Intelligent Size Matching Recommender System: Fuzzy Logic Approach in Children Clothing Selection

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Intelligent Size Matching Recommender System: Fuzzy Logic Approach in Children Clothing Selection

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Abstract. Choosing right-fit clothing is important for children since it is related to the conformity of clothes to the body, especially as we know that children normally engage in active routine activities. During the growth period, children grow-up rapidly in a different pattern. Nowadays, with internet and technology advancement, the online retail business has become the preferred shopping mode for internet-savvy customers, especially in the clothing and textile sector. The recent Coronavirus Pandemic has made online retail a necessity. Therefore, this research focuses on establishing a prototype of the children size matching recommender system, a "sizing advisor" for parents to identify the best clothes fitting which matches the requirement of their children's body size to the sizing of existing brands. The fuzzy logic approach was applied as a heart of the matching system where the triangular membership function has been used in predicting the suitable clothing size. Nine children aged between 6 years old and 12 years old were selected to test the system. The fit was validated by an expert in sizing. The research aims to provide a size matching system to increase buying satisfaction among parents while shopping for children's clothes online. The manufacturers, as well as small and medium-sized enterprises (SMEs) which engage in online retailing of children's clothing, may also benefit from reducing return and thus will help increase sales and profitability.

1. Introduction

In Malaysia, the percentage of internet users increased from 76.9% (24.5 million) in 2016 to 87.4% (28.7 million) in 2018. In addition, the percentage of internet shoppers increased from 48.8% in 2016 to 53.3% in 2018 [1]. In tandem with the increase of shoppers, Malaysia's manufacturing sales increased by 5.2 percent in December 2019 to register at RM76.1 billion as compared to RM72.3 billion a year before, and the increment was driven by textile, clothing, and footwear as the contributing segments [2]. Kearney [3] reported that the clothing industry generated $3 trillion global value with 2% of gross domestic product (GDP) in 2015 and was estimated to continuously grow up to $5 trillion in 2025, while the U.S Embassies abroad [4] reported that fashion and accessories led the export sector in Malaysia online shopping. The rise of online shopping activities can lower purchasing costs and provide savings for the customers in the form of lower transportation costs and less shopping time. These developments motivated this research to visualize how the prototype of a size matching recommender system can be developed and benefit the children's clothing industry, especially in the online business retailing segment. The system will provide a solution to the problem of 'misfit' in

sizing for children's clothing, which is part of an integrated E-Commerce system for the clothing industry, as shown in Figure 1.

This research chooses to focus on children's clothing because children often outgrow clothes very fast compared to the adult, which their clothing size could be based on the sales and fit history [5]. Thus, the purchase of children's clothing is frequent, and this can be very costly [6]. Many studies on consumers' clothing fit and sizing satisfaction have been done. Sizing and fit have been cited as key causes of consumer dissatisfaction, especially for ready to wear clothing [7][8][9][10]. According to Zakaria et al. [11], choosing the right-fit clothing is important for children since it is related to the conformity of clothes to the body. Zakaria et al. were among the pioneers in Malaysia who are actively doing research related to sizing and fitting. A preliminary study done by Saaludin et al. [12] on parents' online shopping satisfaction revealed that, while online shopping is perceived to be a convenient shopping platform, parents have to take risks in purchasing the product because children are unable to try the apparel for fitting. Based on the result of this study, the common complaints among parents were an unintelligible label of sizing, confusing information and variability of the sizing system within and between brands. The study also concluded that purchasing the wrong size clothes requires time to return and exchange.

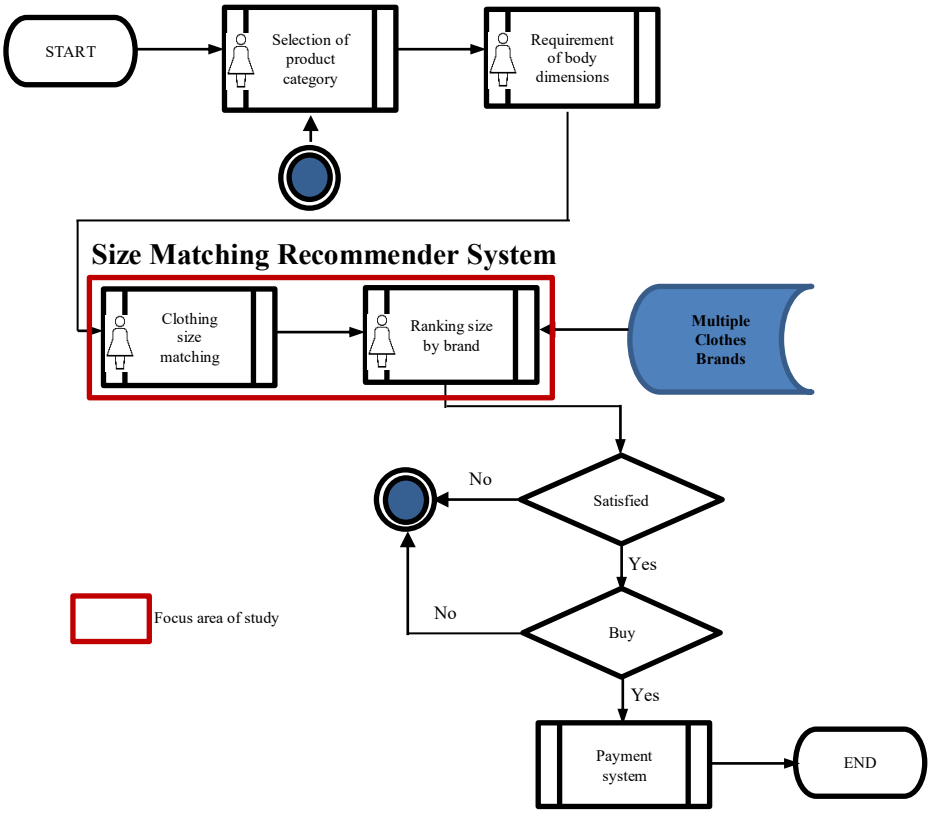

Figure 1. A big picture of a clothing size matching system in an integrated e-commerce system

In order to reduce the return and exchange of the wrong clothes size, many efforts have been done to overcome the fit and sizing issues, including 3D virtual-try-on to provide more information about body sizing to customers. In the case of size selection, several start-up businesses have used different principles to assist customers in making decisions on clothing such as 'Virtusize' and 'True-fit' [13]. The companies use the history of the online customer body type to recommend them with the right size for the next purchase. At 'Virtusize', the online company provides a platform for customers to choose the right size based on the measurement details, including the description of the clothes in 2D.

In this study, the fuzzy logic approach was used to find the right clothing size for customers through the size matching recommender system.

Similar to other artificial intelligence applications such as neural networks and expert systems, fuzzy logic also deals with the uncertainty and vague human assessment in computing problems [14]. Lotfi A. Zadeh founded the fuzzy logic theory in 1973. He discovered the theory after he published his pioneering and controversial research paper on fuzzy sets in 1965 [15]. The theory and the principle of fuzzy logic contribute to a significant impact on the enhancement and modernisation of computing and engineering technology. Zadeh's contribution is immense as the theory has been applied in various fields such as in the manufacturing of intelligent industrial products, and has benefitted consumers.

In many application areas, the fuzzy logic can describe the linguistic variable (i.e., small, medium, large, and extra-large) into the imprecise ("fuzzy") words for computer-understandable terms [16][17]. Fuzzy logic is capable of solving problems beyond identification, pattern recognition, and optimisation to assisting in the decision-making process. Therefore, it is not surprising that fuzzy logic is widely used in many fields, such as in textile and clothing, agriculture, engineering, architecture, and automobile industries.

2. Methodology

In order to develop a clothing size matching recommender system, the fuzzy logic approach has been selected. The approach is set to be the heart of the matching system where the triangular fuzzy logic membership function, as written by Anand and Baratraj [18], has been used in predicting suitable clothing sizes. This study focuses on how the fuzzy logic approach operates in the system. Nine children (seven boys and two girls) aged between 6 years old and 12 years old were selected to test the system and the validation of the fit was done by the subject matter expert (SME). The SME appointed is from the GIAT MARA, an institution which specializes in tailoring. Figure 2 depicts the fuzzy logic approach used to match the body size measurement with the clothes sizes of existing brands, scraped from the online stores' websites. The suitable clothes size of the brand will be recommended through the system.

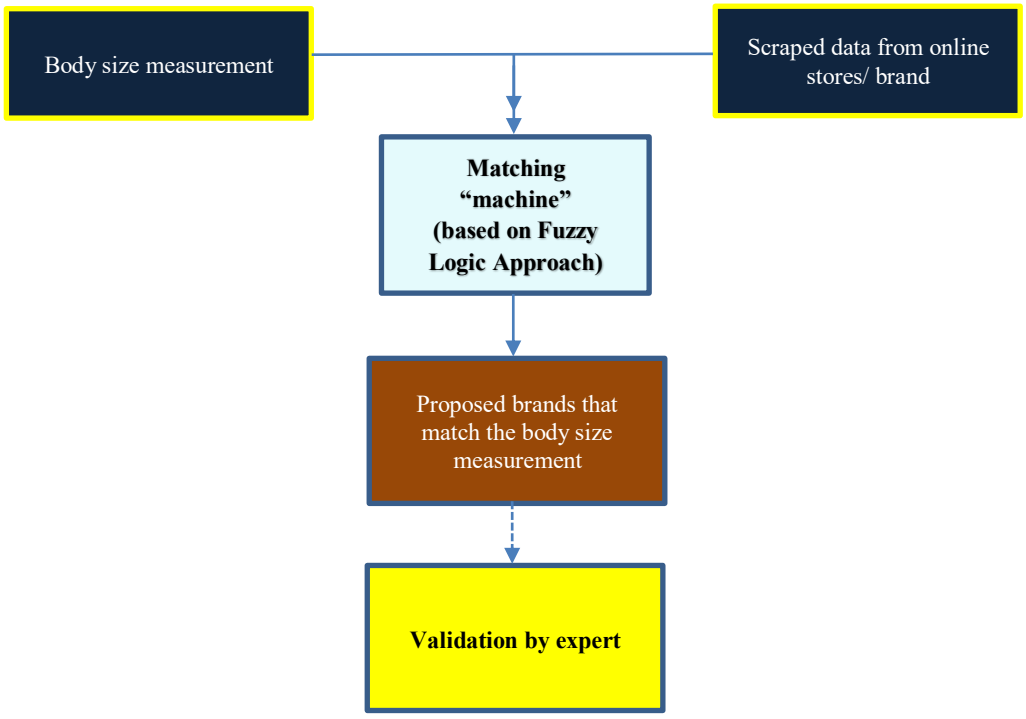

Figure 2. The Clothing Size Matching System Based on the Fuzzy Logic Approach

The development of the clothing size matching recommender system was divided into several stages in order to assist customers to identify the right fit of clothes. The R software has been used to develop the prototype of the matching system.

2.1. The development of matrix system for the body size measurement by customer.
The system was designated for m customer a.k.a children body size measurement, which is represented as follows:

$$B = \begin{bmatrix} b_{11} \\ b_{21} \\ . \\ . \\ b_{m1} \end{bmatrix} \tag{1}$$

Several customer body size measurements are compulsory for the clothing size matching recommender system.

2.2. The development of the matrix system for a triangular fuzzy number by clothing sizes for each of the attributes.
Methods of designing membership functions differ depending on the application purpose. This study proposed to describe the clothing sizes according to linguistic variables (i.e., small, medium, large and extra-large or by age ranges) by the triangular fuzzy logic membership function. Other than triangular, trapezoidal, and gaussian is also often used to represent the variables so that the judgement can be done for the decision making process [15]. In this study, the judgement was carried out to decide the right size for the customer. The triangular fuzzy logic membership function was chosen to avoid complexity, especially in defining parameters (clothing sizes) of the variable into fuzzy numbers set. The numbers will be specified by the ordered triplet as follows:

$$Tr(a,b,c), \quad a \le b \le c \tag{2}$$

Where;
$a =$ lower limit point
$b =$ optimum point
$c =$ upper limit point

Based on Demir et al. [13], they used 85% of the first-class upper point for all lower limit point value for the minimum fitting, which is value ‘a’, and 96.5% of upper limit point for the optimum point value for the best fitting, which is value ‘b’. The values were used in creating a membership function for each of the attributes. All the fuzzy triangular numbers will be arranged based on the clothing sizes for each of the attributes A_i (i.e., height, chest, waist).

$$A_i = \begin{bmatrix} a_{11} & a_{12} & .... & a_{1n} \\ b_{21} & b_{22} & .... & b_{2n} \\ c_{31} & c_{32} & .... & c_{3n} \end{bmatrix} \tag{3}$$

2.3. The development of the matrix system for fuzzy logic membership values.
The membership values of each of the attributes (i.e., height, chess, waist) of the clothing sizes will be calculated by substituting the customer’s body size measurement into the triangular membership function $Tr(x:[a,b,c])$. The membership function will be used as follows:

$$Tr(x:[a,b,c]) = \begin{cases} 0, & x \le a \\ \dfrac{x-a}{b-a}, & a < x \le b \\ \dfrac{c-x}{c-b}, & b < x \le c \\ 0, & x > c \end{cases} \quad (4)$$

The process will produce a matrix system for the membership values for the customers, M as follows:

$$M = \begin{bmatrix} m_{11} & m_{12} & m_{13}.... & m_{1n} \\ m_{21} & m_{22} & m_{23},... & m_{2n} \\ . & . & . & . \\ . & . & . & . \\ m_{m1} & m_{m2} & m_{m3}.... & m_{mn} \end{bmatrix} \quad (5)$$

The minimum value of each of the column shows the degree of fitness for every clothing size. The maximum value of the fitness degree, which approaches 1, shows that the size is recommended to be selected, as stated by Voskoglou [19].

3. Result and Finding

3.1. Sizes reference chart

In this study, two sizes reference charts from US well-known brands (Brand A [20][21] and Brand B [22]) have been scraped from their website in order to match the clothing size of selected children. The sizes reference charts used are shown in Table 1 for Brand A, and Table 2 for Brand B. Brand A uses height, weight, and waist as attributes of size reference for their clothing sizes. Brand A has added another size cluster, namely 6X, on top of the existing size cluster to differentiate the sizes guide of girls from boys. Whereas Brand B uses height, chest, and waist as an attribute of clothing sizes reference. Brand B uses the same size guide for both boys and girls. The sizes reference chart for both of the brands were stated in age and age-range respectively.

Table 1. Clothing sizes reference chart for brand A

Boy								
Sizes reference chart by age		5	6	7	8	10	12	14
Attribute	Height	109-116	117-123	124-134	136-138	140-142	144-149	150-155
	Weight	18-20	20-22	22-25	25-28	28-33	33-39	40-45
	Waist	53	55	56	58	61	64	66
Girl								
Sizes reference chart by age		5	6	6X	7	8	10	12
Attribute	Height	109-116	117-123	124-128	130-134	136-138	140-142	144-147
	Weight	18-20	20-22	22-23	23-25	25-28	28-33	33-39
	Waist	53	55	56	57	58	61	64

Table 2. Clothing sizes reference chart for brand B

Sizes reference chart by age-range		4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14
Attribute	Height	110	116	122	128	134	140	146	152	158	164
	Chest	58	60,5	63	65	68,5	71,5	74,5	78	80	82,5

	Waist	55	56	57	58	60	61,75	64	65,5	66,5	67,25

3.2. Dataset of children body size measurement

The dataset of children's body size measurement and their age has been collected to test the system. Table 3 shows the measurement of the body sizes based on the standard attributes (i.e., height, weight, chest, and waist) of the brand selected provided in their website. In addition, the details measurements for clothing design have also been measured for the validation purpose by an expert. The expert has evaluated the recommended size by the system at the end of the study.

Table 3. Dataset of children body size measurement

Body size measurement and	Name and age of children								
	Darwish (9)	Danish (12)	Arif (9)	Adam (7)	Irfan (12)	Daniel (8)	Iqbal (12)	Irdina (10)	Puteri (8)
Height	125	139	129	125	144.5	122	148	134	112
Weight	22.1	33.4	21.2	19.3	29	20.2	30.9	27.7	18.4
Chest	61	67	58	56	66	56	64	64	55
Waist	55	63	53	51	56	48	58.5	61	49

3.3. Triangular fuzzy logic approach application

In order to match the children's body size with the right clothing size, appropriate values of triangular fuzzy logic have been determined, as shown in Table 4 and Table 5 for both Brand A and Brand B, respectively.

Table 4. Triangular fuzzy numbers for each attribute of Brand A

Height		Sizes reference chart by age							
		5	6	6X (girl only)	7 (girl only)	8	10	12	14
Triangular fuzzy numbers	a	98.60	98.60	98.60	98.60	98.60	98.60	98.60	98.60
	b	111.94	118.70	123.52	129.31	133.17	137.03	143.79	149.58
	c	116.00	123.00	128.00	134.00	138.00	142.00	149.00	155.00
Weight		Sizes reference chart by age							
		5	6	6X (girl only)	7 (girl only)	8	10	12	14
Triangular fuzzy numbers	a	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00
	b	19.30	21.23	22.20	24.13	27.02	31.85	37.64	43.43
	c	20.00	22.00	23.00	25.00	28.00	33.00	39.00	45.00
Waist		Sizes reference chart by age							
		5	6	6X (girl only)	7 (girl only)	8	10	12	14
Triangular fuzzy numbers	a	45.05	45.05	45.05	45.05	45.05	45.05	45.05	45.05
	b	51.15	53.08	54.04	55.01	55.97	58.87	61.76	63.69
	c	53.00	55.00	56.00	57.00	58.00	61.00	64.00	66.00

Table 5. Parameters of each attribute for Brand B (boy and girl)

Height		Sizes reference chart by age-range									
		4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14
Triangular fuzzy numbers	a	93.50	93.50	93.50	93.50	93.50	93.50	93.50	93.50	93.50	93.50
	b	106.15	111.94	117.73	123.52	129.31	135.10	140.89	146.68	152.47	158.26
	c	110.00	116.00	122.00	128.00	134.00	140.00	146.00	152.00	158.00	164.00
Chest		Sizes reference chart by age-range									
		4-5	5-6	6-8	7-8	8-9	9-10	10-11	11-12	12-13	13-14
Triangular fuzzy numbers	a	49.30	49.30	49.30	49.30	49.30	49.30	49.30	49.30	49.30	49.30
	b	55.97	58.38	60.80	62.73	66.10	69.00	71.89	75.27	77.20	79.61
	c	58.00	60.50	63.00	65.00	68.50	71.50	74.50	78.00	80.00	82.50
Waist		Sizes reference chart by age-range									
		4-5	5-6	6-8	7-8	8-9	9-10	10-11	11-12	12-13	13-14
Triangular fuzzy numbers	a	46.75	46.75	46.75	46.75	46.75	46.75	46.75	46.75	46.75	46.75
	b	53.08	54.04	55.01	55.97	57.90	59.59	61.76	63.21	64.17	64.90
	c	55.00	56.00	57.00	58.00	60.00	61.75	64.00	65.50	66.50	67.25

The membership functions were formed from the fuzzy triangular numbers. As an example, the membership function of height for size '5', '6'and '7' is as follows:

$$Tr\left(x_5,125:\left[98.60,111.94,116.00\right]\right)=\begin{cases}0, & x_5\le 98.60\\ \dfrac{x_5-98.6}{13.34}, & 98.60<x_5\le 111.94\\ \dfrac{116.00-x_5}{4.06}, & 111.94<x_5\le 116.00\\ 0, & x_5>116.00\end{cases}$$

$$Tr\left(x_6,125:\left[98.60,118.70,123.00\right]\right)=\begin{cases}0, & x_6\le 98.60\\ \dfrac{x-98.6}{20.10}, & 98.60<x_6\le 118.70\\ \dfrac{118.70-x}{4.30}, & 118.70<x_6\le 123.00\\ 0, & x_6>123.00\end{cases}$$

$$Tr\left(x_7,125:\left[98.60,129.31,134.00\right]\right)=\begin{cases}0, & x_7\le 98.60\\ \dfrac{x_7-98.6}{30.71}, & 98.60<x_7\le 129.31\\ \dfrac{134.00-x_7}{4.69}, & 129.31<x_7\le 134.00\\ 0, & x_7>134.00\end{cases}$$

The membership values $\mu_{attribute,size}$ were calculated by substituting the related children's body size measurement into the membership function. The examples of membership calculation which used the body measurement of one of the children named 'Darwish' is shown as below:

$\mu_{height,5}(125) = 0$

$\mu_{height,6}(125) = 0$

$\mu_{height,7}(125) = 0.860$

The membership values were gathered in a table so that further analysis can be done to find the right clothing size for the 'Darwish.'

Table 6. Membership values for 'Darwish' using clothes size reference chart from Brand A

Clothes size		5	6	7	8	10	12
Attribute	Height (125 cm)	0	0	0,860	0,764	0,687	0,584
	Weight (22.1 kg)	0	0	0,715	0,509	0,343	0,247
	Waist (55 cm)	0	0	0,510	0,911	0,720	0,595
Minimum value of membership		0	0	0,510	0,509	0,343	0,247

The minimum values of membership for each class size were identified to determine the degree of cloth fit to 'Darwish' body measurement. The highest value of the degree provides the best cloth fitting, and the size 7 has been recommended to 'Darwish'.

3.4. Size matching result and validation result by expert

All the membership values were gathered in Table 7. The recommended size and brand were based on the highest degree of membership.

Table 7. Comparison of membership values for brand and size recommendation

Name (children)	Brand A		Brand B		Recommended brand and size
	Membership value	Size	Membership value	Size	
Darwish	0,510	8	0,696	8-9	B; 8-9
Danish	0,446	12	0,682	11-12	B;11-12
Arif	0,589	7	0,518	8-9	A;7
Adam	0,323	7	0,461	7-8	B;7-8
Irfan	0,581	12	0,562	11-12	A;12
Daniel	0,328	7	0,136	7-8	A;7
Iqbal	0,526	14	0,527	12-13	A;14 & B;12-13
Irdina	0,518	12	0,651	10-11	B;10-11
Puteri	0,269	6X	0,309	5-6	B;5-6

The expert has evaluated the results by comparing the detailed measurement with the recommended size by the system. The validation result is shown in Table 8.

Table 8. The validation result by an expert on the satisfaction of clothing fit

Name (children)	Membership value	Recommended brand and size	Validation by expert				
			Very dissatisfied	Partly dissatisfied	Partly Satisfied	Satisfied	Extremely satisfied
Darwish	0,696	B; 8-9				√	
Danish	0,682	B;11-12				√	
Arif	0,589	A;7				√	
Adam	0,461	B;7-8			√		
Irfan	0,581	A;12				√	
Daniel	0,328	A;7			√		
Iqbal	0,527	A;14 & B;12-13				√	
Irdina	0,651	B;10-11				√	
Puteri	0,309	B;5-6			√		

4. Conclusion and Future Works

This study was mooted to visualize how the size matching recommender system by brand could contribute to the development of the clothing industry. The system will provide a reference for parents when buying clothes for their children by recommending the right size according to the brand. The system is expected to have a positive impact on the children's clothing industry by reducing the numbers of return and increasing the consumers a.k.a parents' confidence toward online shopping. In addition, the system will create a value-added to the existing E-commerce system by introducing a more sophisticated system (which will be embedded in an e-commerce system with a purposely derived size predictive system by using fuzzy logic approach). The size matching recommender system will help the local clothing business penetrate and compete in the global market place with regards to children's clothing. This will provide a solution for manufacturers as well as small and medium-sized enterprises (SMEs) businesses to reduce return, lower the cost of doing business, gain a bigger market share, and increase profitability.

At this point of time, the study has some limitations. These limitations might affect the level of customer satisfaction on clothing fit. Firstly, the size matching recommender system can only match the size for the customers, a.k.a children based on the body size measurements and the size reference chart provided by the online stores. The issue arises when the different brands use different attributes (i.e., height, weight, waist) as an indicator of size reference chart. Even though several studies had found that different gender and age groups showed different overall body sizes [23] [24][25], certain brands have not considered these differences when designing clothes, especially for children. This becomes a real challenge for the system to rank the best size for the children by brand. Secondly, the system has matched the children body size into almost the correct age range according to the respective brands, but the accuracy of size can be argued. It can be seen through the degree of membership that the values are less than 0,70. The values can be interpreted as the clothing sizes are not truly fit. The most fitting can only be achieved if the membership values approach 1. The result parallels with the validation result by an expert who noted the degree of fit as partly satisfied and satisfied. This is due to the growth pattern of children is different [26], and most clothing sizing systems references are from Europe or America and China, [28] and several Asian countries such as Japan and Korea [24]. It can be concluded that the sizing system used is less reliable for Malaysian. Thus, there is a need to develop a new standard sizing system based on children's body dimension data, which is still lacking in Malaysia.

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