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Choosing the Size for Ready-to-Wear Clothing in the Size Chart by Fuzzy Logic

Mong Hien Thi Nguyen, Mai-Huong BUI, Tuong Quan Vo

Abstract: ***Choosing the size for Ready-to-Wear clothing usually takes a lot of time to have a fit size. So, researching on this problem is necessary. In this paper presents a method to choose sizes for ready-to-wear clothing by using a fuzzy technique.We use the Sugenomodel for the MISO fuzzy, which includes two inputs and one output.Firstly, we choose primary dimensions in the sizing chart with the first dimension is a horizontal dimension and other is a vertical dimension. Secondly, taking edge conditions for inputting variables. Then, the fuzzy technique is used to choose the fit size on the base of body's measurements in the size chart, and any the body's measurements on the edge conditions. And finally, the simulation results are introduced. In this research, the sizing chart table has 9 sizes with 9 different heights. Pants-waist circumference and body height are two primary dimensions. These dimensions will input variables in the fuzzy simulation model.The fuzzy logic is used to select the size haveMax-Min ruleand membership functions'shape which is triangular.Structure IF-THEN to practice commands effectively in Sugeno. The result is the simulation model to select sizes in the Matlab software. Selecting the fit size with the traditional method takes a lot of time and shows the result is not clearly, but with fuzzy technique reduces the time.The study tested intwo ways, including input measurements from any the body's measurements and input measurements in the sizing chart.It opens another way to select the size suitable for the body.***

Index Terms
Choosing the size, Size chart, Fuzzy logic, Primary dimension, Fit size.

I. INTRODUCTION

With the development of the industrialization, many intelligent control algorithms are used in different fields, such as mathematics, chemical industry, medical industry, garment industry, etc. In the garment industry, there are many studies correlative with fuzzy logic is applied, such as [1], 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 [2], [3], 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 [4], the fuzzy cluster is used to identify patterns by images. Besides that, the fuzzy logic is used to research balance control and effective is used by experienced supervisors in the large garment company [5]. Continuation of the fuzzy logic in the garment having the study [6] which uses a fuzzy-neural network to predict and display images about clothing's drape in kinds of different fabrics. In [7], 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 [8] 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 [9], 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. With sewing clothes from away or ready-made clothes which wears fit have many sizes for every brand, every kind of garment. For example, Technical Reference [10] is shirtdress which has 15 sizes and 5 primary dimensions. Another, Technical Reference CERVO trousers [11] has 11 sizes and 5 primary dimensions, Technical Reference women trousers JML 3247 [12] has 11 sizes and 4 primary dimensions. Novelty shirt has 10 sizes and 4 primary dimensions. Novelty trousers has 9 sizes and 5 primary dimensions. Sanding shirt has 9 sizes and 5 primary dimensions. It is difficult for customers because they don't know what the size is fit. They will take a lot of time to choose the fit size. So, the research "Choosing the size for ready- to-wear clothing by fuzzy logic" is necessary.

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II. MATERIAL AND METHODS

A. Content

There are 4main contents for this research. Firstly, choosing primary dimensions. Secondly, establishing rules of the fuzzy logic. Thirdly,making the simulation model of the selecting the fit size. Finally, testing of the results.

B. Methodology

This paper's contents are shown the Fig.1. The fuzzy logic uses to make the model selection of the fit size and run 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 [13], 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:

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

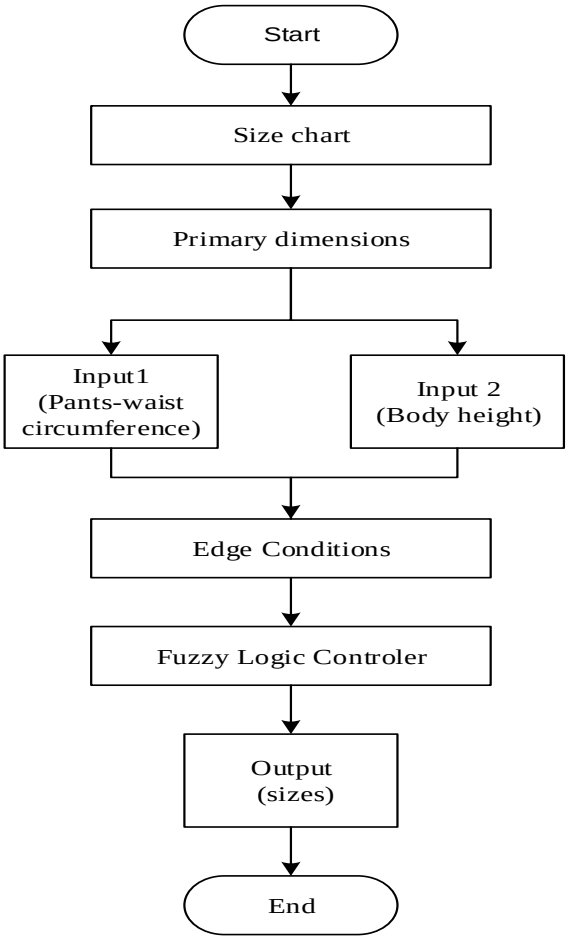

Fig.1. The general concept of the algorithm.

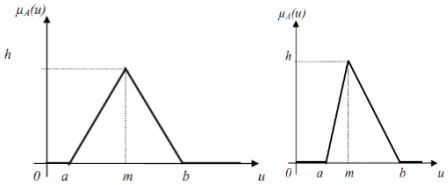

Fig.2. Triangular membership functions.

C. Software

There is three software to use for this research: MS. Word 97, MS. Excel 97, Matlab R14[a].

III. RESULTS AND DISCUSSION

A. Choosing primary dimensions in the sizing system table

The Technical Reference of the Viet Tien trousers [14]is used for this research. It has 9 sizes and signs by numbers. In there, there are two kinds of sizes sign. One is using for khaki pants and it begins from size is 28 to size 36 with interval for sizes is 1. Another is using for trousers with the first size is 94, the final size is 94 and interval for sizes is 3. The author choses numerical order for trousers to establish the model for choosing size as table 1. The sizing charts has 3 primary dimensions, those are pants-waist circumference, hip circumference and body height (Fig 3). Among of them, two primary dimensions are used to input variables in fuzzy model, one is horizontal primary dimension, another is vertical primary dimension. Almost size labels for pants are signed on the base of the pants - waist measuring, so waist circumference is the first primary dimension. Besides that, height is the second primary dimension for various shapes form short to tall.

Table 1. The men's trousers size chart ofViet Tiengarment company.

Size	Pants-waist (cm)	Hip (cm)	Cuff (cm)	Length (cm)	Height (cm)
70	72	85	21	100	156
73	74.5	87.5	22	102	159
76	77	90	23	104	162
79	79.5	92.5	23	106	165
82	82	95	24	107	168
85	84.5	97.5	24	108	171
88	87	99	25	108	174
91	89.5	101.5	25	108	177
94	92	103	25	108	180

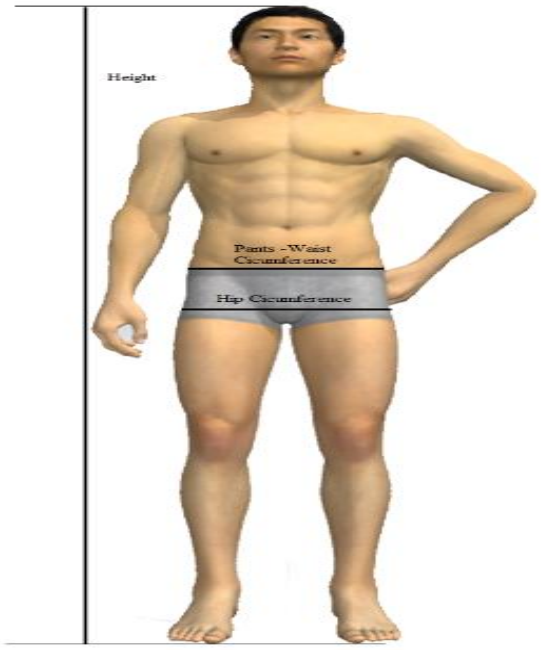

Fig 3. Body's dimensions.

B. The edge conditions for Primary dimensions to put into the simulation program by Fuzzy technique

Through the sizing charts, there are 2 primary dimensions: the pants-waist circumference and the body height. So, the first variable (x1) is the pants-waist circumference measurement and the second variable (x2) is the body height measurement.

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These two primary dimensions are selected to put into the simulation program and used to make out sizes having in the sizing system table with the fuzzy logic technique in the edge conditions:

$70 \le x_1 \le 94$ (cm);

$154 \le x_2 \le 182$ (cm);

C. Fuzzy design

In this paper, the Sugeno method is used, so fuzzy sets have a form: *$Ru^{(p)}$: If (x_1 is A_1^m) and (x_2 is B_1^n) then (y is C^p)*

In there:

x1 is the first variable, that is the pants-waist circumference measurement

x2 is the second variable, that is the body height 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∈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 (waist is w70) and (height is h70) then (size is s70). The result which shows in the simulation model is sizes' numerical order.

D. 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 9 membership functions with the type is triangular as in table 2, input 2 has 9 membership functions with the type is triangular Fig.4, Fig.5.

Table 2. The range of membership functions' parameters for inputs.

Input 1		Input 2	
MF	Parameter	MF	Parameter
w70	[70.5 72 73.5]	h70	[154.2 156 157.8]
w73	[73 74.5 76]	h73	[157.2 159 160.8]
w76	[75.5 77 78.5]	h76	[160.2 162 163.8]
w79	[78 79.5 81]	h79	[163.2 165 166.8]
w82	[80.5 82 83.5]	h82	[166.2 168 169.8]
w85	[83 84.5 86]	h85	[169.2 171 172.8]
w88	[85.5 87 88.5]	h88	[172.2 174 175.8]
w91	[88 89.5 91]	h91	[175.2 177 178.8
w94	[90.5 92 93.5]	h94	[178.2 180 181.8]

In this database, there are 9 output membership functions for the valve output on the system: 70, 73, 76, 79, 82, 85, 88, 91, 94. They are all constants as the table 3. The output data is a number that is the size, which needs looking for. Because there are 9 sizes in the sizing system table so the output needs 9 standards with a range from 0 to 1. They are 1, 2, 3, 4, 5, 6, 7, 8, 9.

Table 3. The range of membership functions' parameters for output.

MF	Parameter	MF	Parameter	MF	Parameter
w70	70	w79	79	w88	88
w73	73	w82	82	w91	91
w76	76	w85	85	w94	94

E. 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:

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

M= $\{x_i|\mu_A(x_i)$ 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 9 (Table 4) and has shape triangles. We 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 4. Rules of sizes.

Rule	If	And	Then
	waist is	height is	size is
1	W70	H70	70
2	W73	H73	73
3	W76	H76	76
4	W79	H79	79
5	W82	H82	82
6	W85	H85	85
7	W88	H88	88
8	W91	H91	91
9	W94	H94	94

F. The result of the selecting size

The simulation program includes two input variables: pants-waist circumference and body height measurement, and 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 second so the fit size has got quick results. Fig 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 Fig 4, Fig 5. In Fig 8 gives the structure to choose the size. There are 2 inputs, 9 membership functions for the input 1 and 9 membership functions for the input 2 so have total 18 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.

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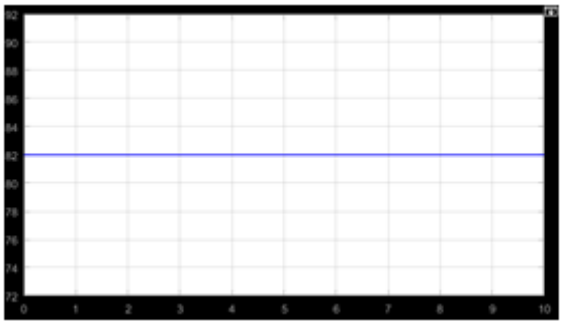

Fig.4. The result of choosing the size 82

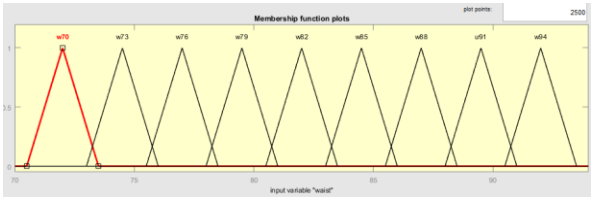

Fig. 5. Input variables for the pants-waist measurement.

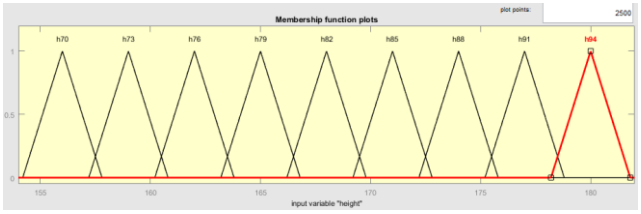

Fig. 6. Input variables for the body height measurement.

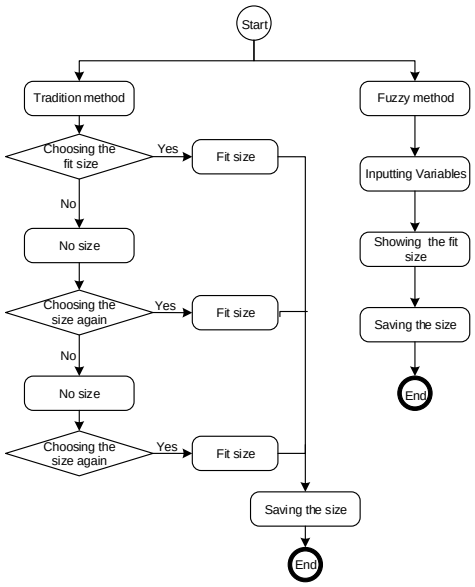

Fig.7. Choosing the size by two methods

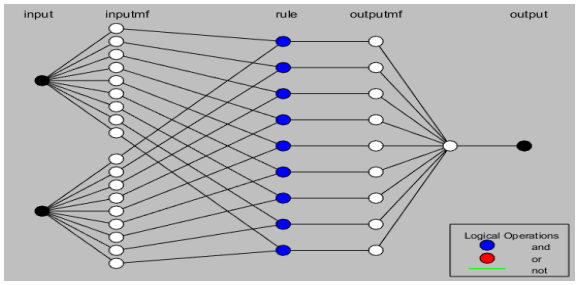

Fig.8. The Anfis Model Structure.

G. Testing of the choosing size

The testing of the choosing size process is evaluated with the tradition method and the fuzzy method by two ways. In the first way, we input measurements form table 5 into the simulation program. Next, the comparison results with sizes in these tables. In the second way, we input any measurements in research's limit from the sample of 10 people. Next, the comparison results with sizes in this tables. By the first way, the result is exactly 100% with the size in sizing chart. By the second way, if measurements are tested with fuzzy logic and measurements in the edge conditions then it shows that the results display a size's any number. If measurements in the edge conditions but not fitly then the results always display a number that is 0.5 as table 6. However, if those measurements are tested by the traditional method then we will choose an approximate size as line 4 in table 6.

Table 5. The results test choosing sizes by the first-way.

size	70	73	76	79	82	85	88	91	94
Pants-waist	72	74.5	77	79.5	82	84.5	87	89.5	92
Height	156	159	162	165	168	171	174	177	180
Choosing size by traditional method	70	73	76	79	82	85	88	91	94
Choosing size by fuzzy logic	70	73	76	79	82	85	88	91	94

Table 6. The results test choosing sizes by the second-way.

Pants-waist	82	93	78	89	88	71.5	87.5	90	73	74.5
Height	168	180	162	178	173	157	171	179	159	161
Choosing size by fuzzy logic	82	94	76	91	88	70	0.5	0.5	0.5	0.5
Choosing size by traditional method	82	94	76	91	88	70	88	91	70/73	73

IV. CONCLUSION

The study on simulation of choosing the right size for Ready-to-Wear clothing by fuzzy technique introduced in this paper. This table has 9 sizes with 9 different body height measurements. Pants-waist circumference and body height are two primary dimensions and selecting to input variables for the fuzzy simulation model. Based on the Fuzzy, we can give a suitable size for men from the experimental measuring data. This result shows that an application of Fuzzy to choose the fit size is feasible. In the next step, we do more practical experimental results to check possibility between the simulation program and the practical measurement data of human size. Also, the method to evaluate the correctness of Fuzzy results will also be considered to find ways to improve the qualification of our proposed method. The research opens another way to select the size suitable for the body. Furthermore, it can apply to other fields in the garment technology.

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Mong Hien Thi Nguyen, born in 1971, Vietnamese. Shefinished her B.S. degree from HCM University of Technology and Education, Vietnam in 2000. She received her M.S.degree from HCM University of Technology and Education, Vietnam in 2004. M.S. degree from Hanoi University of Science and Technology, Vietnam in 2016. She is Ph.D. Student Mechanical-Electronic in Ho Chi Minh City University of Technology, Vietnam. Her current researches are about anthropometric measurements of garment, sizing system table, establishing systemic formulas for patterns, studying on correlation coefficient and using fuzzy logic in garment. She has over 18 years in academic and teaching.

Mai-Huong BUI, born in 1978. Vietnamese. She finished her Master thesis in Hanoi University of Technology in the field of textile technology. Since 2005 to 2008, she was granted OEAD scholarship and spent 3 years in University of Innsbruck- Austria to complete her Ph.D. thesis about advanced cellulosic fiber. She was accredited as Associate Professor in 2018. She is acting as the Head of the Department of Textile-Garment Engineering, Ho Chi Minh City University of Technology. Her current research interests include textile mechanics, natural dyes, advanced textile material and applying natural and renewable fiber and resource in technical and functional textiles.

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