EAI Endorsed Transactions
on Sustainable Manufacturing and Renewable Energy Research Article EAI.EU

An approach to determining garment sizes with fuzzy logic

Mong Hien Thi Nguyen[1,*], Minh Duong Nguyen[2], Mau Tung Nguyen[3]

[1] Department of Textile & Garment Engineering, Faculty of Mechanical Engineering, University of Technology-VNU–HCM, Ho Chi Minh City, Vietnam
[2] Metrology Lab, Faculty of Mechanical Engineering, University of Technology-VNU–HCM, Ho Chi Minh City, Vietnam
[3] Faculty of Garment Technology-Fashion, Industrial University of Ho Chi Minh City, Ho Chi Minh City, Vietnam

Abstract

This paper introduces a method for determining men's trousers sizes using a fuzzy logic technique. The Sugeno model is employed in a MISO fuzzy system with three inputs and one output. The process begins by choosing primary dimensions from the size chart, specifically one horizontal and one vertical dimension, followed by defining the value ranges for the membership functions. The model results, based on a size chart that includes six different dimensions. In this study, waist girth and outseam are selected as the primary dimensions, acting as input variables for the simulation model. Fuzzy logic is utilized to determine the size based on the Min-Max rule, with the IF-THEN structure effectively implementing commands within this model. The result of this process is an optimal size selection that aligns more accurately with the individual's body measurements. Moreover, the application of fuzzy logic significantly reduces the time required for size determination compared to traditional methods. This approach offers an alternative method for size selection, one that accounts for the inherent variability in body measurements, thus providing a more tailored and accurate fit for consumers. The study underscores the potential of fuzzy logic to enhance the efficiency and effectiveness of garment sizing systems, offering a promising solution to the challenges posed by standardized sizing methods.

Keywords: size chart, fuzzy logic, primary dimension, trousers, model, garment, trousers length, waist girth

Received on 04 04 2024, accepted on 02 09 2024, published on 03 10 2024

doi: 10.4108/eetsmre.7136

1. Introduction

Nowadays, nearly everyone buys ready-to-wear, although the frequency of these purchases varies. Finding the right size remains a significant challenge since each type of garment typically comes in multiple sizes. This issue of sizing is a major concern for businesses, customers, and designers alike. A study [1] focused on plus-size clothing designs for both German men and women. In this research, two sizing surveys were conducted using 3-D scanning technology to measure and analyze the body shapes and sizes of plus-size individuals. Virtual 3-D body models were then generated, leading to the development of optimized basic patterns for pants and jackets. Another study [2] applied fuzzy clustering to choose clothes. A fuzzy logic approach serves as a fundamental component of the matching system, utilizing a triangular membership function to predict the suitable clothing size. The system was tested on nine children aged between 6 and 12 years. Continuing the trend of using fuzzy logic in the garment industry, a separate study [3] employed fuzzy logic to predict the drape behavior of various fabrics. The results revealed that changes in fabric parameters significantly influenced the drape, and a strong correlation was found between the experimental values and those predicted by the fuzzy system. In study [4], the authors employed a triangular fuzzy classification method to

*Corresponding author. Email: ntmhien14719@hcmut.edu.vn

determine an appropriate size from the sizing data system using fuzzy techniques. It aims to identify the best-fitting size for individuals based on actual data in the table and various body dimensions under edge conditions. The authors implement fuzzy logic for size selection using the Sugeno model and If–Then rules. This study presents an algorithm to automatically extract the size and body shape of a 3D scanned model. The methods used in this research include factor analysis, linear regression equation, cluster analysis, and discriminant analysis. Authors use fuzzy logic to establish the mathematical model. In this model, the input variables are the inseam height and the neck girth measurements, and the output variables are the numbers of the human size coding and body shape [5]. Additionally, the research explored the applications of fuzzy logic in the textile industry, including the development of fuzzy expert systems and the use of fuzzy logic for predicting clothing sizes. This research illustrates that determining the appropriate clothing size is significantly influenced by fuzzy logic. By employing fuzzy logic methods, the accuracy of size predictions can improve compared to traditional approaches, enhancing consumer experience and production efficiency in the textile sector [6]. In research (Pengpeng et al., 2020), the authors analyzed a sample of Chinese men from 18 to 60 years old and showed 6 body shape groups to improve the efficiency and accuracy of predicting human body shape through principal component analysis method. [7]. Another study utilized Artificial Neural Networks (ANNs) to create a model for predicting the fit of virtual clothing in Optitex software, using data from 50 women aged 18 to 35 years [8]. Research has also explored the use of genetic algorithms to propose a 3D design method for polo shirts [9], as well as designing Kansei-style T-shirts using back-propagation neural networks [10-11]. These intelligent algorithms are applied not only in design but also in other areas such as technology, sewing materials, and production management within the garment industry [12-17]. In the field of production technology, several studies [18-20] have been conducted. Similarly, intelligent algorithms for sewing materials have been explored in studies [21-23]. The above content summarizes several previous studies relevant to the research presented in this paper. Selecting the correct size for ready-to-wear clothing often requires considerable time to ensure a proper fit, making research in this area essential. By integrating these insights, the authors aim to develop a more accurate and practical model for predicting clothing sizes using advanced techniques. This model has the potential to significantly improve the fit and comfort of ready-to-wear clothing.

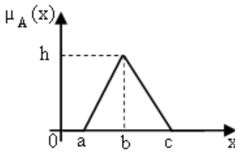
2. Material and methods

2.1. Material

The size chart for men's trousers at Sanding Company in Vietnam includes four horizontal dimensions and one vertical dimensions, resulting in a total of six distinct sizes. These dimensions are carefully measured to accommodate various body types, resulting in a total of six different sizes. The size range starts from size 28, which is suitable for individuals with smaller waist and hip measurements, and extends to size 33, designed for those with larger proportions. Each size increases in increments of one unit, ensuring a gradual progression in fit [24].

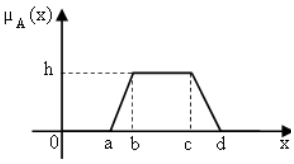
2.2. Methods

Fuzzy logic is used to develop a model for selecting the appropriate size and running the simulation program. This study employs the Sugeno model for a MISO fuzzy system, incorporating two inputs and one output. The fuzzy logic rules are based on fuzzy sets and utilize Max-Min rules. This model employs two types of membership functions: the triangular membership function and the trapezoidal membership function. The trapezoidal membership function is used for the first and last membership functions. Figure 1 illustrates the triangular membership function, which has three parameters: lower limit, peak, and upper limit, and is calculated according to Equation (1). Figure 2 shows the trapezoidal membership function, which has two parameters at the lower end and two parameters at the top and is calculated according to Equation (2) [25].



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

Figure 1. The triangular membership function



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

Figure 2. The trapezoidal membership function

Since there are no adjacent or intersecting membership functions at either end of the interval, a trapezoidal membership function is employed. This allows for an extension of the range of input values by supporting gradual transitions at both ends of the interval while maintaining a consistent membership value within the central region. Such a design offers a broader and more flexible representation of the fuzzy set, accommodating uncertainty across a wider span.

In contrast, within the central region where many adjacent or intersecting membership functions exist, a triangular membership function is preferred. This function serves to concentrate the input values at a single point, resulting in a sharper peak at the centre, where the degree of membership reaches its maximum. The membership value then symmetrically decreases on both sides, providing a more focused representation of fuzzy input around a central value.

In this study, triangular, trapezoidal fuzzy sets are used for the input variables. The model has structured IF-THEN to practice commands effectively in Sugeno:

If (x_1 is A_1^m) and (x_2 is B_1^n) then (y_1 is C^p)

In there:

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

x_2 is the second 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 size that needs to look for and C∈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 size number having in rules.

3. Results and discussion

3.1. The primary dimensions and coding sizes

The trousers have measurement positions as in Figure 3. These measurement points encompass the trousers' overall length, waist girth, hip girth, thigh girth, and hem circumference. In this study, two of these primary dimensions are used as input variables within the fuzzy logic model, a technique commonly employed to handle uncertainty and imprecision in sizing algorithms. One dimension corresponds to the horizontal plane (waist girth), while the other reflects a vertical measurement (trousers length). The use of waist girth as the dominant size indicator in most standardized size labels is rational, given its critical role in ensuring a secure and comfortable fit. Thus, waist girth is identified as the primary dimension, followed by trousers length as the secondary dimension. The size coding follows the systematic classification detailed in the size chart (Table 1), ensuring consistency and precision in the labeling of different sizes across various body types.

Table 1. The men's trousers size chart and coding sizes

Dimension (cm)	Sizes symbol in the size chart					
	28	29	30	31	32	33
	Coding sizes					
	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

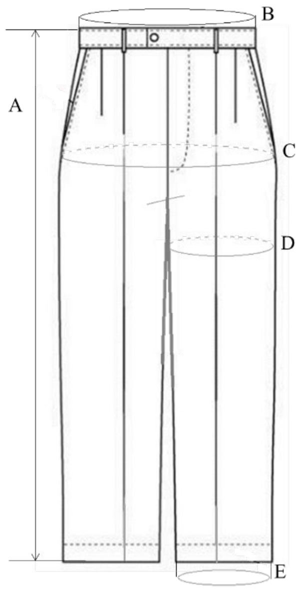


Figure 3. Trousers measurement positions

3.2 The boundary conditions for input's three variables

The simulation model incorporates three key anthropometric variables for size determination. The first variable (x_1) represents the waist girth measurement. The second variable (x_2) pertains to the trousers length measurement. The third variable (x_3) corresponds to the hip girth measurement of the trousers. Each of these variables is constrained within specific boundary conditions to ensure the accuracy and relevance of the size determination process. The waist girth is bounded by the range 60 cm to 86 cm. The trousers length falls within the range of 92 cm to 100 cm. The hip girth measurement is constrained between 76.5 cm and 101.5 cm. These boundary conditions are established to define the feasible input range for each variable, thereby ensuring that the simulation model operates within realistic and practical limits. By adhering to these constraints, the model effectively accommodates variations in body measurements while maintaining the integrity of the size selection process.

3.3 Input-Output data for the fuzzy logic model

The fuzzy logic system is composed of three input variables and one output variable (Figure 4). Each input variable is characterized by multiple membership functions, which represent the degree of membership to a specific fuzzy set. For instance, the first input variable is associated with six membership functions, which are of trapezoidal and triangular types, as detailed in Table 2 and illustrated in Figure 5. Similarly, the second input variable is linked to three membership functions, also of trapezoidal and triangular types, as depicted in Table 2 and Figure 6. The third input variable shares the same structural configuration as the first, with six membership functions of the same types, as outlined in Table 2 and Figure 7. The size chart, representing the system's output, consists of six distinct sizes. Accordingly, the output variable contains six membership functions corresponding to specific size values, namely 28, 29, 30, 31, 32, and 33, as shown in Table 2. The output of the fuzzy logic system thus provides a mapping to the size value that is to be determined based on the input data, facilitating the identification of the appropriate size category.

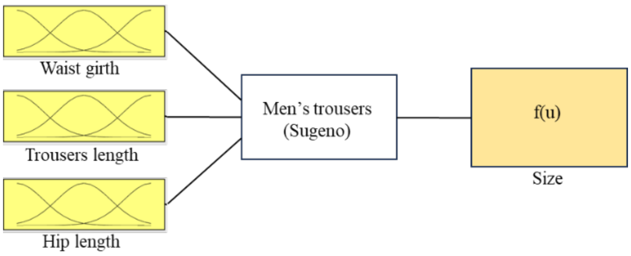


Figure 4. The fuzzy logic system of looking for the men's trousers size

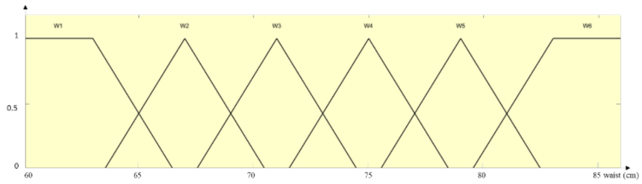


Figure 5. Membership functions for the first input variable (Waist girth)

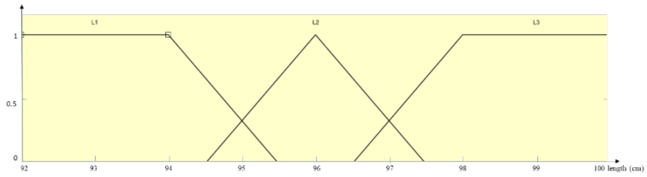


Figure 6. Membership functions for the second input variable (Trousers length)

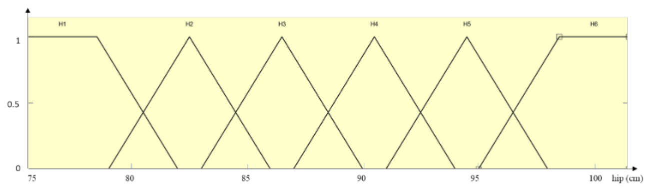


Figure 7. Membership functions for the third input variable (Hip girth)

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 (Trouser Length)			
MF	Parameter (cm)	MF	29	MF	Parameter (cm)	MF	Parameter (coding size
W1	[60 60 63 66.5]	H1	[75.5 75.5 78.5 82]	L1	[92 92 94 95.5]	28	28
W2	[63.5 67 70.5]	H2	[79 82.5 86]			29	29
W3	[67.5 71 74.5]	H3	[83 86.5 90]	L2	[94.5 96 97.5]	30	30
W4	[71.5 75 78.5]]	H4	[87 90.5 94]			31	31
W5	[75.5 79 82.5]	H5	[91 94.5 98]	L3	[96.5 98 100 100]	32	32
W6	[79.5 83.02 86 86]	H6	[95 98.5 101.5 101.5]			33	33

3.4 The result of fuzzy sets

The integration of the variable pair will demonstrate the fit using the CoM - Center of 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 values generated by the simulation model are determined based on various combinations of the three input variables. Specifically, six membership functions are associated with the first input variable, waist girth measurement. For the second input variable, the trousers length, there are three membership functions. The third input variable, hip girth measurement, is characterized by six membership functions. Given these parameters, the total number of fuzzy rules employed amounts to 108, reflecting the comprehensive nature of the rule set used to evaluate and determine size recommendations. Size code output is primarily derived from waist girth measurement, which serves as a key determinant in the sizing process.

The parameters of the model, including the membership functions and fuzzy rules, are based on values established from the size chart used in the study. For reference, the complete fuzzy rule set utilized in this research is detailed in Table 3. This table provides an overview of the rules that guide the size determination process, illustrating the systematic approach taken to integrate and apply fuzzy logic within the model.

Table 3. Fuzzy rule sets

Fuzzy rules	Waist girth	Trousers length	Hip girth	Size	Fuzzy rules	Waist girth	Trousers length	Hip girth	Size	Fuzzy rules	Waist girth	Trousers length	Hip girth	Size
1	W1	L1	H1	28	37	W3	L1	H1	28	73	W5	L1	H1	28
2		L2			38		L2			74		L2		
3		L3			39		L3			75		L3		
4		L1	H2	29	40		L1	H2	29	76		L1	H2	29
5		L2			41		L2			77		L2		
6		L3			42		L3			78		L3		
7		L1	H3	30	43		L1	H3	30	79		L1	H3	30
8		L2			44		L2			80		L2		
9		L3			45		L3			81		L3		
10		L1	H4	31	46		L1	H4	31	82		L1	H4	31
11		L2			47		L2			83		L2		
12		L3			48		L3			84		L3		
13		L1	H5	32	49		L1	H5	32	85		L1	H5	32
14		L2			50		L2			86		L2		
15		L3			51		L3			87		L3		
16		L1	H6	33	52		L1	H6	33	88		L1	H6	33
17		L2			53		L2			89		L2		
18		L3			54		L3			90		L3		
19	W2	L1	H1	28	55	W4	L1	H1	28	91	W6	L1	H1	28
20		L2			56		L2			92		L2		
21		L3			57		L3			93		L3		
22		L1	H2	29	58		L1	H2	29	94		L1	H2	29
23		L2			59		L2			95		L2		
24		L3			60		L3			96		L3		
25		L1	H3	30	61		L1	H3	30	97		L1	H3	30
26		L2			62		L2			98		L2		
27		L3			63		L3			99		L3		
28		L1	H4	31	64		L1	H4	31	100		L1	H4	31
29		L2			65		L2			101		L2		
30		L3			66		L3			102		L3		
31		L1	H5	32	67		L1	H5	32	103		L1	H5	32
32		L2			68		L2			104		L2		
33		L3			69		L3			105		L3		
34		L1	H6	33	70		L1	H6	33	106		L1	H6	33
35		L2			71		L2			107		L2		
36		L3			72		L3			108		L3		

3.5 The result of looking for the men's trousers sizes

For a detailed representation of the fuzzy logic rules utilized in this study, Figure 8 should be consulted. This figure illustrates the interrelationships between body measurements and garment sizing, with particular emphasis on the output parameters derived from neck girth classifications. Within this framework, the size corresponding to each neck girth category is determined by referencing the waist measurement. Furthermore, the diagram reveals how the waist girth classification is cross-referenced with three distinct trousers length groups, facilitating more precise size alignment. Additionally, six hip girth classifications are incorporated, further enhancing the accuracy of the sizing process. This comprehensive approach, grounded in the principles of fuzzy logic, ensures the selection of appropriate trouser sizes is tailored to the specific anthropometric profiles represented.

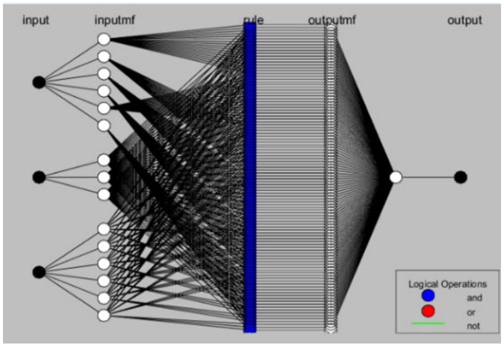


Figure 8. The ANFIS structure for men trousers sizes

The simulation procedure is designed to ensure fast and efficient determination of the appropriate size. Each input member functions in the system is tightly coupled to an output member function through a predefined set of rules, as shown in Figure 9. This coupling facilitates the calculation and determination of the final size, which is represented as a number according to the established sizing system data. The sizing procedure incorporates a rounding mechanism based on the decimal portion of the calculation result. Specifically, if the decimal portion of the result is less than 0.5, the selected size code will correspond to the integer portion of the result. For example, if the calculation result is 30.4, the assigned size code will be 30. Conversely, if the decimal portion is 0.5 or greater, the size code will be incremented to the next integer. Therefore, if the result is 30.5, the size code will be 31. This method ensures that the size selection is both accurate and practical, covering a wide range of male body sizes that satisfy the boundary conditions of the three input variables. By combining these rounding rules, the simulation system aims to provide the user with a recommendation for the most suitable size to purchase.

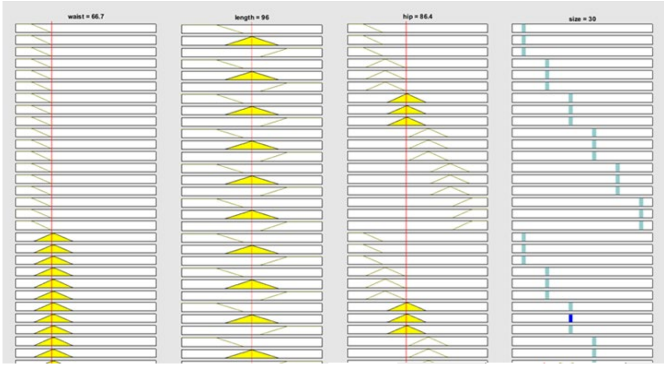


Figure 9. The result of choosing the size

The result generated from the output represents the numerical code associated with a particular size. To determine the corresponding size, this code should be cross-referenced with the size numbers listed in the line 4 of Table 1. By comparing the output code with the values in the table, one can accurately identify the most suitable size based on the predefined size classification.

3.6 Testing the Size Selection Model

The evaluation of the size selection process was conducted through two distinct testing methods. In the first method, the measurements provided in Table 1 were input into the simulation program, as illustrated in Figure 9. Following this, the output results were compared with the corresponding sizes listed in the table. The second method involved inputting the waist girth, trousers length, and hip girth measurements of a sample group consisting of 30 men into the simulation program. The resulting sizes were then compared with those listed in the sizing tables. In both approaches, the outcomes demonstrated a high level of appropriateness and alignment with the expected sizes, confirming the reliability of the size selection process employed in the study.

4. Conclusion

This paper presents the application of fuzzy logic techniques for simulating the selection of appropriate trouser sizes for men. The using of fuzzy logic enables customers to determine the most suitable sizes based on experimental and empirical body measurement data. The model employed in this study utilizes three key anthropometric input variables: waist girth, hip girth, and trousers length. The output is represented by a specific size code, which corresponds to standardized sizing systems used in the garment industry. To enhance precision, the model integrates six membership functions for waist girth, six for hip girth, and three for trousers length, creating a nuanced and adaptable framework for size prediction. The decision-making process is governed by the Max-Min composition rule, coupled with an extensive set of 108 fuzzy rules. These rules are designed to manage the inherent uncertainties in body measurements and to produce more accurate sizing recommendations. This simulation program not only streamlines the size selection process but also offers a user-friendly interface that allows consumers to identify their ideal size quickly and confidently. This, in turn, reduces the likelihood of poor fit, which is a common issue in ready-to-wear clothing. The results of the study demonstrate the practicality and effectiveness of applying fuzzy logic to clothing size determination, suggesting that this approach can significantly enhance the accuracy of size selection compared to traditional methods. The findings highlight the feasibility of fuzzy logic as a tool for improving the garment fitting process, with implications for both manufacturers and consumers alike. This exploration of fuzzy logic in garment sizing not only opens new avenues for further refinement but also demonstrates the potential for broader application across various aspects of garment production and customization. This study, therefore, contributes a significant advancement to predict garment sizes, offering a foundation for future research and industry application.

In the future, this research is expected to expand into various other areas of the textile and garment industry, including predicting customer demand, forecasting fabric colors, assessing clothing fit, and analyzing the pressure exerted by garments on the wearer's body. By leveraging fuzzy logic in these domains, we can enhance decision-making processes, improve product design, and ultimately create a more personalized and comfortable experience for consumers.

Acknowledgements.
This research is funded by Vietnam National University Ho Chi Minh City (VNU-HCM) under grant number C2024-20-06.
The size chart in the study has been approved by Saigon 2 Garment Joint Stock Company, Vietnam for the author's use.

References

[1] Simone M, Andreas S, Anke K, Christine L. Sizing and fit for plus-size men and women wear. Anthropometry. Apparel Sizing and Design, Second Edition. 2020: 371-406.
[2] Nurashikin Saaludin1, Amna Saad1 and Cordelia Mason, " Intelligent Size Matching Recommender System: Fuzzy Logic Approach in Children Clothing Selection " in IOP Conference Series: Materials Science and Engineering, 2020, doi 10.1088/1757-899X/917/1/012014.
[3] Thouraya H, Adel G, Faten F. Fuzzy Logic Method for Predicting the Effect of Main Fabric Parameters Influencing Drape Phenomenon. Autex Research Journal. 2020; 20(3): 220-227, doi: 10.2478/aut-2019-0034.
[4] Nguyen, M.H.T., Vo, T.Q. & Bui, M.H. Using of fuzzy theory extracts the fit size of human. Int J Syst Assur Eng Manag 14, 29–36 (2023). Doi: 10.1007/s13198-020-01010-w
[5] Nguyen, M. H. T., Vo, T. Q., Bui, M. H., & Pham, V. A. (2022). The Algorithm to Automatically Extract Body Sizes and Shapes . Tekstilec, 65(1), 67-80. Doi:10.14502/tekstilec.65.2021018.
[6] Imran Hassan * and Suman Kar. The application of fuzzy logic techniques to improve decision making in apparel size. World Journal of Advanced Research and Reviews. 2023, 19(02), 607–615
[7] Pengpeng, C., Daoling, C. and Jianping, W. (2020) "Clustering of the body shape of the adult male by using principal component analysis and genetic algorithm–BP neural network. Soft Comput, Vol. 24, pp. 13219–13237, doi:10.1007/s00500-020-04735-9.
[8] Ah PC, Wai CC, Kwan YL, Kai YC. Improving the Apparel Virtual Size Fitting Prediction under Psychographic Characteristics and 3D Body Measurements Using Artificial Neural Network, Human Factors for Apparel and Textile Engineering. 2022; 32: 94–105, doi: 10.54941/ahfe1001543.
[9] Zhang Z, Cong H. 3D modeling design and rapid style recommendation of polo shirt based on interactive genetic algorithm. Journal of Engineered Fibers and Fabrics. 2020; 15: 1-9, doi: 10.1177/1558925020966664.
[10] Han X, Ruoan R, Han C. Research on T-shirt-style design based on Kansei image using back-propagation neural networks. AUTEX Research Journal. 2024; 24(1): 20230007. doi:10.1515/aut-2023-0007.
[11] Yuki K, Mayumi U, Masayoshi K. Prediction of clothing comfort sensation of an undershirt using artificial neural networks with psychophysiological responses as input data. Textile Research Journal. 2022; 92(3-4): doi: 10.1177/00405175211034242.
[12] Bilgiç, H., Kuvvetlı, Y., & Duru Baykal, P. (2021). Determination of Difficulty Level for Garment Model with Fuzzy Logic Method. Tekstil Ve Mühendis, 28(121), 39-47.
[13] Zhujun W, Yingmei X, Jianping W, Xianyi Z, Yalan Y, Shuo X. A knowledge-supported approach for garment pattern design using fuzzy logic and artificial neural networks. Multimed Tools. 2022; 81: 19013–19033. doi: 10.1007/s11042-020-10090-6.
[14] Junjie Z, Kaixuan L, Min D, Hua Y, Chun Z & Xianyi Z. An intelligent garment recommendation system based on fuzzy techniques". The Journal of The Textile Institute. 2019; 111(9): 1324–1330.
doi: 10.1080/00405000.2019.1694351.
[15] Wang J. Classification and Identification of Garment Images Based on Deep Learning. Journal of Intelligent & Fuzzy Systems. 2023; 44 (3): 4223-4232, doi: 0.3233/JIFS-220109.
[16] Evrim BO, Fatma B, Deniz A, Fatma K. Predicting consumers' garment fit satisfactions by using machine learning. AUTEX Research Journal. 2024; 24(1): doi:10.1515/aut-2023-0016.
[17] Rajkishore N, Rajiv P. Artificial intelligence and its application in the apparel industry. Automation in Garment Manufacturing. The Textile Institute Book Series. 2018; 109-138.
[18] Joy S, Niaz MR, Sakib UZ, Abdullah AF, Zawad HP. Advanced Technology in Apparel Manufacturing. Advanced Technology in Textiles. Springer, Singapore. 2023; 177-231, doi: 10.1007/978-981-99-2142-3_7.
[19] Onaran E, Yanık S. Predicting Cycle Times in Textile Manufacturing Using Artificial Neural Network. Intelligent and Fuzzy Techniques in Big Data Analytics and Decision Making. INFUS 2019. Advances in Intelligent Systems and

Computing, 1029. Springer, Cham. 2020; 305-312, doi: 10.1007/978-3-030-23756-1_38.
[20] Bilgiç H, Kuvvetl Y, Duru BP. Determination of Difficulty Level for Garment Model with Fuzzy Logic Method. Tekstil Ve Mühendis. 2021; 28(121): 39-47.
[21] Joy S, Abdullah AF, Elias K. Predicting the tearing strength of laser engraved denim garments using a fuzzy logic approach. Heliyon. 2022; 8(1): doi: 10.7216/1300759920212812105.
[22] Joy S, Abdullah AF, Moni SM. Modeling the seam strength of denim garments by using fuzzy expert system. Journal of Engineered Fibers and Fabrics. 2021; 1, doi: 10.1177/15589250219889.
[23] Özgen KB. Application of Neural Network for the Prediction of Loss in Mechanical Properties of Aramid Fabrics After Thermal Aging. Textile and Apparel. 2024; 34(1): 77-86, doi: 10.32710/tekstilvekonfeksiyon.1280482.
[24] https://sanding.vn/ao-so-mi-nam-tay-dai/ao-somi-nam-soc-caro-nhuyen-mau-xanh-navy-130228-sdm3010.html
[25] James K. Peckol. Introduction to Fuzzy Logic. Wiley; 1st edition. 2021.