Taxonomy of Fuzzy Multi-Attribute Decision Making Systems in Terms of Model, Inventor and Data Type

By SUNARDI

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Taxonomy of Fuzzy Multi-Attribute Decision Making Systems in Terms of Model, Inventor and Data Type

Rusydi Umar
Department of Informatics Engineering
Universitas Ahmad Dahlan
Yogyakarta, Indonesia
rusydi_umar@rocketmail.com

Sunardi
Department of Electrical Engineering
Universitas Ahmad Dahlan
Yogyakarta, Indonesia
sunardi@mti.uad.ac.id

Yasinta Bella Fitriana
Department of Informatics Engineering
Universitas Ahmad Dahlan
Yogyakarta, Indonesia
yasintabella13@gmail.com

***Abstract*—Decision support systems are one of the choices decision-makers make in an attempt to cope with the problems related to the time length required in decision-making process. Such systems are known to improve the efficiency and accuracy in the decision-making processes. In developing a decision support system, a certain calculation method is required as part of its processing. One of the most commonly used methods is FMADM. This research discusses the clustering of decision support system using FMADM in an attempt to provide a taxonomy of decision support system based on FMADM.**

Keywords-artificial intelligence; decision support system; fuzzy; taxonomy

I. INTRODUCTION

A decision support system (DSS) is a computerized system that will provide results in the form of ranking based on the assessment aspects determined by decision makers. DSSs are derived from expert systems and are part of the artificial intelligence (AI) field and of the applications that aim to help solving common knowledge-based cases [1]. DSSs are systems that try to gather and exploit human knowledge and experience in artificial intelligence systems so that they may assist in, or even perform, decision making [2]. Some examples of research on expert systems are stroke detection [3], animal disease identification [4, 5] and motor engine damage detection [6]. One of the algorithms used in DSSs is the Multiple Criteria Decision Making (MCDM) algorithm. However, MCDM is divided into several types. This paper, following a similar approach to the one in [7], provides a short literature review on MCDM taxonomy focusing on Multi Attribute Decision Making (MADM) aiming to provide a taxonomy of Fuzzy Multi-Attribute Decision Making Systems in Terms of Model, Inventor, and Data Type Methods.

II. RESULT AND DISCUSSION

MCDM is a decision-making method that can be used to establish the best choice from a number of alternatives based on certain criteria, e.g. size, standard etc [8]. However, MCDM has a minor disadvantage: if the data provided by the decision maker or the attribute of the data is incomplete, then the resulting decision will contain uncertainty. The problem of uncertainty can be caused by several things, namely: 1. Information that cannot be calculated, 2. Incomplete information, 3. Unclear information and 4. Partial abandonment [9]. To solve these problems, some research on the use of Fuzzy MCDM began to be conducted in order to find methods that proved to have excellent performance. FMCDM can be divided into 2 models: fuzzy multi objective decision making (FMODM) and fuzzy multi attribute decision making (FMADM). FMADM model then can be further divided into 2 models namely the Yager and the Baas & Kwakernaak model. Based on the type of data, FMADM can be divided into 3 types, namely fuzzy data, crisp data, fuzzy and crisp data [10]. While based on the method of application, FMADM can be divided into 3 types, namely SAW method, WP method and TOPSIS. FMADM taxonomies are shown in Figures 1-4 and are presented below.

A. FMADM Inventor-Based Taxonomy

1) Yager Model

The Yager model FMADM is the standard form of FMADM. According to [11],Yager model has 5 completion stages, which are:

1. Set a pairwise comparison matrix between attributes M based on Saaty's hierarchy procedure.
2. Determine the consistent weight of w_j for each attributes for each attribute based on the eigenvector method of Saaty.
3. Calculate the value of $\left(\tilde{C}_j(x_i)\right)^{w_i}$
4. Determine the intersection of all $\left(\tilde{C}_j(x_i)\right)^{w_i}$
5. Select x_i with the largest membership degree in $\tilde{D}$, and set the optimal alternatives.

One of the researches related to DSS using Yager method is [12] which emphasize on theapplication of DSS to solve cases about the determination of families as poor. A similar research, [13], was conducted to solve the best custom selection case. Both researches resulted in a desktop-based decision support system that was able to assist the decision-making process in their respective cases.

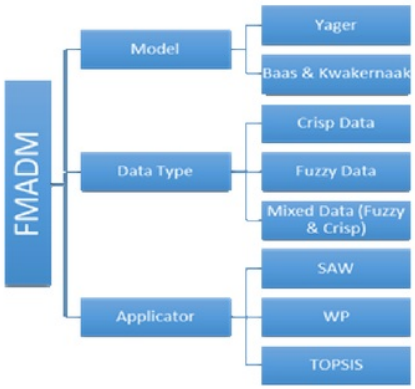

Fig. 1. FMADM taxonomy

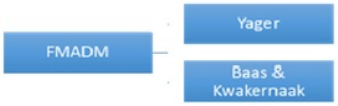

Fig. 2. FMADM inventor-based taxonomy

2) Baas & Kwakernaak Model

In contrast to the Yager model, the Baas &Kwakernaak model is not a standard form of FMADM, but the concept is often used by some researchers for further development [10]. The Baas &Kwakernaak model is a method that describes the ranking of some aspects of an alternative using fuzzy sets[14].According to[11]Baas and Kwakernaakmodel contains the following steps:

1. Evaluate each alternative a_i, through function g as follows:

$$g_i(z) = \frac{\sum_{j=1}^{m} w_j r_{ij}}{\sum_{j=1}^{m} w_j} \quad (1)$$

where w = (w_1, ... , w_m ; r_1, ... , r_m). The membership function of μ_{Zi} is defined as follows :

$$\mu_{zi} = \min\left\{ \min_{j=1,..m} \left(\mu_{wj}(w_j)\right), \min_{k=1,..m} \left(\mu_{Rik}(r_k)\right)\right\} \quad (2)$$

Through the g function, the fuzzy set$\tilde{Z} = \Re^{2m}, (\mu_{zi})$will be brought to a fuzzy set$\tilde{R}_i = (\Re, \mu_{\tilde{R}i})$with membership function:

$$\mu_{\tilde{R}i} = \sup\left(\mu_{Zi}(z)\right) \quad (3)$$

The value$\mu_{\tilde{R}i} = (\bar{r})$) is an alternative end value a_i.

2. The best alternative is chosen as follows:

$$\{i \in I \mid \bar{r}_j \geq \bar{r}_j, \forall j \in I\}, \text{and } I = \{1, \ldots, n\}. \quad (4)$$

B. FMADM Data-Type-Based Taxonomy

1. Crisp data, also called standard data is the original data obtained directly from the source [15] and grouped by their respective attributes. Use of crisp data is considered less suitable.

2. Fuzzy data, this data is chosen as the solution to overcome the problem of uncertain decision maker's request. In this case the fuzzy data is crisp data that has been transformed into fuzzy set. The fuzzy set [16] is a generalization of the concept of a characteristic function, the fuzzy set has an unclear boundary with its membership value being in the range 0 to 1 [15].

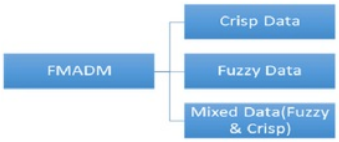

Fig. 3. FMADM data-type-based taxonomy

C. FMADM Applicator-Based Taxonomy

1) Simple Additive Weighting (SAW)

SAW[17] is known as the linear weighting combination or the most commonly used valuation methods for ranking simple multi-attribute decisions. The basic concept is to find a weighted sum of performance ratings on each alternative on all attributes[10]. SAW method requires the process of normalizing the decryption matrix (x) to a scale proportional to all alternative judgments. The normalized formula is as follows [18] :

$$r_{ij} = \begin{cases} \frac{x_{ij}}{\underset{i}{Max}\, x_{ij}} & j \text{ is the attribute of benefit} \\ \frac{\underset{i}{Min}\, x_{ij}}{x_{ij}} & j \text{ is the attribute of cost} \end{cases} \quad (5)$$

where r_{ij} is the normalized performance rating of the A_i alternatives in the attributeC_j; i = 1,2, ..., m and j = 1,2, ...,n. The preference value for each alternative (V_i) is given as:

$$V_i = \sum_{j=1}^{n} w_j r_{ij} \quad (6)$$

A larger $V_i$value indicates that the A_i alternative is preferred/chosen.

2) Weighted Product (WP)

The WP method [19] uses the normalization process, where the rating of each attribute must be raised first with the corresponding attribute weights. This process is given by (7).

$$S_i = \prod_{j=1}^{n} x_{ij}^{w_j} \quad (7)$$

Where i = 1,2, ..., m, S represents an alternative preference, x denotes the criterionvalue, w denotes the criterion's weight, n denotes the criteria number. The rank w_j is a positive-valued rank for the attribute c gain, and is negatively valued for the attribute of cost. The relative preferences of each alternative can be given as :

$$V_i = \frac{\prod_{j=1}^{n} x_{ij}^{w_j}}{\prod_{j=1}^{n} \left(x_j^*\right)^{w_j}} \quad (8)$$

Where V denotes alternative preferences, x denotes the value of criteria, and w denotes the weight of criteria.

3) Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS is a multi-criteria method to identify solutions of limited alternatives. The basic principle is that the chosen alternative must have the shortest distance from the ideal positive solution and the furthest distance from the ideal negative solution [17]. In general, TOPSIS procedures can described as follows [10]:

1. Create a normalized decision matrix
2. Create a weighted normalized decision matrix
3. Determe the matrix of positive ideal solutions and matrices of negative ideal solutions;
4. Determine the distance between the value of each alternative with positive ideal solution matrix and negative ideal solution matrix;
5. Determine the preference value for each alternative.

TOPSIS requiresperformance rating of each alternative A_i on each of the normalized C_j criteria, namely:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad (9)$$

where i =1, 2, ..., m; and j = 1, 2, ..., n.The ideal positive solution A^+ and the ideal negative solution A^-can be determined based on the normalized weighted rating (y_{ij}) as:

$$y_{ij} = w_i r_{ij} \quad (10)$$

where i = 1, 2, ..., m; and j = 1, 2, ..., n.

$$A^+ = \left(y_1^+, y_2^+, \ldots, y_n^+\right) \quad (11)$$

$$A^- = \left(y_1^-, y_2^-, \ldots, y_n^-\right) \quad (12)$$

Whereas

$$y_j^+ = \begin{cases} \max_i y_{ij}; if\ j\ is\ the\ attribute\ of\ benefit \\ \min_i y_{ij}\ ;\ if\ j\ is\ the\ attribute\ of\ cost \end{cases} \quad (13)$$

and

$$y_j^- = \begin{cases} \min_i y_{ij}; if\ j\ is\ the\ attribute\ of\ benefit \\ \max_i y_{ij}\ ;if\ j\ is\ the\ attribute\ of\ cost \end{cases} \quad (14)$$

where j = 1,2,...n.

The distance between alternative A_i with the ideal positive solution is formulated as:

$$D_i^+ = \sqrt{\sum_{j=1}^{n} \left(y_i^+ - y_{ij}\right)^2}\ ;\ where\ i = 1, 2, \ldots, m \quad (15)$$

The distance between alternative A_i with the ideal negative solution is formulated as:

$$D_i^- = \sqrt{\sum_{j=1}^{n} \left(y_{ij} - y_i^-\right)^2}\ ;\ where\ i = 1, 2, \ldots, \quad (16)$$

The preference value for each alternative (V_i) is given as:

$$V_i = \frac{D_i^-}{D_i^- + D_i^+}\ ;where\ i = 1, 2, \ldots, m \quad (17)$$

A largerV_i score indicates that A_i alternatives are preferred.

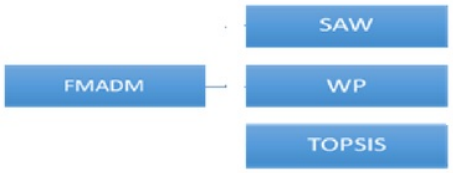

Fig. 4. FMADM applicator-based taxonomy

III. Conclusion

The MCDM method is not considered appropriate for decision making due to the uncertainty in results if incomplete information is provided. Fuzzy MCDM method has been developed as a solution to that issue. A short literature review is presented in this paper in an attempt to provide a taxonomy of fuzzy multi-attribute decision making systems in terms of model, inventor and data type.

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