is [−1 0.5 1.5 4], the neutral color is [2 5 8], and the cool color is [6 8.5 9.5 12].

These variables will be combined by the fuzzy rule "If-Then" as the **Figure 38**.

3.5. Defuzzification

Through the defuzzification modeling (**Figure 39**), designers or customers will know the sample that is suitable for requirements of form, color, and fabric. These statistics will be compared with the figures in **Table 3** to know the style

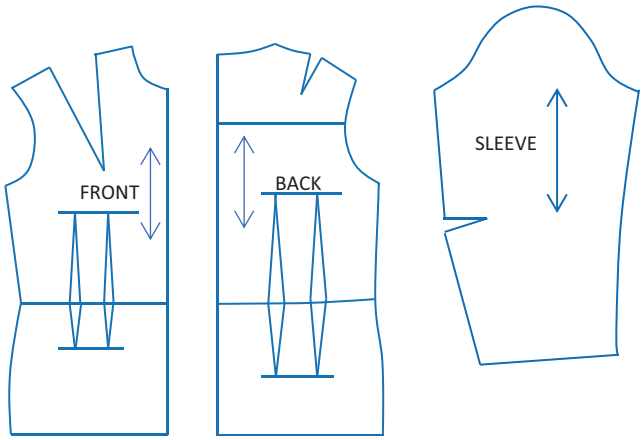

FIGURE 35 | The Torso patterns (20).

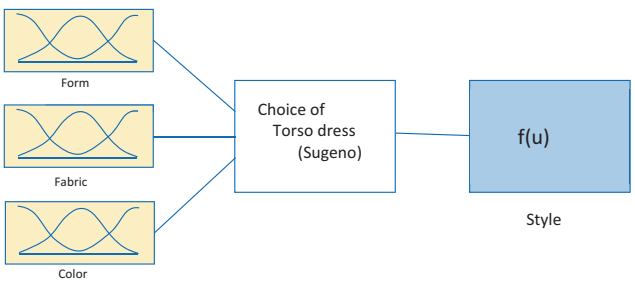

FIGURE 36 | The fuzzy logic modeling for choosing the Torso dress.

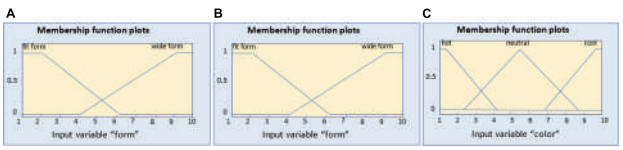

FIGURE 37 | The graph of membership functions for input variables. **(A)** The first input, **(B)** The second input, **(C)** The third input.

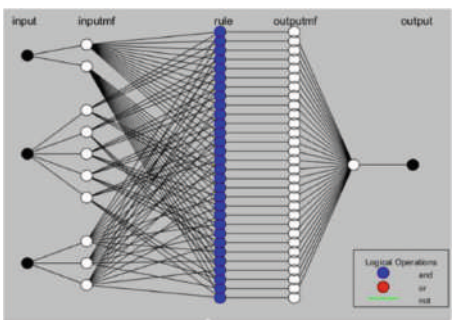

FIGURE 38 | The third input. The Anfis Model Structure of the Torso Dress.

of dress. This is a fit dress, medium fabric, cool color. The results are shown in **Figure 40**, and the flowchart of choosing the Torso dress is presented in **Figure 41**.

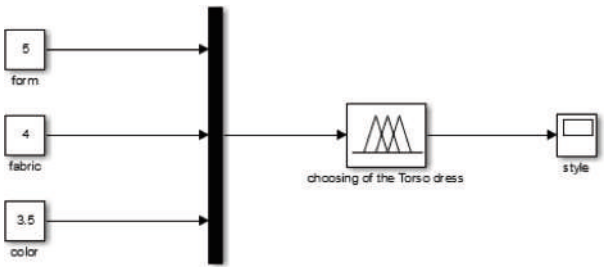

FIGURE 39 | The Fuzzy logic controller modeling of the Torso dress.

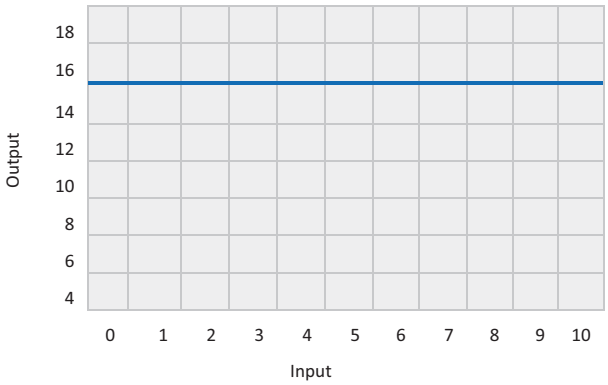

FIGURE 40 | The result of choosing the Torso dress.

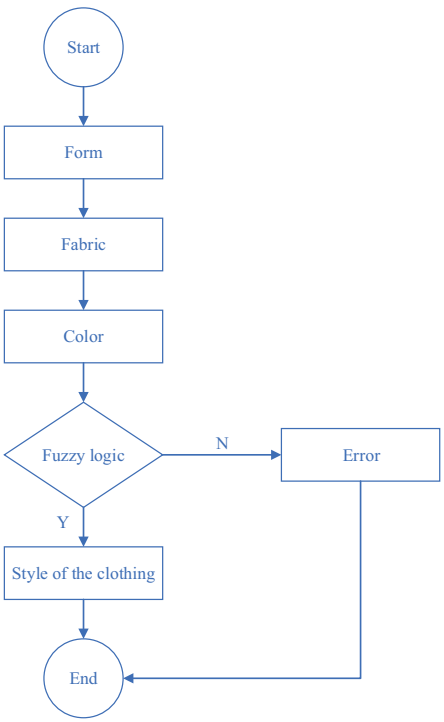

FIGURE 41 | The modeling for choosing the Torso dress.

3.6. Experiment to test and evaluate the modeling

A total of 6 lecturers and technical staff working at the garment company play the role running the simulation

TABLE 4 | Figures of Torso dresses.

	Easily using modeling	Observing the form of the dress before sewing the pattern	Observing the thickness of the fabric	Knowing the color of the dress fabric	Choosing a quick dress style	Easily choosing a different dress style	Suitable for online shopping	Cronbach's Alpha
1	0.84	0.85	0.85	0.93	0.93	0.91	0.64	0.94
2	0.92	0.92	0.92	0.92	0.91	0.87	0.70	0.96
3	0.79	0.73	0.90	0.90	0.93	0.94	0.73	0.95
4	0.97	0.97	0.85	0.63	0.97	0.97	0.77	0.96
5	0.37	0.77	0.89	0.87	0.89	0.87	0.68	0.92
6	0.94	0.83	0.83	0.94	0.96	0.99	0.86	0.96

program and modeling evaluation to choose the type of compaction according to the expert method. The results after testing give 7 criteria: Observing the dress form before sewing the pattern; Observing the fabric thickness; Knowing the color of the dress fabric; Choosing a quick dress style; Easily choosing a different dress style; Suitable for online shopping; Cronbach's Alpha coefficient is greater than 0.7. In conclusion, the study results are reliable (**Table 4**). The limitation of the study was that it did not involve many kinds of fabrics with different patterns.

4. Conclusion

The study has established a simulation model to choose a Torso dresses style by the fuzzy logic technique. The modeling requires 3 input variables which are form, thickness, and color of the fabric, as well as the output variables result from Torso-style. The fuzzy If-Then rule and Sugeno controller were used in this modeling. In addition, there were 30 Torso dress styles coded for application to fuzzy logic modeling. A total of 145 people took part in a survey conducted by the author about their priorities when choosing new clothes or new sewing according to questions related to 3 input variables. Among the takers, there were two lecturers teaching in Garment Technology, and four people were working in the technical departments of garment companies. Moreover, this modeling has also been tested and evaluated by expert methods. This research opens up the direction of choosing a style completely different from the traditional method. Customers or designers only need to enter the parameters of movement according to the width of fabric form, color, and thickness. Then the favorite color group will know the code number of the dress. This result will be compared with the collection album to know the right dress style. The choosing clothes by the fuzzy logic method is suitable for current trend in the strong development of online clothing shopping. This study has practical applications in the production and trading of costumes and is in line with the current 4.0 trend.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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