

## Creating a Program to Predict the Clothing Size Using Fuzzy Logic

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### ABSTRACT

This study presents a program to predict trousers' size using a fuzzy logic technique. There are three variables to input into the program to give the output result of the fit size. The first variable is the waist measurement. The second variable is the hip measurement. The third variable is the trousers' length measurement. The size determination is done by the Min-Max rule through the IF-THEN structure, effectively managing the commands in the model. The fuzzy rule matrix consists of 108 rows and 6 columns, in which each row represents a fuzzy rule. Each row is a fuzzy rule. The first column represents six groups of neck circumference. The second column represents six groups of hip circumference. The third column represents three groups of pants length. The fourth column represents six predicted output sizes. The fifth column is the weight coefficient. The last column represents the type of logical connection. This size prediction method only takes about five to six seconds to predict the fit size. This reduces the time to choose the size compared to the traditional method. In addition, it reduces the risk of damaging the sample. This method to predict sizes can apply to many other types of clothing as well as many other fields of the garment industry.

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## 1. Introduction

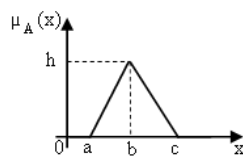
Today, numerous studies have explored body size prediction using AI algorithms. For example, one study developed a back-propagation neural network model to predict body size by inputting key human body dimensions [1]. Another research project employed Artificial Neural Networks to create a model for predicting virtual clothing fit in Optitex software, using data from 50 women aged 18 to 35 years [2]. Additional research has focused on applying genetic algorithms to propose a 3D design method for polo shirts [3] and on designing Kansei-style T-shirts using back-propagation neural networks [4]. Other studies have explored clothing fit prediction through various algorithms [5]-[7]. These intelligent algorithms are applied not only in garment design but also in areas such as technology, sewing materials, and production management within the garment industry. For instance, several studies have investigated advancements in production technology [8]-[12], while others have focused on intelligent algorithms for sewing materials [13]-[15]. One study proposed a new size chart, building upon existing market size charts, and linking secondary body measurements to primary measurements without relying on linear regression [16]. The research presented in this paper builds upon these previous studies, emphasizing the importance of selecting the correct size for ready-to-wear clothing, a process that often requires significant time to ensure proper fit. By integrating insights from these studies, the authors aim to develop a more accurate and practical model for predicting clothing sizes using advanced techniques. This model has the potential to greatly enhance the fit and comfort of ready-made clothing, addressing the ongoing challenge of achieving optimal sizing in the garment industry. In studies [17]-[22], the authors employed a triangular fuzzy classification method to determine appropriate sizes from the sizing data system using fuzzy techniques. The goal is to identify the best-fitting size for individuals based on actual data in the table and various body dimensions under edge conditions. The authors used fuzzy logic to establish the mathematical model, where the input variables are inseam height and neck girth measurements, and the output variables are the human size codes and body shapes [23]. Selecting the correct size for ready to wear clothing often requires considerable time, doing research in this area

essential. It can be said that clothing is always an essential need of every person. It not only protects the body but also helps people beautify. Especially in today's social conditions, most people go out to work or do business at home. In any environment, they are interested in dressing well. Men are no exception. This is also the group of people who are too lazy to try on clothes when shopping, especially trousers. Men's trousers are an important part of men's wardrobe. Research on choosing men's trousers sizes using fuzzy logic techniques is important not only for the garment industry but also to meet the increasing demand for fashion and comfort of consumers. This research brings long-term value to both manufacturers and customers. This is also the reason why the group of authors chose this topic for research.

## 2. Materials and Methods

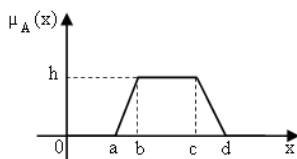
The size chart for men's trousers at Sanding Company in Vietnam consists of four horizontal dimensions and one vertical dimension, leading to a total of six distinct sizes. These dimensions are meticulously measured to cater to various body types. The size range begins at size 28, which is suitable for individuals with smaller waist and hip measurements, and goes up to size 33, tailored for those with larger proportions. Each size increases by one unit, ensuring a smooth and gradual progression in fit [24].

Fuzzy logic is applied to develop a model for extracting the fit size and executing the simulation program. This study utilizes the Mamdani model in a MISO fuzzy system, incorporating two inputs and one output. The fuzzy logic rules are derived from fuzzy sets and follow the Max-Min principle. The model makes use of two types of membership functions: triangular and trapezoidal. The trapezoidal membership function is used for the first and last sets of the membership functions. Figure 1 illustrates the triangular membership function, defined by three parameters: the lower limit, peak, and upper limit, which are calculated using Equation (1). Figure 2 displays the trapezoidal membership function, characterized by two parameters at the lower end and two at the top, calculated using Equation (2) [25].



**Figure 1.** The triangular membership functions.

$$\mu_A(x) = \begin{cases} 0, & \text{if } x \leq a, \text{ or } x \geq c \\ \frac{x-a}{b-a}, & \text{if } a < x < b \\ \frac{c-x}{c-b}, & \text{if } b < x < c \\ h, & \text{if } h \leq 1 \end{cases} \quad (1)$$



**Figure 2.** The trapezoidal membership functions.

$$\mu_A(u) = \begin{cases} 0, & \text{if } x \leq a, \text{ or } x \geq d \\ \frac{x-a}{b-a}, & \text{if } a < x \leq b \\ 1, & \text{if } b < x \leq c \\ \frac{d-x}{d-c}, & \text{if } c < x < d \\ h, & \text{if } h \leq 1 \end{cases} \quad (2)$$

The model has structured IF-THEN to practice commands effectively in Mamdani:

If ( $x_1$  is  $A_1^m$ ) and ( $x_2$  is  $B_1^n$ ) and ( $x_3$  is  $C_1^p$ ) then ( $y_1$  is  $D^q$ )

In there:

$x_1$  is the first variable, that is the waist girth.

$x_2$  is the second variable, that is the hip girth.

$x_3$  is the third variable, that is the trousers length.

$y$  is the output.

$A$  is the MF for the first input.

B is the MF for the second input.

C is the MF for the third input.

D 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 the first input.

n is the number which shows the total of the MF for the second input.

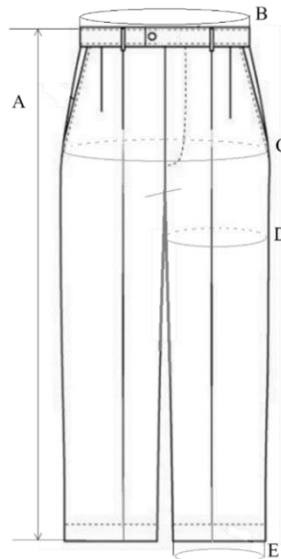
p is the number which shows the total of the MF for the third input.

q is the size number having in rules.

### 3. Results and Discussion

#### 3.1. Primary dimensions in the size chart

The size chart for Sanding trousers, utilized in this study, consists of six sizes, each represented by a number (Table 1). The chart includes two types of size labels and covers five dimensions (Figure 3). Of these dimensions, three are considered primary: waist girth, hip girth and trousers length. These primary dimensions are used as input variables in the fuzzy model.



**Figure 3.** The men's trousers size chart.

**Table 1.** The men's trousers size chart.

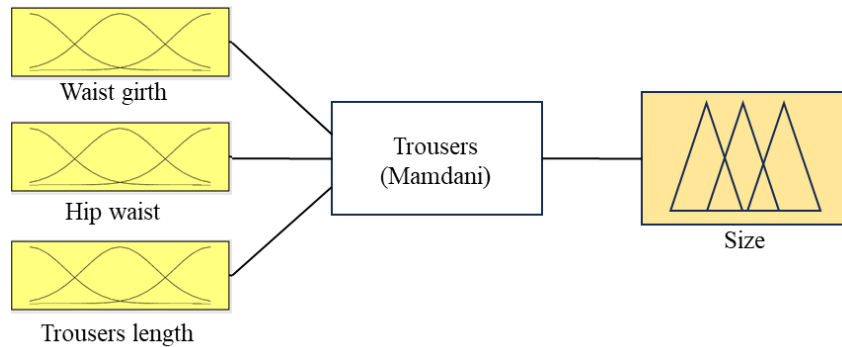
Dimension (cm)	Sizes symbol					
	28	29	30	31	32	33
Trousers length (A)	94	96	96	98	98	98
Waist girth (B)	63	67	71	75	79	83
Hip girth (C)	78.5	82.5	86.5	90.5	94.5	98.5
Thigh girth (D)	42	45	48	51	54	57
Leg opening (E)	31	32	32	34	34	35

#### 3.2. The boundary conditions for input's two variables

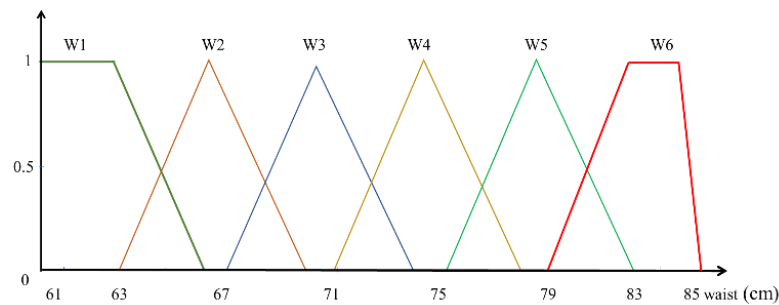
The first variable ( $x_1$ ) is the waist girth, The second variable ( $x_2$ ) is the hip girth and the third variable ( $x_3$ ) is the trousers length. These variables are subject to the following boundary conditions:  $61 \leq x_1 \leq 85$  (cm);  $76.5 \leq x_2 \leq 100.5$  (cm),  $92 \leq x_3 \leq 100$  (cm).

### 3.3. The input – output variables

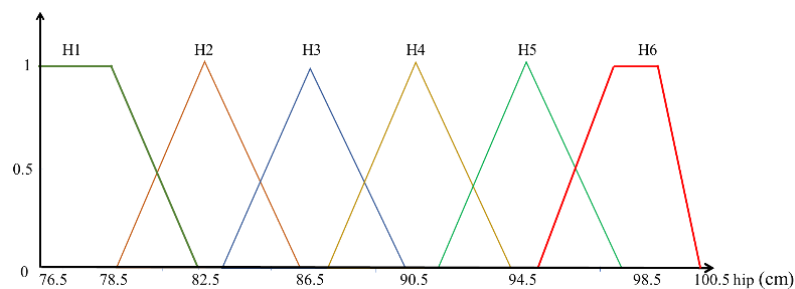
The fuzzy logic system consists of three input variables and one output variable (Figure 4). Each input variable is associated with several membership functions, representing the degree of belonging to a specific fuzzy set. For instance, the first input variable includes six membership functions of trapezoidal and triangular shapes, as detailed in Table 2 and illustrated in Figure 5. Similarly, the second input variable has six membership functions of the same types, as shown in Table 2 and Figure 6. The third input variable follows the same structure as the first, with three membership functions of trapezoidal and triangular forms, as outlined in Table 2 and Figure 7. The output variable is defined by six membership functions, as indicated in Table 2 and Figure 8.



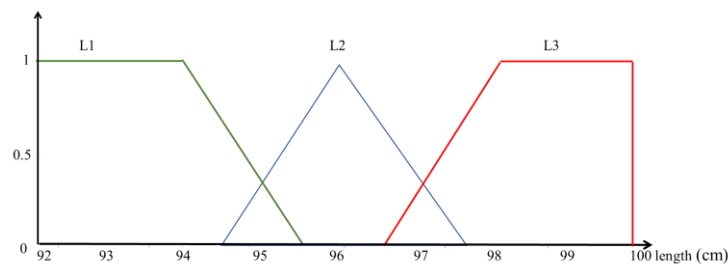
**Figure 4.** The fuzzy logic system of looking for the men's trousers size.



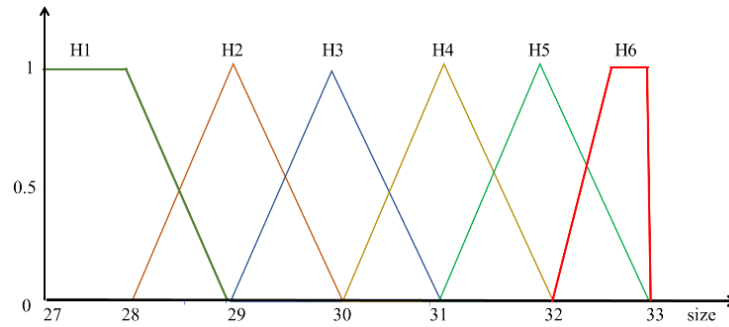
**Figure 5.** Membership functions for the first input variable (Waist girth).



**Figure 6.** Membership functions for the second input variable (Hip girth).



**Figure 7.** Membership functions for the third input variable (Trousers length).



**Figure 8.** Membership functions for the output (Size).

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

The input				The output			
The first input (Waist girth)		The second input (Hip girth)		The third input (Trousers Length)			
MF	Parameter (cm)	MF	29	MF	Parameter (cm)	MF	Parameter (coding size)
W1	[60 60 63 66.5]	H1	[75 76.5 78.5 82]	L1	[92 92 94 95.5]	28	[27 27 28.5 29]
W2	[63.5 67 70.5]	H2	[79 82.5 86]			29	[28 29 30]
W3	[67.5 71 74.5]	H3	[83 86.5 90]	L2	[94.5 96 97.5]	30	[29 30 31]
W4	[71.5 75 78.5]	H4	[87 90.5 94]			31	[30 31 32]
W5	[75.5 79 82.5]	H5	[91 94.5 98]	L3	[96.5 98 100 100]	32	[31 32 33]
W6	[79.5 83 84 85]	H6	[95 98.5 100 100.5]			33	[32 32.5 33 33]

The first input has six membership functions with the type trapezoidal and triangular. The code for waist girth:

```
fis = addvar(fis, 'input', 'Waist', [61 85]);
fis = addmf(fis, 'input', 1, '63', 'trapmf', [W1]);
fis = addmf(fis, 'input', 1, '67', 'trimf', [W2]);
fis = addmf(fis, 'input', 1, '71', 'trimf', [W3]);
fis = addmf(fis, 'input', 1, '75', 'trimf', [W4]);
fis = addmf(fis, 'input', 1, '79', 'trimf', [W5]);
fis = addmf(fis, 'input', 1, '84', 'trapmf', [W6]);
```

The second input has six membership functions with the type trapezoidal and triangular. The code for hip girth:

```
fis = addvar(fis, 'input', 'Hip', [76.5 100.5]);
fis = addmf(fis, 'input', 2, '78.5', 'trapmf', [H1]);
fis = addmf(fis, 'input', 2, '82.5', 'trimf', [H2]);
fis = addmf(fis, 'input', 2, '86.5', 'trimf', [H3]);
fis = addmf(fis, 'input', 2, '90.5', 'trimf', [H4]);
fis = addmf(fis, 'input', 2, '94.5', 'trimf', [H5]);
fis = addmf(fis, 'input', 2, '100', 'trapmf', [H6]);
```

The third input has three membership functions with the type trapezoidal and triangular. The code for length trousers:

```
fis = addvar(fis, 'input', 'Length', [92 100]);
fis = addmf(fis, 'input', 3, '94', 'trapmf', [L1]);
fis = addmf(fis, 'input', 3, '96', 'trapmf', [L1]);
fis = addmf(fis, 'input', 3, '98', 'trapmf', [L3]);
```

The output result is a number. This number is the size which needs looking for. The code for the output:

```

fis = addvar(fis, 'output', 'Size', [27 34]);
fis = addmf(fis, 'output', 1, 'S28', 'trapmf', [S28]);
fis = addmf(fis, 'output', 1, 'S29', 'trimf', [S29]);
fis = addmf(fis, 'output', 1, 'S30', 'trimf', [S30]);
fis = addmf(fis, 'output', 1, 'S31', 'trimf', [S31]);
fis = addmf(fis, 'output', 1, 'S32', 'trimf', [S32]);
fis = addmf(fis, 'output', 1, 'S33', 'trimf', [S33]);
    
```

**3.4. The matrix of fuzzy logic rules**

The output values for any combination of the three input variables. Because there are six membership functions for the first input variable and six membership functions for the second input variable. There are three membership functions for the third input variable, so the total number of fuzzy rules in the study is 108. The size notation is numbered according to the waist girth measurement. Values of a model's set parameters are the results having from the establishing the size chart. The fuzzy rule set of the study is presented in Table 3. In this table, the numbers 1, 2, 3, 4, 5, and 6 represents the order in which the member functions were defined as follows:

Waist girth: W63 = 1; W67 = 2; W71 = 3; W75 = 4; W79 = 79; W83 = 6

Hip girth: H78.5 = 1; H82.5 = 2; H86.5 = 3; H90.5 = 4; H94.5 = 5; H98.5=6.

Length trousers: L94 = 1; L96 = 2; L98 = 3.

Size: S28 = 1; S29 = 2; S30 = 3; S31 = 4; S32 =5; S33 = 6

**Table 3.** The matrix of fuzzy rule set.

Fuzzy rules	Waist	Hip	Length	Size	Fuzzy rules	Waist	Hip	Length	Size	Fuzzy rules	Waist	Hip	Length	Size
1	1	1	1	1	37	3	1	1	1	73	5	1	1	1
2			2		38			2		74			2	
3			3		39			3		75			3	
4		2	1	2	40		2	1	2	76		2	1	2
5			2		41			2		77			2	
6			3		42			3		78			3	
7		3	1	3	43		3	1	3	79		3	1	3
8			2		44			2		80			2	
9			3		45			3		81			3	
10		4	1	4	46		4	1	4	82		4	1	4
11			2		47			2		83			2	
12			3		48			3		84			3	
13		5	1	5	49		5	1	5	85		5	1	5
14			2		50			2		86			2	
15			3		51			3		87			3	
16		6	1	6	52		6	1	6	88		6	1	6
17			2		53			2		89			2	
18			3		54			3		90			3	
19	2	1	1	1	55	4	1	1	1	91	6	1	1	1
20			2		56			2		92			2	

21		3		57		3		93		3	
22	2	1	2	58	2	1	2	94	2	1	2
23		2		59		2		95		2	
24		3		60		3		96		3	
25	3	1	3	61	3	1	3	97	3	1	3
26		2		62		2		98		2	
27		3		63		3		99			
28	4	1	4	64	4	1	4	100	4	1	4
29		2		65		2		101		2	
30		3		66		3		102		3	
31	5	1	5	67	5	1	5	103	5	1	5
32		2		68		2		104		2	
33		3		69		3		105		3	
34	6	1	6	70	6	1	6	106	6	1	6
35		2		71		2		107		2	
36		3		72		3		108		3	

Through Table 3, a rule list is established, consisting of 108 lines and 6 columns. All lines represent a rule, while each column in the rule matrix corresponds to the following: the first input variable (Waist), the second input variable (Hip), the third input variable (Length) the output variable (Size), the weight factor, and the logic connection type. The matrix is presented below:

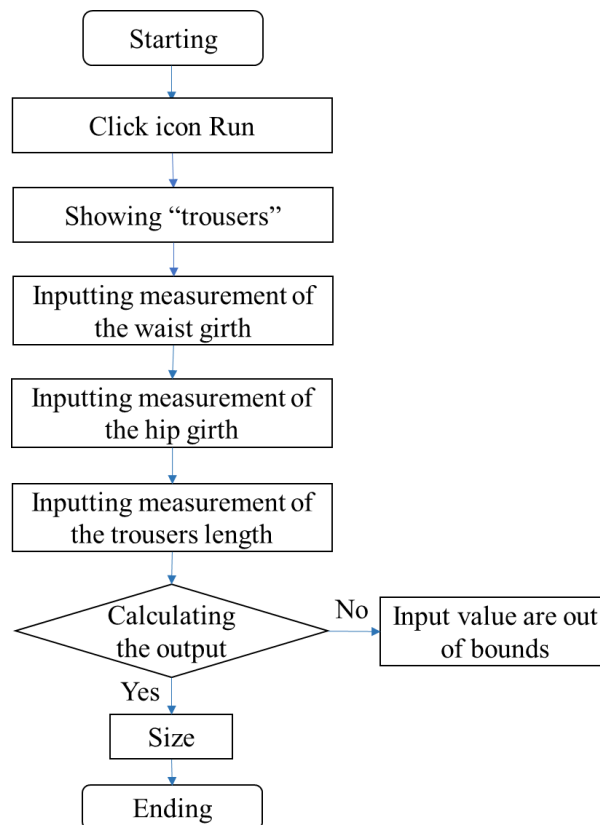
ruleList =

```
[1 1 1 1 1 1; % If (waist is W63) and (hip is H78.5) and (length is 94) then (size is S28)
1 1 2 1 1 1; % If (waist is W63) and (hip is H78.5) and (length is 96) then (size is S28)
1 1 3 1 1 1; % If (waist is W63) and (hip is H78.5) and (length is 98) then (size is S28)
1 2 1 2 1 1; % If (waist is W63) and (hip is H82.5) and (length is 94) then (size is S29)
1 2 2 2 1 1; % If (waist is W63) and (hip is H82.5) and (length is 96) then (size is S29)
1 2 3 2 1 1; % If (waist is W63) and (hip is H82.5) and (length is 98) then (size is S29)
1 3 1 3 1 1; % If (waist is W63) and (hip is H86.5) and (length is 94) then (size is S30)
1 3 2 3 1 1; % If (waist is W63) and (hip is H86.5) and (length is 96) then (size is S30)
1 3 3 3 1 1; % If (waist is W63) and (hip is H86.5) and (length is 98) then (size is S30)
1 4 1 4 1 1; % If (waist is W63) and (hip is H90.5) and (length is 94) then (size is S31)
1 4 2 4 1 1; % If (waist is W63) and (hip is H90.5) and (length is 96) then (size is S31)
1 4 3 4 1 1; % If (waist is W63) and (hip is H90.5) and (length is 98) then (size is S31)
1 5 1 5 1 1; % If (waist is W63) and (hip is H94.5) and (length is 94) then (size is S32)
1 5 2 5 1 1; % If (waist is W63) and (hip is H94.5) and (length is 96) then (size is S32)
1 5 3 5 1 1; % If (waist is W63) and (hip is H94.5) and (length is 98) then (size is S32)
1 6 1 6 1 1; % If (waist is W63) and (hip is H98.5) and (length is 94) then (size is S33)
1 6 2 6 1 1; % If (waist is W63) and (hip is H98.5) and (length is 96) then (size is S33)
1 6 3 6 1 1; % If (waist is W63) and (hip is H98.5) and (length is 98) then (size is S33)
6 1 1 1 1 1; % If (waist is W86) and (hip is H78.5) and (length is 94) then (size is S28)
6 1 2 1 1 1; % If (waist is W86) and (hip is H78.5) and (length is 96) then (size is S28)
```

6 1 3 1 1 1; % If (waist is W86) and (hip is H78.5) and (length is 98) then (size is S28)  
 6 2 1 2 1 1; % If (waist is W86) and (hip is H82.5) and (length is 94) then (size is S29)  
 6 2 2 2 1 1; % If (waist is W86) and (hip is H82.5) and (length is 96) then (size is S29)  
 6 2 3 2 1 1; % If (waist is W86) and (hip is H82.5) and (length is 98) then (size is S29)  
 6 3 1 3 1 1; % If (waist is W86) and (hip is H86.5) and (length is 94) then (size is S30)  
 6 3 2 3 1 1; % If (waist is W86) and (hip is H86.5) and (length is 96) then (size is S30)  
 6 3 3 3 1 1; % If (waist is W86) and (hip is H86.5) and (length is 98) then (size is S30)  
 6 4 1 4 1 1; % If (waist is W86) and (hip is H90.5) and (length is 94) then (size is S31)  
 6 4 2 4 1 1; % If (waist is W86) and (hip is H90.5) and (length is 96) then (size is S31)  
 6 4 3 4 1 1; % If (waist is W86) and (hip is H90.5) and (length is 98) then (size is S31)  
 6 5 1 5 1 1; % If (waist is W86) and (hip is H94.5) and (length is 94) then (size is S32)  
 6 5 2 5 1 1; % If (waist is W86) and (hip is H94.5) and (length is 96) then (size is S32)  
 6 5 3 5 1 1; % If (waist is W86) and (hip is H94.5) and (length is 98) then (size is S32)  
 6 6 1 6 1 1; % If (waist is W86) and (hip is H98.5) and (length is 94) then (size is S33)  
 6 6 2 6 1 1; % If (waist is W86) and (hip is H98.5) and (length is 96) then (size is S33)  
 6 6 3 6 1 1; % If (waist is W86) and (hip is H98.5) and (length is 98) then (size is S33)

### 3.5 The result of prediction for the men's trousers sizes

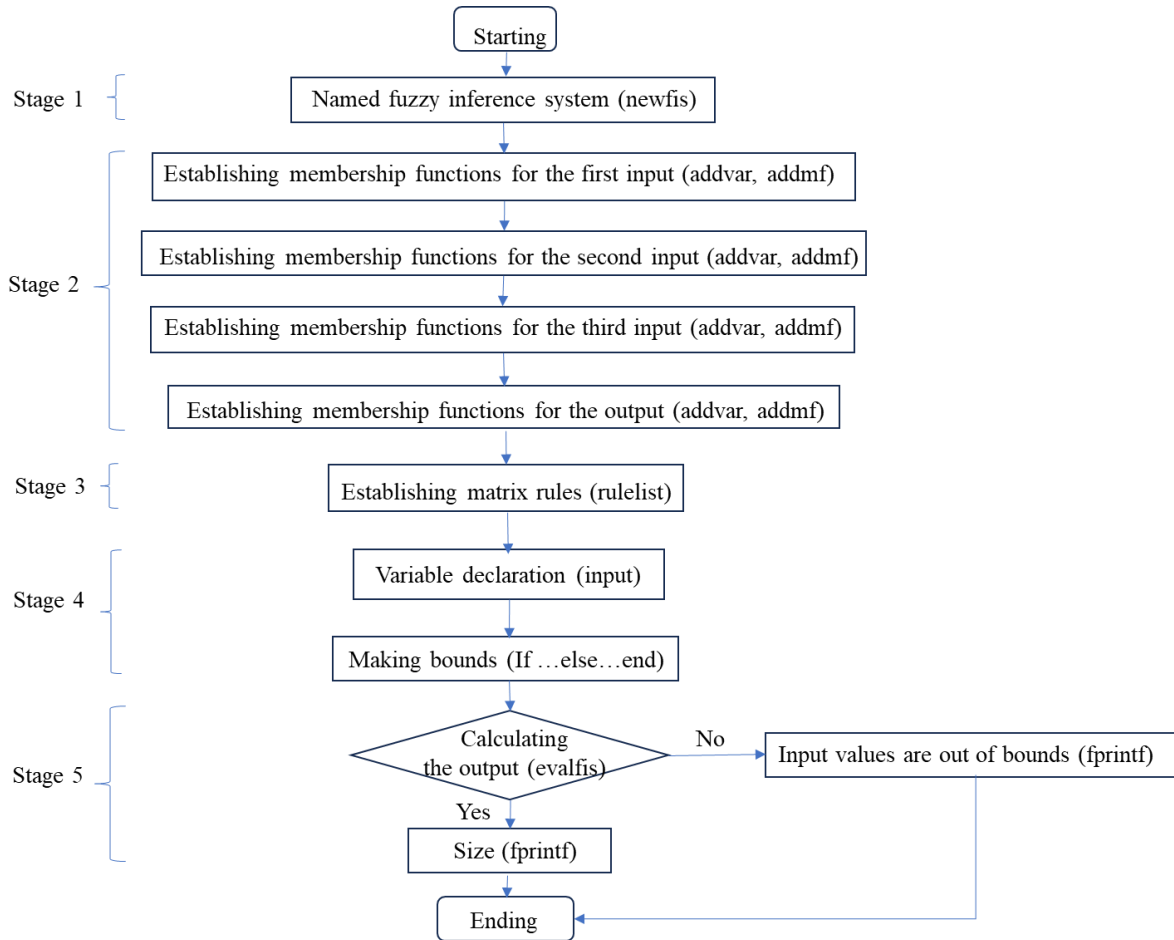
In the program's command window, start by entering the file name. Then, inputting the waist girth, hip girth, and trousers length measurements (Figure 9). The program will process these values and provide the corresponding size. For instance, if the waist measurement is 66 cm, the hip girth is 75.5 cm, and the trousers length is 92 cm, the resulting size will be 28. If any input values are out of bounds, an error will be displayed.



**Figure 9.** The flowchart for the predicting sizes.

### 3.6 The flow chart to predict the trousers size

The program is written in Matlab software and consists of five stages (Figure 10). In Stage 1, the program is named using the `newfis` command. In Stage 2, the `addvar` and `addmf` commands are used to set up the membership functions for the input variables: waist, hip, and trousers length. Additionally, the output membership function, which corresponds to the predicted size, is set up. In Stage 3, the fuzzy rule matrix is defined using the `rulelist` command. In Stage 4, the input data for the three variables are specified using the `input` command. The `if-else, end` command is then used to define the measurement range for the variables. Finally, the results are displayed when running the `fprintf` command. The displayed result will be the size (as shown in Table 1) if the values of the three input variables are within the boundary conditions; otherwise, the message "Input values are out of bounds" will be shown.



**Figure 10.** The algorithm to predict trousers size.

### 3.7. Testing the Size Selection Model

The research sampled individuals aged 18 to 60, divided into three age groups: 18-25, 25-45, and 45-60, with 10 men tested in each group. The size prediction process was evaluated using two distinct testing methods. In the first method, the measurements from Table 1 were entered into the program. The output sizes were then compared with the corresponding sizes listed in the table. In the second method, waist girth, hip girth and trousers length measurements were input into the prediction program. The resulting sizes were compared with those in the size chart. Both methods showed a high level of accuracy and consistency with the expected sizes, confirming the reliability of the size selection process used in the study. The fuzzy inference times for one size selection was about five to six seconds (from when starting to enter the waist girth, hip girth and trousers length). If choosing the size using the traditional method (choosing and wearing the sample many times to select the right size for the body size), it would take at least 10 minutes to choose the fit size for the body size. Therefore, it shows that the size prediction

method using fuzzy logic techniques will reduce the time needed to choose the sample. At the same time, it also reduces the risk of damage due to repeated sample testing.

### 3.8. Discussion

In the future, the size prediction model using fuzzy logic techniques will be applied to a wider variety of clothing styles and user groups. This application will enable consumers to quickly find clothing that fits their body shape, saving time in sample selection and reducing the likelihood of product damage. Furthermore, these research results align with current Industry 4.0 trends, contributing to advancements in personalized and efficient retail experiences.

However, this technique faces challenges when scaling to more complex systems. As the number of input variables increases, the number of rules grows exponentially, making it difficult to manage and optimize.

### 4. Conclusions

This paper presents a study that explores the use of fuzzy logic for predicting men's trousers size. The proposed model incorporates three key input variables: waist girth, hip girth, and trousers length. To effectively capture the nuances of these measurements, the model utilizes six membership functions for waist girth, six for hip girth, and three for trousers's length. The size prediction program is based on the Max-Min composition rule within the Mamdani fuzzy system. It consists of five stages, with a fuzzy rule matrix comprising 108 rows and 6 columns. This system helps customers quickly determine their appropriate size, significantly improving the process of selecting the right fit. It not only saves time but also reduces the risk of product damage due to repeated sample testing. Moreover, the model is well-suited for e-commerce platforms, where size selection is critical. Overall, this study offers a promising approach to size prediction, with strong potential for practical applications in apparel technology, paving the way for more efficient and personalized clothing solutions.

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Saigon 2 Garment Joint Stock Company, Vietnam, has approved the size chart in the study for the author's use.

### Conflict of Interest

The authors confirm that there is no conflict of interest to declare for this publication.

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