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ORIGINAL ARTICLE

Using of fuzzy theory extracts the fit size of human

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Abstract This paper presents a method to select a fit size from the data sizing system by using fuzzy technique. First, we coding size from data in the sizing system with the numerical order to use looking for sizes. Second, choosing primary dimensions from the sizing table which is coded. Then, the fuzzy technique is used to choose the fit size of human which is based on the real data in the table and any the body's dimension in the edge conditions. And finally, the simulation results are introduced. The sizing system table in this research has 24 sizes and 3 kinds of different inseam length measurements for three human shapes have different height, such as regular, short and tall. The principal component analysis method and look at directly size sign in the table are used to have primary dimensions. There are variables to input the fuzzy logic model. We apply fuzzy logic for selection size of human by the Sugeno model and using the If–Then rule. The result of the research is the simulation program for selection of the size with the Matlab software. Selecting the fit size with the traditional method will be taken a lot of time and shows the result is not clearly. This study is tested by two ways from input any the body's measurements and measurements from the sizing system into the simulation program. Extracting sizes are very useful in the manufacture of garments and business clothing by online, face to face. It will reduce the time to choose the size for fitting body measurements.

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Keywords Simulation · Fuzzy logic · Sizing system · Coding size · Primary dimension

1 Introduction

To keep up with the trend of 4.0 industry development, many intelligent control algorithms are used in different fields, such as mathematics, chemical industry, medical industry, garment industry, etc. Among them, fuzzy logic technique is based on the intelligent control just like human decision. There are many researches correlative with fuzzy logic is applied in the garment industry, such as Wang et al. (2015), the author proposes the system to choose intelligent fashion through body measurements and basic sensory descriptors with using fuzzy decision trees. The other about the ease is the subject (Chena et al. 2009a,b), which takes optimization for the ease allowance of clothing by using the fuzzy logic and sensory evaluation at different locations when garments are worn on the body. In the study (Wang and Li 2008), the fuzzy cluster is used to identify patterns by images. Besides, the fuzzy logic is used to research balance control and effective is used by experienced supervisors in the large garment company (Hui et al. 2002). Continuation of the fuzzy logic in the garment having the study (Fan et al. 2001) which uses a fuzzy-neural network to predict and display images about clothing's drape in kinds of different fabrics. In Liu et al. (2016), the author uses triangular fuzzy classification method represent lower body shapes base on the measurement of the height, waist girth and hip girth from anthropometric data of 116 young women from the Northeast of China. The other research Qin and Yang (2009) related to design fit clothing by the fuzzy method, the author presents the optimization model

from a style, color, materials to identify best sizes through images that have got from a 3D scan. About the sizing system has got the study (Hsu et al. 2009), that presents the technique to establish a sizing system from the anthropometric data females from 20 to 30 years old by fuzzy clustering data mining. In the garment industry, the sizing table has many sizes, so selecting one fit size will spend much time and difficult and the result isn't clear. With the fuzzy logic has many advantages for an input databases are not clearly will be become an output clearly and reduce time to look for the fit size. In this paper, we present the method of selecting a fit size form the sizing system table with the fuzzy logic algorithm.

2 Section

2.1 Contents

- Choosing primary dimensions in the sizing system table.
- A simulation model of selecting the fit size.
- Testing of the simulation model's results.

2.2 Methodology

This paper's contents are shown the Fig. 1. The principal component analysis method uses to look for the primary dimension and together with the Linear Regression for a building of correlational functions to establish the sizing system table. The fuzzy logic uses to make the model selecting of the fit size and runs the simulation program. This research uses the Sugeno model for the MISO fuzzy, which includes two inputs and one output. The base of rules in the fuzzy logic is fuzzy sets. This model uses Max–Min rules. Type of fuzzy set is used in this research that is triangular fuzzy set for input variables. So Klir and Yuan (1995), it has got three parameters: lower limit, top, upper limit and μ is calculated as in Eq. (1) and has shapes following like the Fig. 2 (Chena et al. 2009b):

$$\mu_A(u) = \begin{cases} 0, & if\ u\ a,\ or\ u\ b \\ \dfrac{u-a}{m-a}, & if\ a\ u\ m \\ \dfrac{b-u}{b-m}, & if\ m\ u\ b \\ h, & if\ h\ 1 \end{cases} \quad (1)$$

2.3 Softwares

This study uses two software, one is Matlab R14a for the simulation program and other is SPSS 22 (Trong and Chu 2005) for establishing of the sizing system table.

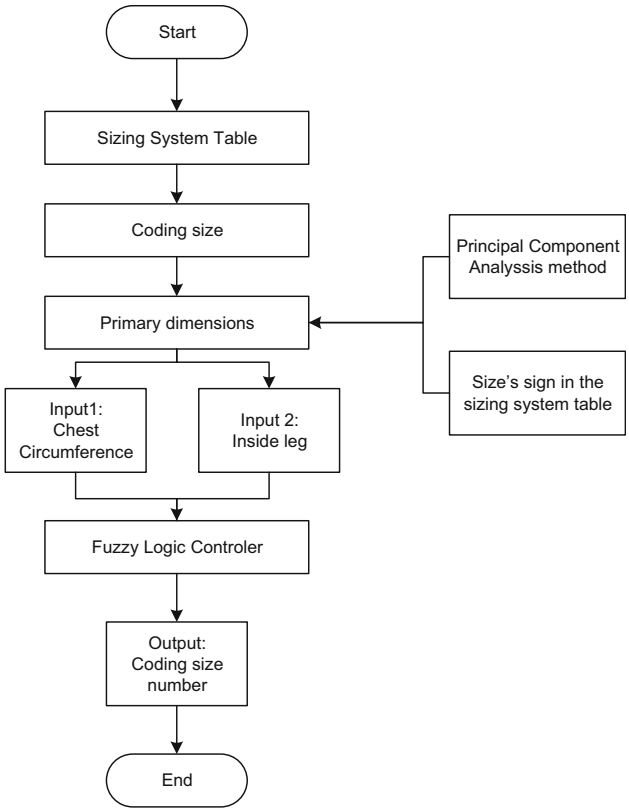

Fig. 1 The general concept of the algorithm

3 Results and discussion

3.1 Choosing primary dimensions in the sizing system table

The sizing system data (Kim and Kim 2014) has 16 dimensions (Fig. 3) and 24 sizes with three different kind of body height. Group 1 is Men's Regular Sizes (Table1), Group 2 is Men's Short Sizes (Table 2) and group 3 is Men's Tall Sizes (Table 3). There are 8 sizes in every group. These table is coded by numerical order from 1 to 24, that is corresponding with sizes sign. After analyzes the measurements data in the new table by Extraction method, it shows 2 principal components (Table 4). The first principal component is horizontal dimensions and there are 4 primary dimensions, those are neck circumference, chest circumference, waist circumference, waist circumference with high values from 0.959 to 0.960. The second component is vertical dimensions and there are 3 primary dimensions, those are inseam length, outseam length and arm length with values from 0.960 to 0.995. Sizes in the sizing table are signed by chest circumference or hip circumference because the chest circumference and hip circumference measurements are equal. So, we chose chest circumference is the first primary dimensions and another

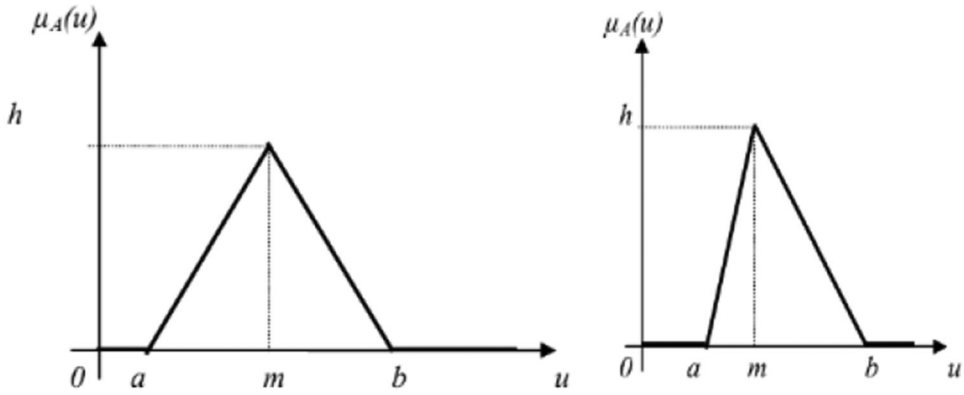

Fig. 2 Triangular membership functions

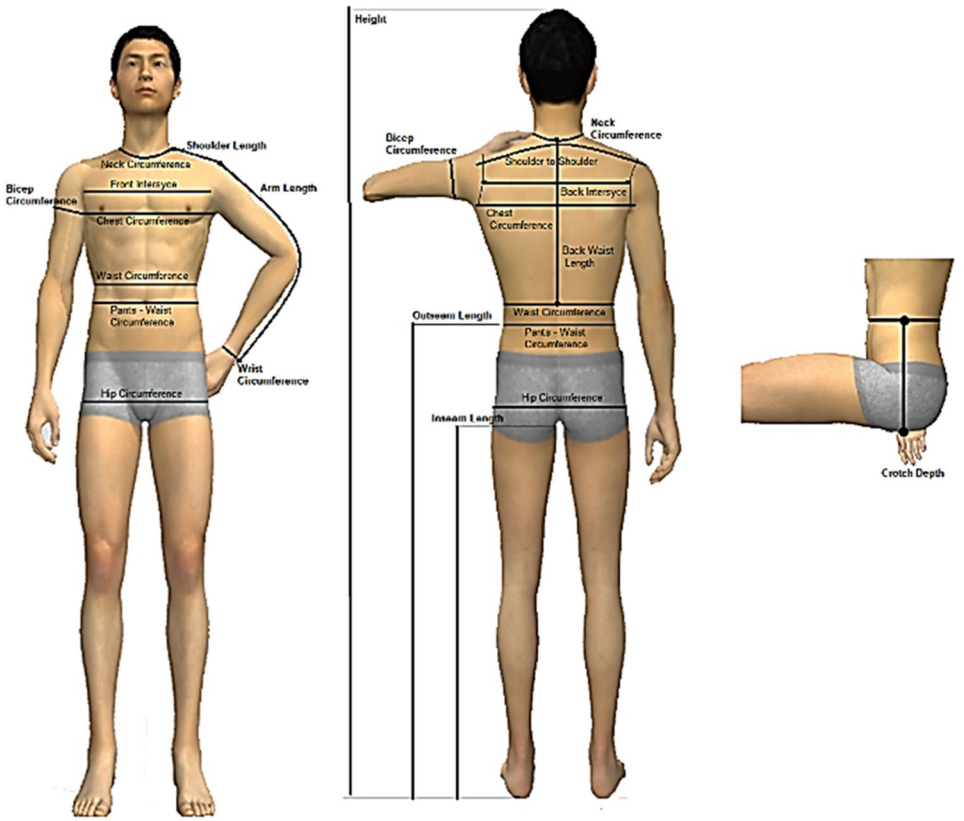

Fig. 3 Standard body measurements

Table 1 Coding size system table of the group 1

Size	34R	36R	38R	40R	42R	44R	46R	48R
Coding size	1	2	3	4	5	6	7	8
Chest (inches)	34	36	38	40	42	44	46	48
Inseam (inches)	32	32	32	32	32	32	32	32

Table 2 Coding size system table of the group 2

Size	32S	34S	36S	38S	40S	42S	44S	46S
Coding size	9	10	11	12	13	14	15	16
Chest (inches)	32	34	36	38	40	42	44	46
Inseam (inches)	30	30	30	30	30	30	30	30

body's horizontal dimensions will depend on this dimension. The second primary dimension is inseam length because it's value is the highest (0.995) in the second component.

Table 3 Coding size system table of the group 3

Size	36T	38T	40T	42T	44T	46T	48T	50T
Coding size	17	18	19	20	21	22	23	24
Chest (inches)	36	38	40	42	44	46	48	50
Inseam (inches)	34	34	34	34	34	34	34	34

Table 4 The principal component's extracted from the sizing system data

	Component	
	1	2
Component matrix		
Back interscye	.960	.280
Front interscye	.960	.280
Shoulder length	.960	.280
Bicep circumference	.960	.280
Hip circumference	.960	.280
Neck circumference	.960	.280
Chest circumference	.960	.280
Wrist circumference	.960	.280
Waist circumference	.959	.272
Shoulder to shoulder	.953	.294
Iseam length	.058	.995
Outseam length	.189	.978
Arm length	.267	.960
Back waist length	.539	.840
Crotch depth	.539	.840
Coding size	.355	.520

Extraction method: principal component analysis

A 2 Components extracted

3.2 The edge conditions for primary dimensions to put into the simulation program by fuzzy technique

Through the sizing system data, we analyze the principal components and the result is 2 primary dimensions: the chest circumference and the inseam length. So, the first variable ($\times 1$) is the chest circumference measurement and the second variable ($\times 2$) is the inseam length measurement. These two primary dimensions are selected to put into the simulation program and used to make out sizes having in the sizing system table. In every group, these values are different (Tables 1, 2 and 3) and will are used to select the size with the fuzzy logic technique in the edge conditions:

$$31 \leq x_1 \leq 51;$$
$$29 \leq x_2 \leq 35;$$

3.3 Fuzzy design

In this paper, the Sugeno method is used, so fuzzy sets have a form: Ru(p): If ($\times 1$ is A_1^m) and ($\times 2$ is B_1^n) then (y is C^p).

In there:

$\times 1$ is the first variable, that is the chest circumference measurement

$\times 2$ is the second variable, that is the inseam length measurement.

y is the output.

A is the membership function for input 1.

B is the membership function for input 2.

C is the size that needs to look for and $C \in N$.

m is the number which shows a total of the membership function for input 1.

n is the number which shows the total of the membership function for input 2.

p is the size number having in rules.

For example, If (Chest is Ch1) and (inseam length is R) then (Size is 34R). The result which shows in the simulation model is sizes' numerical order.

3.4 Input–output data for the fuzzy

The content 3.2 shows that the fuzzy system has two variables for the input and one variable for the output. Every input has many membership functions, such as input 1 has 24 membership functions with the type is triangular

Table 5 The range of membership functions' parameters for input 1

MF	Parameter	MF	Parameter
Ch1	[32.8 34 35.2]	Ch 13	[38.8 40 41.2]
Ch 2	[34.8 36 37.2]	Ch 14	[40.8 42 43.2]
Ch 3	[36.8 38 39.2]	Ch 15	[42.8 44 45.2]
Ch 4	[38.8 40 41.2]	Ch 16	[44.8 46 47.2]
Ch 5	[40.8 42 43.2]	Ch 17	[34.8 36 37.2]
Ch 6	[42.8 44 45.2]	Ch 18	[36.8 38 39.2]
Ch 7	[44.8 46 47.2]	Ch 19	[38.8 40 41.2]
Ch 8	[46.8 48 49.2]	Ch 20	[40.8 42 43.2]
Ch 9	[31 32 33.2]	Ch 21	[42.8 44 45.2]
Ch 10	[32.8 34 35.2]	Ch 22	[44.8 46 47.2]
Ch 11	[34.8 36 37.2]	Ch 23	[46.8 48 49.2]
Ch 12	[36.8 38 39.2]	Ch 24	[48.8 50 51]

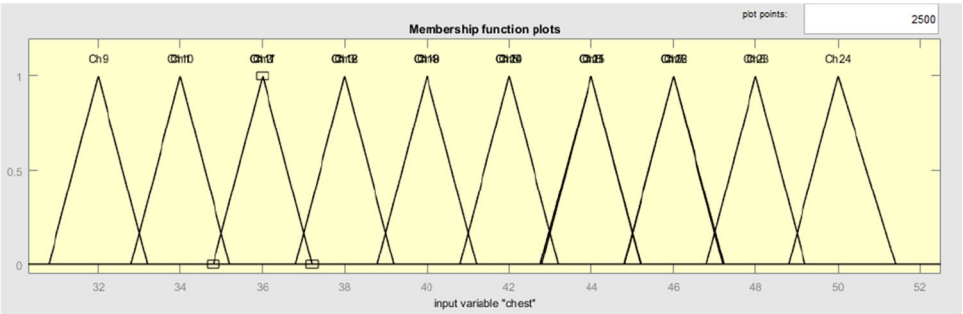

Fig. 4 Input variables for the chest measurement

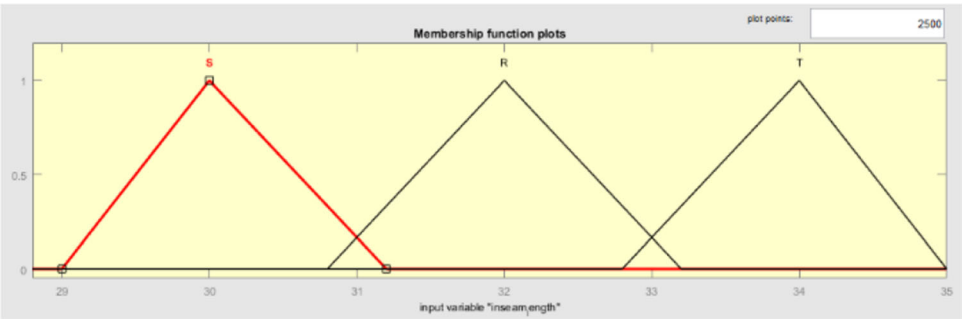

Fig. 5 Input variables for the inseam length measurement

as in Table 5. The range value of these parameters is from 31 to 51.

In this database, the first input the chest circumference measurements data are divided into 10 groups (Fig. 4) with range [31 51] inches. Group 1 includes Ch9; group 2 includes Ch1 and Ch10; group 3 includes Ch2, Ch11 and Ch17; group 4 includes Ch3, Ch12 and Ch18; group 5 includes Ch4, Ch13 and Ch19; group 6 includes Ch5, Ch14 and Ch20; group 7 includes Ch6, Ch15 and Ch21; group 8 includes Ch7, Ch16 and Ch22; group 9 is Ch8 and Ch23; group 10 is Ch24. These results are fit with chest circumference measurements in Tables 1, 2 and 3. The second input is the inseam length measurement, which has three membership functions as: Regular, Short and Tall. The range of the measurements in membership function is made from Tables 1, 2 and 3. In the Fig. 5, If membership function is Regular then the inseam length parameter is [30.8 32 33.2]; If membership function is Short then the inseam length parameter is [29 30 31.2]; If membership function is Tall then the inseam length parameter is [32.8 34 35]. There are 24 output membership functions for the valve output on the system: 34R, 36R, 38R, 40R, 42R, 44R, 46R, 48R, 32S, 34S, 36S, 38S, 40S, 42S, 44S, 46S, 36T, 38T, 40T, 42T, 44T, 46T, 48T, 50T. They are all constants as the Table 6.

The output data is a number that is the size, which needs looking for. Because there are 24 sizes in the sizing system table so the output needs 24 standards with a range from 0 to 1. They are 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24.

Table 6 The range of membership functions' parameters for input 2

MF	Parameter	MF	Parameter	MF	Parameter
34R	1	32S	9	36T	17
36R	2	34S	10	38T	18
38R	3	36S	11	40T	19
40R	4	38S	12	42T	20
42R	5	40S	13	44T	21
44R	6	42S	14	46T	22
46R	7	44S	15	48T	23
48R	8	46S	16	50T	24

3.5 The result of fuzzy sets

With the pair of a variable will show the fit is integrated rules by CoM-Center of the Maximum method:

$$x^* = \frac{\sum x_{i\in M} x_i}{|M|}$$

M = {xi|μA(xi) is equal to the height of the fuzzy set A} and |M| is the cardinality of the set M. The output value for any combination of the two input variable, so fuzzy sets are 24 (Table 7) and has shape triangles. They have structure IF–THEN to practice commands effectively in Sugeno. Values of model's set parameters are results having from the establishing the sizing system table.

Table 7 Rules matrix of sizes

	Inseam 1 (regular)	Inseam 2 (short)	Inseam 3 (tall)
Chest 1 (Ch1)	34R	0	0
Chest 2 (Ch2)	36R	0	0
Chest 3 (Ch3)	38R	0	0
Chest 4 (Ch4)	40R	0	0
Chest 5 (Ch5)	42R	0	0
Chest 6 (Ch6)	44R	0	0
Chest 7 (Ch7)	46R	0	0
Chest 8 (Ch8)	48R	0	0
Chest 9 (Ch9)	0	32S	0
Chest 10 (Ch10)	0	34S	0
Chest 11 (Ch11)	0	36S	0
Chest 12 (Ch12)	0	38S	0
Chest 13 (Ch13)	0	40S	0
Chest 14 (Ch14)	0	42S	0
Chest 15 (Ch15)	0	44S	0
Chest 16 (Ch16)	0	46S	0
Chest 17 (Ch17)	0	0	36T
Chest 18 (Ch18)	0	0	38T
Chest 19 (Ch19)	0	0	40T
Chest 20 (Ch20)	0	0	42T
Chest 21 (Ch21)	0	0	44T
Chest 22 (Ch22)	0	0	46T
Chest 23 (Ch23)	0	0	48T
Chest 24 (Ch24)	0	0	50T

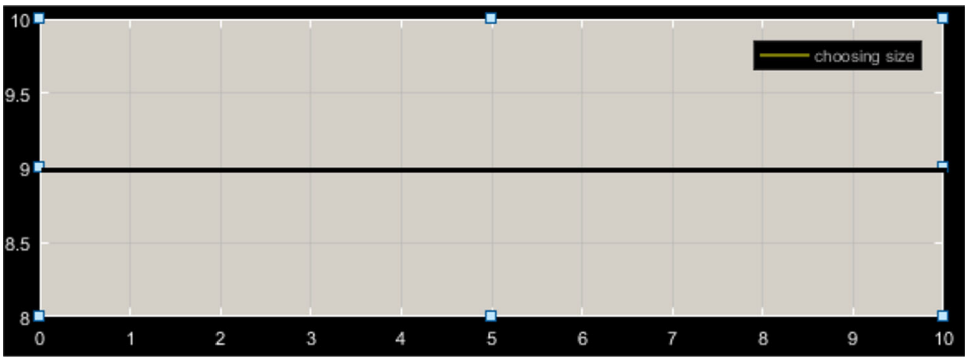

Fig. 6 The result of choosing the size 32S

3.6 The result of the selecting size model

The simulation program includes two input variables, those are chest circumference and inseam length measurement; one output, that is the size needing to look for and one the fuzzy logic controller and the result shows as the Fig. 6. Choosing the time to run is 10 s so the fit size has got quick results. Figure 7 is the flowchart and shows different from selecting the size by traditional method and fuzzy method.

The range values of the two variables depends on the limitation as in Figs. 4 and 5. Figure 8 shows the structure to choose the size. There are 2 inputs, 24 Membership functions for the input 1 and 3 membership functions for the input 2 so have total 27 input membership functions. One input membership functions will connect to one output membership functions by the rule to calculate and make one output which is the size looking for. That is the size numerical is code from the sizing system data. Quantity rules for every input membership function are quantity

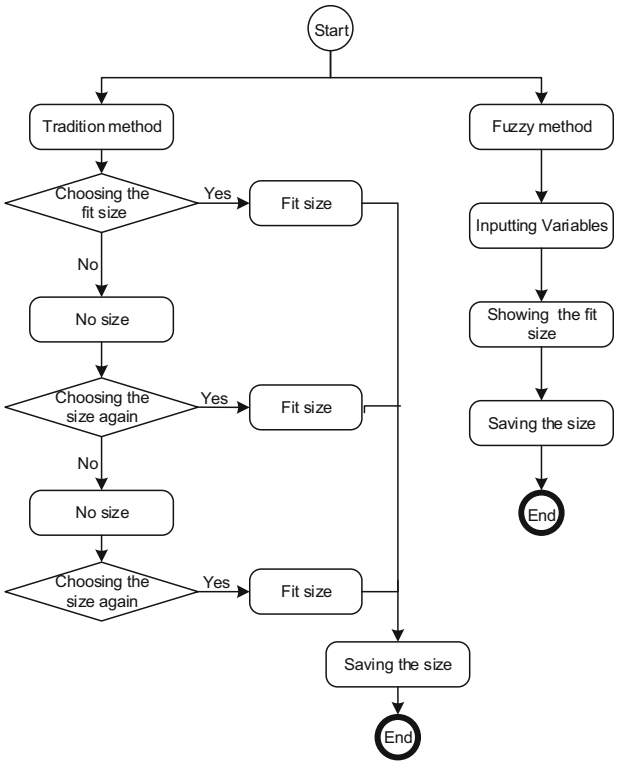

Fig. 7 Choosing the size by two methods

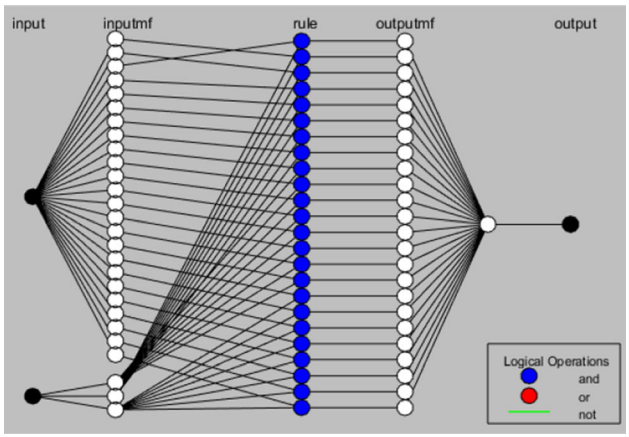

Fig. 8 The anfis model structure

sizes for every group, such as group 1 has 8 sizes so it has 8 rules, group 2 has 8 sizes so it has 8 rules, group 3 has 8 sizes so it has 8 rules.

3.7 Testing of the choosing size model

The testing of the choosing size process is evaluated by two ways. In the first way, we input measurements form Tables 1, 2 and 3 into the simulation program. Next, the comparison results with sizes in those tables. In the second way, we input any measurements in research's limit from the sample of 5 people for every group to test the simulation program. Next, the comparison results with sizes in tables. By the first way, the result presents in Table 8 and showing shows that the result with the running Simulink is a number which similar to coding size. If this result compares with sizes in Tables 1, 2 and 3 then it is exactly 100%. By the second way, if measurements are tested with fuzzy logic and measurements in the edge conditions and fit then it shows that the results display a size's any number. However, if measurements in the edge conditions but unfit then the results always display a number that is 0.5 as Table 9.

4 Conclusions

The study on simulation of selecting the fit size for human being by fuzzy technique is introduced in this paper. Based on the fuzzy, we can give the suitable size for the men from the experimental measuring data. This results show that the application of Fuzzy to choose the fit and suitable size of the textile for human is feasible. In the next step, we will carry on some more practical experimental results to check the agreement between the simulation program and the practical measurement data of human size. Also, the method to evaluate the correctness of the Fuzzy results will also be considered to find the way to improve the qualification of our proposed method. This research opens another way to select the size suitable for the body. Furthermore, it can apply to other fields in the garment technology.

Table 8 The results test choosing sizes by the first-way

Size	34R	36R	38R	40R	42R	44R	46R	48R	32S	34S	36S	38S
Coding size	1	2	3	4	5	6	7	8	9	10	11	12
Fuzzy logic model	1	2	3	4	5	6	7	8	9	10	11	12
Size	40S	42S	44S	46S	36T	38T	40T	42T	44T	46T	48T	50T
Coding size	13	14	15	16	17	18	19	20	21	22	23	24
Fuzzy logic model	13	14	15	16	17	18	19	20	21	22	23	24

Table 9 The results test choosing sizes by the second-way

Group 1	Chest circumference	*31.6*	33.2	34.8	36.4	38.0
	Inseam length	*31.5*	31.5	31.5	31.5	31.5
	Size	*0.5*	1	1	2	3
Group 3	Chest circumference	31.7	33	34.9	36.5	38
	Inseam length	29.5	29.5	29.5	29.5	29.5
	Size	9	9.5	10.3	11	12
Group 2	Chest circumference	*31.6*	*33.2*	*34.7*	36.3	37.9
	Inseam length	*33.5*	*33.5*	*33.5*	33.5	33.5
	Size	*0.5*	*0.5*	*0.5*	17	18

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