



**TEKSTİL VE MÜHENDİS**  
**(Journal of Textiles and Engineer)**



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**Determination of Difficulty Level for Garment Model with Fuzzy Logic Method**

**Giyisi Modeli İçin Zorluk Seviyesinin Bulanık Mantık Yöntemi İle Belirlenmesi**

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Online Erişime Açıldığı Tarih (Available online): 1 Nisan 2021 (1 April 2021)

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**Bu makaleye atıf yapmak için (To cite this article):**

Hilal BİLGİÇ, Yusuf KUVVETLİ, Pınar DURU BAYKAL (2021): Determination of Difficulty Level for Garment Model with Fuzzy Logic Method, Tekstil ve Mühendis, 28: 121, 39-47.

**For online version of the article:** <https://doi.org/10.7216/1300759920212812105>

## **DETERMINATION OF DIFFICULTY LEVEL FOR GARMENT MODEL WITH FUZZY LOGIC METHOD**

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*Gönderilme Tarihi / Received: 23.06.2020*

*Kabul Tarihi / Accepted: 29.01.2021*

**ABSTRACT:** The purpose of this study is a rule-based fuzzy logic approach is proposed for determining model difficulty in manufacturing top clothing for ladies. A decision framework concerned with different scenarios (main pattern types and material types) is proposed for determining the model difficulty. Each scenario modeled as a Mamdani type fuzzy inference system which is known as one of the best approximator fuzzy logic models. The fuzzified input variables are unit operation time, second quality rate and fabric weight. Moreover, two different defuzzification methods which are centroid and middle of maxima are compared for finding best fuzzy logic structure over the six different test instances. According to the results, both defuzzification methods find similar model difficulty determinations. A graphical user interface of the proposed decision framework is designed in order to apply this to real-life applications. Finally, six different clothing models are identified to be simple, medium-hard, hard and very hard. The results of this study showed that defuzzification methods is not significantly effected the model difficulty decisions off is systems regarding different test instances. The model difficulty values range between 0-10. In order to find a useful difficulty assignment (linguistic), the model difficulty is determined by using the closeness to center value ( $a_2$ ) of membership functions. This research offers a solution to determine the difficulty levels of the garment models.

**Keywords:** Garment industry, fuzzy logic, pattern, woman knitting clothes.

### **GIYSİ MODELİ İÇİN ZORLUK SEVİYESİNİN BULANIK MANTIK YÖNTEMİ İLE BELİRLENMESİ**

**ÖZET** Bu çalışmada, bayan üst giyim üretiminde model zorluğunun belirlenmesi üzerine kural tabanlı bir bulanık mantık yaklaşımı geliştirilmiştir. Model zorluğunu belirlemek için farklı senaryolarla (ana model türleri ve malzeme türleri) ilgili bir karar çerçevesi önerilmektedir. Her senaryo, en iyi bulanık mantık yaklaşım modellerinden biri olarak bilinen Mamdani tipi bulanık çıkarım sistemi olarak modellenmiştir. Bulanıklaştırılmış giriş değişkenleri birim çalışma süresi, ikinci kalite oranı ve kumaş ağırlığıdır. Dahası, altı farklı numune için ağırlık merkezi ve en büyüklerin ortalaması olmak üzere iki farklı durulaştırma yöntemi karşılaştırılmıştır. Sonuçlara göre, her iki durulaştırma yöntemi benzer model zorluk tespitleri bulmuştur. Bunu gerçek hayattaki kullanımlara uygulamak için önerilen karar çerçevesinin bir grafik kullanıcı arayüzü tasarlanmıştır. Son olarak, altı farklı giysi modelinin basit, orta-zor, zor ve çok zor olduğu belirlenmiştir. Çalışma sonuçlarına göre durulaştırma yöntemleri, farklı numunelere ait model zorluğu kararları üzerinde anlamlı bir etkiye sahip değildir. Model zorluk değerleri 0-10 arasında değerlendirilmektedir. Kullanılabilir bir zorluk ataması (dilsel) bulmak için model zorluğu, üyelik fonksiyonlarının merkez değerine ( $a_2$ ) yakınlığı kullanılarak belirlenir. Bu çalışma, giysi modellerinin zorluk seviyelerini belirlemek için bir çözüm sunmaktadır.

**Anahtar Kelimeler:** Hazır giyim, bulanık mantık, model, bayan örme giyim

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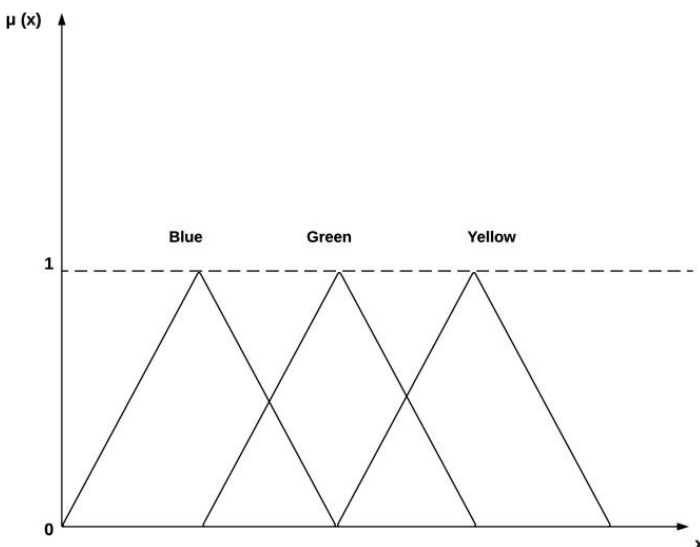
**DOI:** <https://doi.org/10.7216/1300759920212812105> [www.tekstilvemuhendis.org.tr](http://www.tekstilvemuhendis.org.tr)

## 1. INTRODUCTION

Most of the terms we use in our daily lives usually have a fuzzy structure. Numeral or verbal expressions that we use when we define a concept, explain an occurrence, and in many other situations have a certain degree of fuzziness. Terms like old, young, long, short, hot, cold, warm, cloudy, partly cloudy, sunny, fast, slow, much, many, little, some, hard, simple and many others can be given as examples. We humans use blurry expressions like these when we tell about an event or make a decision in the face of an incident [1]. Usage of these terms lacking certainty forms the basis of the concept of fuzzy logic. Fuzziness is defined as the state of being uncertain or obscure in expressions defining an objective, a concept and a system. In other words, it is the uncertainty found in the meaning of a word or the definition of a concept [2].

Fuzzy logic was first introduced in 1960 by the University of California, Berkeley. It was put forth by Lotfi Zadeh to model natural uncertainty. Zadeh asks the fuzzy logic theory to be considered as a methodology for generalization of fuzzification rather than an independent and complete theory by transforming any theory from crisp discrete form to continuous fuzzy form [3].

In fuzzy sets, the value of the variable is explained by interlaced sets using the granulation approach in certain sets, instead of quantization approach for all the values the variable can get [4]. For this reason, each term composed by semantic rules in fuzzy sets makes up of linguistic values or variables [4]. Colors are the best example for how the linguistic variables work. Colors have linguistic values like blue, green, yellow, purple and red in accordance with wavelength of light. Figure 1 shows how the color is comprised with linguistic variables. In this example, triangular membership functions are used in order to determine the primary colors by fuzzy numbers.



**Figure 1.** Defining color as a linguistic variable according to three linguistic values

In the year 1987, the first subway system was built which worked with a fuzzy logic-based automatic train operation control system in Japan. It was a big success and resulted in a fuzzy boom [5]. Today, Fuzzy Logic concept used widely in many implementations like automobile engine & automatic gear control systems, air conditioners, video enhancement in TV sets, washing machines, mobile robots, sorting and handling data, Information Systems, Pattern Recognition, decision support, traffic control systems, textile and garment industry and many, many others [6].

Academic studies using Fuzzy Logic method in the field of textile and garment are as follows, evaluation of plant's physical conditions, evaluation of textile products image, development of a supplier selection model, predicting yarn quality, for determining size number ...etc. Some of these studies are summarized below.

Park, Shin-Woong, et al (2000) investigated two new total hand simulating methods for knits uses fuzzy theory and neural networks. One method, a neural network system trained with a back-propagation algorithm, performs functional mapping between mechanical properties and the resulting total hand values of the fuzzy predicting method. The second method, a fuzzy-neural network system, uses the fuzzy membership function, weighted factor vector, and error back-propagation algorithm [7].

Hui, et al. (2002) extend the literature on fuzzy logic applications to control systems by proposing a simple, yet effective, rule-based system that captures the knowledge of experienced supervisors in a set of fuzzy rules. These rules specify how balance control can be achieved based on the level of difference between 1) the actual and target buffer level and 2) the actual and target section performance. The system was found to increase in production efficiency by 30% [8]. Hui, et al. (2005) aim to design and develop a learning-based fuzzy color prediction system for providing more effective apparel design in computer-aided design system using such an approach, an apparel designer could predict the favorite colors of garment for a target group of customers [9].

Yang, Zhang, et al. (2007) aim to provide an overview of the area of digital pattern developing for customized apparel. The paper outlines several methods of digital pattern developing for customized apparel, and discusses the principles, characters and applications [10]. Dong, A.H. et al. (2007) presented a simulation model linking manufacturer, retailer and customer in an apparel supply chain. The purpose of the model is to generate a portfolio that satisfies the apparel retailer-defined customer service level. The portfolio consists of replenishment strategy and performance index under different degrees of forecasting errors in sales. Fuzzy logic is integrated into the simulation model so as to investigate the different forecasting error degree between the sales forecasting and the customer demand in the apparel supply chain [11]. In a study by Zoumpouros and Aspragathos (2008), an innovative fuzzy logic approach for the robotic laying of fabrics on a work table and based on fuzzy sets is presented. Finally, the effectiveness of the two path-planning systems is investigated in an experimental

stage where the robot successfully places on a table fabrics of a variety of materials and sizes [12].

In the study by Güner, İlleez, et al. (2009), measurements are taken from all departments for each physical factors (illumination, noise, climate) that affect the working condition of an apparel company. Results gained from the measurements in departments are evaluated and graded by using fuzzy logic. According to these grades priority of reorganization of departments 'conditions are determined [13]. Ordoobadi's (2009) paper aims to provide a tool for decision makers to help them with selection of the appropriate supplier. The paper describes a decision model that incorporates decision maker's subjective assessments and applies fuzzy arithmetic operators to manipulate and quantify these assessments [14]. The research of Yıldız and Kışoğlu (2011), with the size tables and body size numbers taken from ready-wear enterprises carrying out activities in the women's outside wear field, modelling a common body numbering system was aimed through the fuzzy logic system [15].

Guo, et al. (2011) investigated a systematic review on the state-of-art of artificial intelligence (AI) applications in the apparel industry. The existing literature is reviewed based on different research issues and AI-based methodologies [16]. In a study by Haşiloğlu (2012) the image of Turkish origin textile products in the UK was evaluated with fuzzy set theory based on the analysis of Denizli, Turkey sample. The results of ideal solution results suggest that Denizli exporters are to focus on common brand and retailing and that "original" image of their products is to be brought forth by spreading Denizli hand woven textile products [17].

Ofluoğlu and Miran (2014), the objective of their study is comprehending the criteria hierarchy and the priority considered as base for selecting the suppliers and maintaining the relations with the existing suppliers. For that purpose, the priority of supplier selection criteria, which is assigned by the companies, is tried to be determined by using fuzzy pair-wise comparison [18]. Ghanmi, et al.(2015) purpose to predict a global quality index of a ring spun yarn whose count Ne is ranging between 7.8 (76.92 tex) and 22.2 (27 tex). To fulfill this goal, a hybrid model based on artificial neural network (ANN) and fuzzy logic has been established [19]. Eldessouki and Hassan (2015) present another textile application of fuzzy logic systems combined with ANN. They determine the textural features of fabric's surface by using adaptive neuro-fuzzy systems with a percent of 85.8 accurately [20].

Academic studies, using Fuzzy Logic method in the field of textile and garment, show that this method has not been applied in determining the model difficulty in apparel.

The difficulty / simplicity of the model, barely during the production of the garment, is understood. In clothing industry,

before production, the difficulty of the model is decided subjectively based on experience. In this study, it is aimed to predict the model difficulty with fuzzy logic method before production. For this purpose, a rule-based fuzzy logic approach is proposed for determining model difficulty in manufacturing top clothing for ladies.

The main contribution of this study is to demonstrate the applicability of fuzzy logic method in the clothing industry and to propose a new decision model for determining the model difficulty.

## 2. MATERIALS AND METHOD

### 2.1 Materials

In this study, six different clothing models are carefully selected to be different from each other in terms of pattern number and the number of small patterns. Figure 2 shows the selected models [21, 22, 23].

In order to see the effect of pattern type on model difficulty more clearly, models with both standard and non-standard main pattern are selected. In addition, 100% cotton, 100% viscose and 95% viscose-5% lycra knitted fabrics are preferred. Thus, the effect of fabric type on model difficulty can be evaluated.

### 2.2 Method

#### 2.2.1 Fuzzy Logic Model

In the study, a rule-based fuzzy inference approach is proposed for determining the model difficulty with fuzzy logic. Besides many different configurations of fuzzy systems can be applied, the Mamdani type accepted as an universal approximator that can be used for approximating different kind of functions as shown in [24]. Therefore, the Mamdani type fuzzy interface system is used in the modelling of the proposed fuzzy logic system. In a typical system, fuzzification, rule based decision making and defuzzification processes are taken place. Firstly, inputs are fuzzified with linguistic variables. Triangular fuzzy linguistic variables are selected in the fuzzy logic systems proposed in this study. After fuzzification process, a fuzzy output value are calculated regarding rule basis and input values. Finally, defuzzification is applied to the fuzzy output value in order to convert it to precise value. In this study, centroid and middle of maxima methods are compared for the built fuzzy systems. While centroid or center of gravity method calculates the area under the output membership function (equation 1) [25], middle of maxima method determines the mean of the maximum membership degree of the output membership function (equation 2) [26].

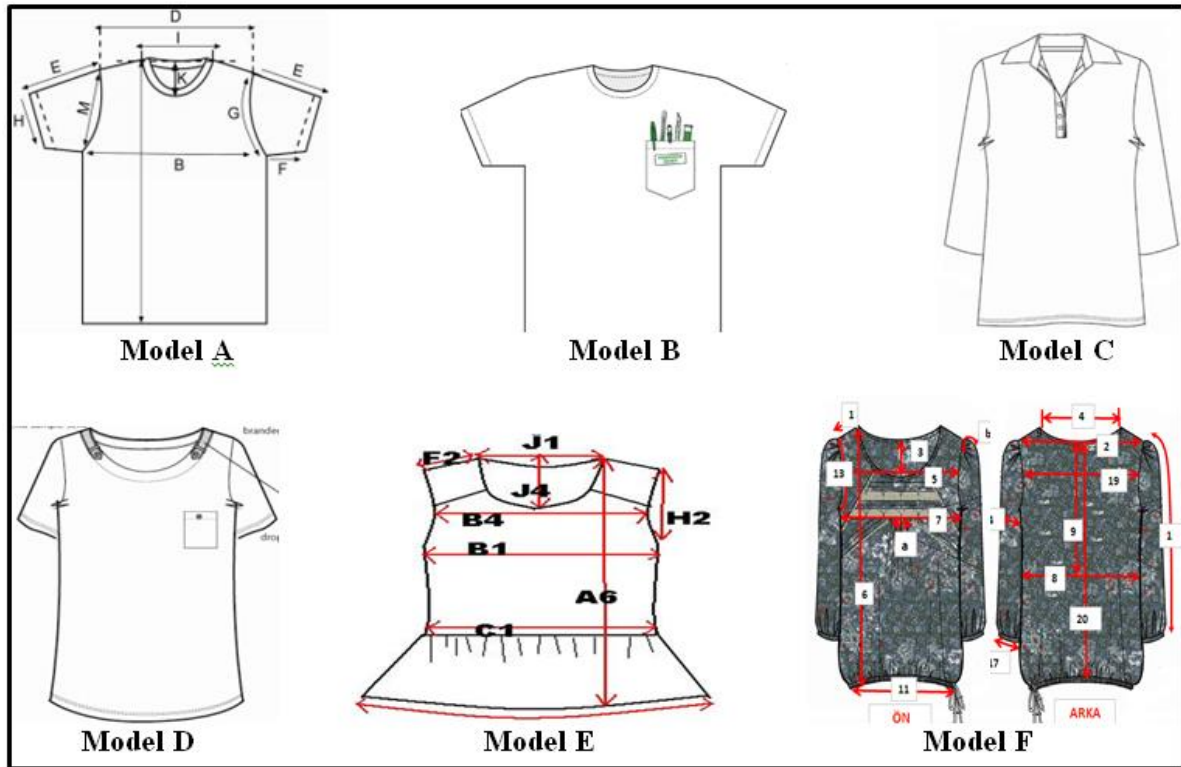


Figure 2. Technical drawings of selected models [21, 22, 23]

**Model A;** is a short sleeve, crew neck, basic t-shirt. It has 1 front body pattern, 1 back body pattern and 2 arm patterns.

**Model B;** is a short sleeve, crew neck, applique pocket t-shirt. It is made of 1 front body pattern, 1 back body pattern, 2 arm patterns and 1 pocket pattern.

**Model C;** is a long sleeve, stand-up collar, basic t-shirt with fly. It consists of 1 front body pattern, 1 back body pattern, 2 arm patterns, 2 collar patterns and 2 pieces of collar foot patterns.

**Model D;** is a short sleeve, crew neck, applique pocket t-shirt with epaulette. It is formed of 1 front body pattern, 1 back body pattern, 2 arm patterns, 1 front collar pattern, 1 back collar pattern, 1 pocket pattern and 4 epaulette patterns.

**Model E;** is a sleeveless, scoop neck, flounced blouse. It has 1 front body pattern, 2 back body patterns, 2 pieces of hem patterns and 2 shoulder patterns.

**Model F;** is a long sleeve, scoop neck, bounded blouse. It is composed of 1 front body pattern, 1 back body pattern, 2 arm patterns, 2 shoulder patterns, 2 pieces of side yoke patterns and 1 piece middle yoke pattern.

$$o^* = \frac{\int_u \mu_U(u) \cdot u \, du}{\int_u \mu_U(u) \, du} \quad (\text{Eq. 1})$$

$$o^* = \frac{\inf_{u \in \mathcal{U}} \{u \in \mathcal{U} \mid \mu_U(u) = \text{hgt}(U)\} + \sup_{u \in \mathcal{U}} \{u \in \mathcal{U} \mid \mu_U(u) = \text{hgt}(U)\}}{2} \quad (\text{Eq. 2})$$

Middle of maxima method finds the average of first and last values of  $o^*$ , where  $\mathcal{U}$  denotes the maximal membership degree while  $\text{hgt}(U)$  is the highest membership degree of  $U$ .

### 2.2.2 Decision Making Framework

In order to determine the model difficulty, a decision framework regarding different inputs and rules is proposed. The proposed system's decision tree is shown in Figure 3. Five main inputs are

used for predicting model difficulty. These are main pattern type (crisp), material type (crisp), sewing time, second quality rate and fabric weight. Unit operation (sewing) time, second quality rate and fabric weight are expressed with fuzzy numbers. Regarding these crisp conditions six different fuzzy logic system that has own rules for input variables are generated.

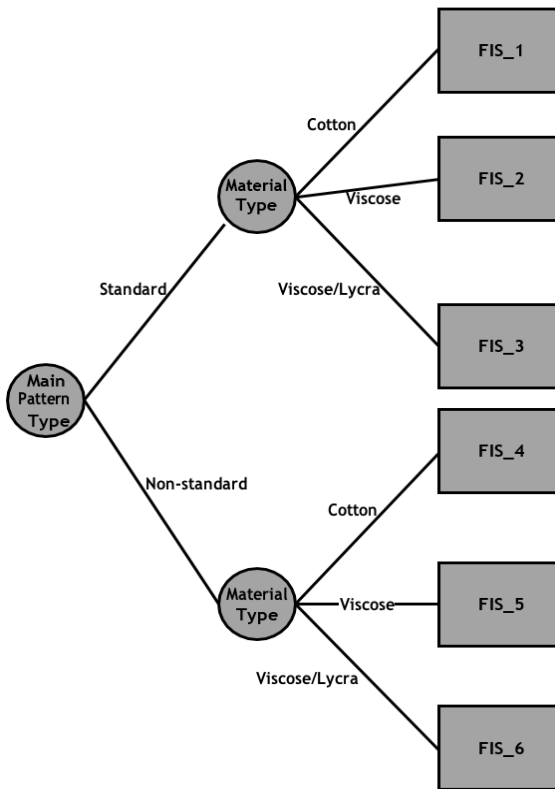


Figure 3. Framework of the proposed system

### 2.2.3 Determining Linguistic Expressions

In order to find the fuzzy equivalence of model difficulties, sewing (unit operation) time and second quality rate, 0-10 scale, 3-25 scale and 0-5 scale are used respectively (Tables 1, 2 and 3). Then fuzzy numbers are identified in accordance with the view of experts [27].

A scale of five values seen in Table 2 is used in determining the sewing time. Besides, a scale between 3-25 is used to create fuzzy comparisons for sewing time and fuzzy numbers for each sewing time are identified in accordance with expert view [21].

Similarly, as seen in Table 3, a scale between 0-5 is used to create fuzzy comparisons for second quality rate and fuzzy numbers for each second quality rate are identified in accordance with expert view [21].

The last determinant variable on the model difficulty is fabric weight. A fabric weight can be changed between 0 and more than 250 (g/m<sup>2</sup>) and it can be fuzzified with low, medium and high membership functions as given in Table 4.

The fuzzy inference system determines the output via the input variables and the rules. In this study, six different fuzzy inference systems are developed due to crisp input variables. The six fuzzy inference systems are shown in Figure 3, for instance first model considers standard main pattern type with cotton material decisions. Different number of rules are generated for each fuzzy

system and 270 rules are defined in total. The MATLAB software package is used for this aim. An example of a rule is given below:

**Rule 1** (for main pattern type is standard and materials type is cotton)

If sewing time is very short; second quality rate is low; fabric weight is low

Then: the model difficulty is very simple

Table 1. Linguistic expressions for model difficulty

| Model difficulty | Lower, Middle and Upper Bound of the Triangle Membership Function |       |       |
|------------------|---|-------|-------|
|                  | $a_1$   | $a_2$ | $a_3$ |
| Very simple      | 0   | 0     | 1     |
| Simple           | 0   | 1     | 3     |
| Medium           | 1   | 3     | 5     |
| Medium-Hard      | 3   | 5     | 7     |
| Hard             | 5   | 7     | 9     |
| Very hard        | 7   | 9     | 10    |

Table 2. Linguistic expressions for sewing time

| Sewing Time (min) | Lower, Middle and Upper Bound of the Triangle Membership Function |       |       |
|-------------------|---|-------|-------|
|                   | $a_1$   | $a_2$ | $a_3$ |
| Very Short        | 3   | 4     | 5     |
| Short             | 4   | 6     | 7     |
| Medium            | 6   | 8     | 10    |
| Long              | 8   | 15    | 17    |
| Very long         | 15  | 20    | 25    |

Table3. Linguistic expressions for second quality rate

| Second Quality Rate (%) | Lower, Middle and Upper Bound of the Triangle Membership Function |       |       |
|-------------------------|---|-------|-------|
|                         | $a_1$   | $a_2$ | $a_3$ |
| Low                     | 0   | 1     | 1.5   |
| Medium                  | 1   | 2     | 2.5   |
| High                    | 2   | 3     | 5     |

Table 4. Linguistic expressions for fabric weight

| Fabric Weight (g/m <sup>2</sup> ) | Lower, Middle and Upper Bound of the Triangle Membership Function |       |       |
|-----------------------------------|---|-------|-------|
|                                   | $a_1$   | $a_2$ | $a_3$ |
| Low                               | 0   | 100   | 200   |
| Medium                            | 150   | 225   | 250   |
| High                              | 225   | 500   | 1000  |

### 2.2.4 Model Difficulty Determiner GUI

A graphical user interface (GUI) is designed for the proposed system as shown in Figure 4. This GUI provides an easy implementation of real-life applications. The application takes user inputs for all input variables (main pattern type, material type, sewing time, second quality rate and fabric weight) and built proper FIS regarding decision tree that aforementioned before. When the user click the model difficulty button, a gauge is set regarding the output of the selected FIS and the closest response is given in the text.

### 3. RESULTS AND DISCUSSION

The proposed system's fuzzy membership functions are given in Figure 5. The proposed fuzzy systems are evaluated under different conditions (main pattern types and material types) in order to test the proposed system. The comparative results between proposed system model difficulty levels (centroid and middle of maxima approaches) are summarized in Table 5.

It can be concluded from the results, defuzzification methods is not significantly effected the the model difficulty decisions off is systems regarding different test instances. The model difficulty values range between 0-10. In order to find a useful difficulty

assignment (linguistic), the model difficulty is determined by using the closeness to center value ( $a_2$ ) of membership functions.

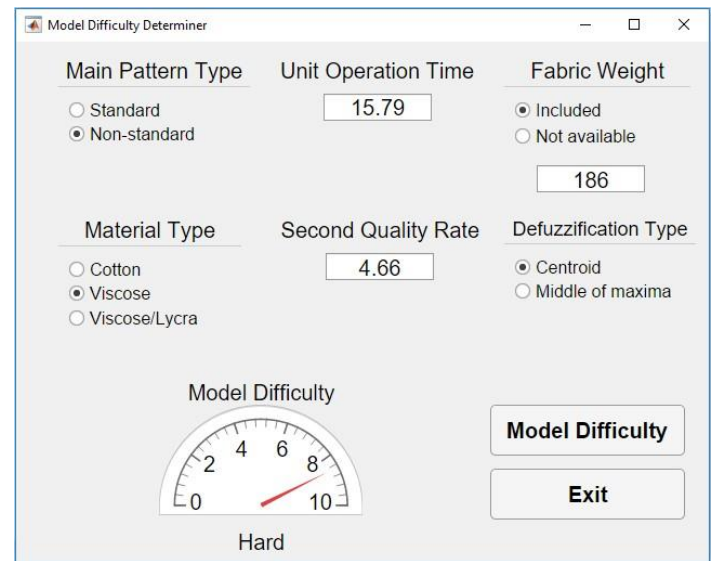


Figure 4. Model difficulty determiner application

The Model difficulty is identified through fuzzy logic model and shown in Table 6 for used models.

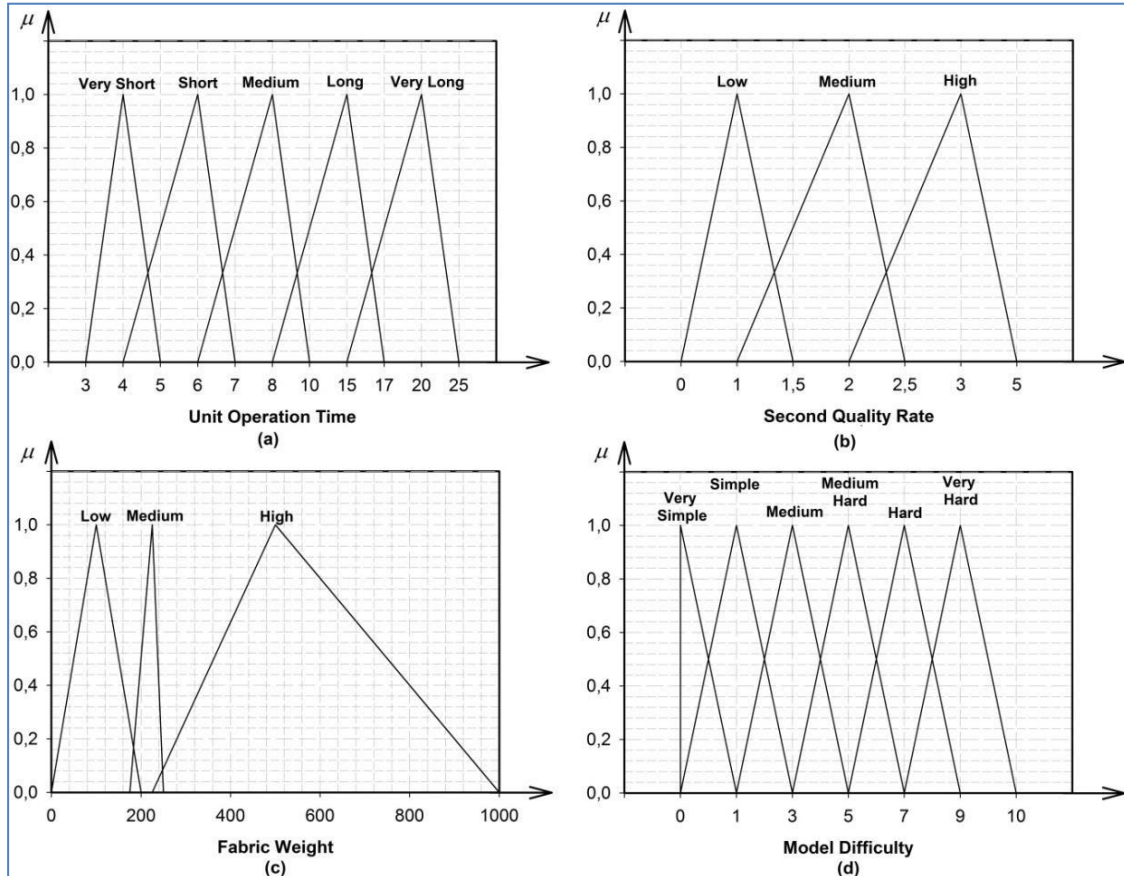


Figure 5. Fuzzy linguistic definitions of (a) unit operation time (input), (b) second quality rate (input), (c) fabric weight (input) and (d) model difficulty (output)

**Table 5.** Model test results

| Model   | Sewing time (min) | Second quality rate (%) | Main pattern shape | Type of Material | Fabric Weight (g/m <sup>2</sup> ) | Model Difficulty (centroid) | Model Difficulty (middle of maxima) |
|---------|-------------------|-------------------------|--------------------|------------------|-----------------------------------|-----------------------------|-------------------------------------|
| Model 1 | 5.6               | 1.8                     | Standard           | cotton           | 155                               | Medium (2.89)               | Medium (2.95)                       |
| Model 2 | 9.1               | 2.8                     | Standard           | viscose          | 242                               | Medium-hard (5)             | Medium-hard (5)                     |
| Model 3 | 8.1               | 2.4                     | Non-standard       | viscose-lycra    | 260                               | Hard (7)                    | Hard (7)                            |
| Model 4 | 7.2               | 2.2                     | Standard           | viscose-lycra    | 180                               | Hard (7)                    | Hard (6.95)                         |
| Model 5 | 6.8               | 2.3                     | Standard           | viscose          | 172                               | Medium-hard (5.205)         | Medium-hard (5)                     |
| Model 6 | 11.3              | 2.0                     | Non-standard       | cotton           | 320                               | Medium-hard (5)             | Medium-hard (5)                     |

**Table 6.** Test results for models used in this study

| Model   | Sewing time (min) | Second quality rate (%) | Main pattern shape | Type of Material | Fabric Weight (g/m <sup>2</sup> ) | Model Difficulty (centroid) | Model Difficulty (middle of maxima) |
|---------|-------------------|-------------------------|--------------------|------------------|-----------------------------------|-----------------------------|-------------------------------------|
| Model A | 6.007             | 2.22                    | Standard           | cotton           | <b>238</b>                        | <i>Medium (2.0949)</i>      | <i>Simple (1.25)</i>                |
| Model A | 6.007             | 2.22                    | Standard           | Viscose          | <b>186</b>                        | <i>Medium (3.0376)</i>      | <i>Medium (3)</i>                   |
| Model A | 6.007             | 2.22                    | Standard           | Viscose-lycra    | <b>292</b>                        | <i>Medium (3.0628)</i>      | <i>Medium (3)</i>                   |
| Model B | 9.222             | 2.79                    | Standard           | cotton           | <b>238</b>                        | <i>Medium-hard (5)</i>      | <i>Medium-hard (5)</i>              |
| Model B | 9.222             | 2.79                    | Standard           | Viscose          | <b>186</b>                        | <i>Hard (5.522)</i>         | <i>Medium-hard (5)</i>              |
| Model B | 9.222             | 2.79                    | Standard           | Viscose-lycra    | <b>292</b>                        | <i>Hard (7)</i>             | <i>Hard (7)</i>                     |
| Model C | 15.468            | 2.9                     | Standard           | cotton           | <b>238</b>                        | <i>Very Hard (7.523)</i>    | <i>Very Hard (7.55)</i>             |
| Model C | 15.468            | 2.9                     | Standard           | Viscose          | <b>186</b>                        | <i>Very Hard (7.523)</i>    | <i>Very Hard (7.55)</i>             |
| Model C | 15.468            | 2.9                     | Standard           | Viscose-lycra    | <b>292</b>                        | <i>Very Hard (8.5229)</i>   | <i>Very Hard (8.55)</i>             |
| Model D | 18.063            | 4.59                    | Standard           | cotton           | <b>238</b>                        | <i>Very Hard (7.5501)</i>   | <i>Very Hard (7.6)</i>              |
| Model D | 18.063            | 4.59                    | Standard           | viscose          | <b>186</b>                        | <i>Very Hard (7.5501)</i>   | <i>Very Hard (7.6)</i>              |
| Model D | 18.063            | 4.59                    | Standard           | viscose-lycra    | <b>292</b>                        | <i>Very Hard (8.5492)</i>   | <i>Very Hard (8.6)</i>              |
| Model E | 15.786            | 4.66                    | Non-standard       | cotton           | <b>238</b>                        | <i>Very Hard (7.5358)</i>   | <i>Very Hard (7.6)</i>              |
| Model E | 15.786            | 4.66                    | Non-standard       | viscose          | <b>186</b>                        | <i>Very Hard (8.5353)</i>   | <i>Very Hard (8.6)</i>              |
| Model E | 15.786            | 4.66                    | Non-standard       | viscose-lycra    | <b>292</b>                        | <i>Very Hard (8.5353)</i>   | <i>Very Hard (8.6)</i>              |
| Model F | 21.438            | 4.96                    | Non-standard       | cotton           | <b>238</b>                        | <i>Hard (7.5)</i>           | <i>Very Hard (7.5)</i>              |
| Model F | 21.438            | 4.96                    | Non-standard       | viscose          | <b>186</b>                        | <i>Very Hard (8.5)</i>      | <i>Very Hard (8.5)</i>              |
| Model F | 21.438            | 4.96                    | Non-standard       | viscose-lycra    | <b>292</b>                        | <i>Very Hard (8.5)</i>      | <i>Very Hard (8.5)</i>              |



According to the developed fuzzy logic model, of the models used in this study **Model A** is identified as **simple**, when type of material is cotton and the fabric weight is 238 g/m<sup>2</sup>, Model A is identified as **medium**, when type of materials are viscose and viscose-lycra and the fabric weights are 186 and 292 g/m<sup>2</sup>. As can be seen, the fabric type in terms of raw material and weight has affected the difficulty level of the model.

Although Model B with 1 extra pocket pattern, is very similar to Model A, model difficulty of B is harder than A. An extra small pattern causes the sewing time of Model B to increase.

Model D has a relatively higher number of total pattern and small pattern than the other models. Generally, higher pattern number makes sewing harder and lengthens the time. Consequently the difficulty value of this model is expected to increase. As a result of the applied fuzzy logic method, Model D is evaluated as very hard. This result supports our expectations.

Model F is also evaluated as very hard as a result of the applied fuzzy logic model once again. It has the highest number of patterns and small patterns after Model D. Moreover, the forms of small and main patterns are non-standard.

Results of this study showed that, also the increasing of second quality rates indicate that the models are difficult. This is also an expected situation in clothing industry, as the models get harder, the probability of error increases.

#### 4. CONCLUSION

In this study, the fuzzy logic method is used to determine the difficulty levels of models in clothing industry. Thus, it has been seen that a new method can be applied in determining the difficulty level of model in clothing.

Generally, models with fewer pattern number, with standard pattern shapes and with cotton raw materials, are easier to work with. Results from this study also confirmed this.

In the method proposed in this study, five main inputs are used for predicting model difficulty. These are form of main patterns (standard or non-standard), fabric raw material type, sewing time, second quality rate and fabric weight. As a result, this study reveals that fuzzy logic method can be used to predict the model difficulty before production.

In fuzzy logic method other type membership functions (like trapezoidal, Gaussian, etc.) can be used with more number of model types and compared for further studies.

#### Postscript

Some results of the study were presented as an oral presentation at "16<sup>th</sup> AUTEX World Textile Conference", June 8-10, 2016, Ljubljana, SLOVENIA [28].

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