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Fuzzy Lambda-Max Criteria Weight Determination for Feature Selection in Clustering

Nurul Adzlyana Mohd Saadon*, Rosma Mohd Dom and Nurazzah Abd Rahman

Faculty of Computer & Mathematical Sciences, Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor, Malaysia

ABSTRACT

Clustering refers to reducing selected features involved in determining the clusters. Raw data might come with a lot of features, including unimportant ones. A hybrid similarity measure (discovered in 2014) used in selecting features can be improvised as it might select all the attributes, including insignificant ones. This paper suggests Fuzzy Lambda-Max to be used as a feature selection method since Lambda-Max is normally used in ranking of alternatives. A set of AIDS data is used to measure the performance. Results show that Fuzzy Lambda-Max has the ability to determine criteria weights and ranking the criteria. Hence, feature selection can be done by choosing only the important criteria.

Keywords: Clustering, criteria weight determination, feature selection, Fuzzy Lambda-Max

INTRODUCTION

Clustering is actively studied in statistics, pattern recognition, machine learning and many other fields. Mining a big dataset is complicated as it involves many different attributes. Cluster analysis divides data into meaningful and useful clusters. It groups data based on information found in the data that describes the objects and their relationships. The goal of cluster analysis is to have similar object within a group (Rokach & Maimon, 2008).

One popular clustering technique is similarity measure. Cluster analysis aims to group a collection of patterns into clusters based on similarity. Clustering aims at grouping a set of objects into clusters so that objects in the same clusters should be similar as possible, whereas objects in one cluster should be as dissimilar as possible from objects in other clusters. Similarity measures in data mining is usually described as a

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E-mail addresses:
nuruladzlyana@gmail.com (Nurul Adzlyana Mohd Saadon),
rosma@tmsk.uitm.edu.my (Rosma Mohd Dom),
nurazzah@tmsk.uitm.edu.my (Nurazzah Abdul Rahman)
*Corresponding Author

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distance with dimensions representing features of the objects. A small distance means a high degree of similarity and vice versa. Similarity is very subjective and is highly dependent on the domain and application (Yong, 2010). Similarity between two objects plays an important role in data mining jobs such as clustering and classification which involve distance computations. The distance or similarity for integer-type data and ratio-scaled data are well defined and understood (Alamuri et al., 2014).

Alamuri et al. (2014) has suggested a hybrid similarity measure that combines learning algorithm for context selection and distance computation based on the learned context. Nonetheless, the existing context selection algorithm has the tendency to select all the given attributes, making it more complicated. Therefore, a suitable threshold is needed.

This study uses Fuzzy Analytic Hierarchy Process (AHP) (Saaty, 1980; Ernest, 1999) in order to limit the features as AHP is commonly used in Multi Criteria Decision Making. It is an effective way of determining the criteria weight as it is based on the pair wise comparison method and thus no criterion is ignored. It is also a good method for dealing with human knowledge because AHP does not use artificial intelligence in the process to convert human thinking to fuzzy rule base. In AHP, the input is obtained from experts themselves and it is not randomly given by the system. This means information from professional people is still appreciated in the computer intelligence system. For each pair of criteria, the decision maker is required to do a pair wise comparison evaluation on the relative importance of the two. It is based on a well-defined mathematical structure of consistent matrices and eigenvectors to generate true or approximate weights (Saaty, 1980).

Ernest (1999) agreed that AHP is a good method to be used in determining criteria weight based on three primary steps involved in AHP. First, the structuring technique in AHP works similar to the way humans deal with complexity. Second, the measurement on a ratio scale which ranges from the lowest to the highest in terms of properties makes AHP necessary to represent proportion and fundamental to physical measurement and finally the synthesis technique in AHP places together parts into a complete system.

The AHP has been used in many criteria weight decision making problem. It can be used in determining criteria weights and also ranking of alternatives. It is also often used for criteria weight determination only or combined with other method for multi criteria decision making problem. The AHP can be the substitute of finding the weights in Artificial Neuro Fuzzy Inference System (ANFIS). Dom et al. (2013) used Lambda-Max AHP to find criteria weight for determining criteria weights of factors impacting the melt flow index of degradable plastics. The weights are then applied in back-propagation method in ANFIS for forecasting purposes (Saadon, 2013). Besides that, AHP is used to find the criteria weights for Extract, Transform and Load (ETL) software solution. It is used to determine the criteria weights for six characteristics given by ISO/IEC 9126-1 (2001): functionality, reliability, usability, efficiency and maintainability. After criteria weights is found, another method called TOPSIS is used to rank the alternative and to select the best ETL software for running the Business Intelligence systems (Hanine et al., 2016).

In AHP, there are three common criteria weight determination methods. The first method is the Fuzzy Logarithmic Least Square method (LLSM), proposed by Van Laarhoven and Pedrycz, in 1983. In LLSM method, the criteria weight is obtained in the form of triangular fuzzy weights from a fuzzy comparison matrix. The second method in criteria weight determination in fuzzy AHP is the Extent Analysis method which was proposed by Chang, in 1996. It derives crisp weights from fuzzy comparison matrices. The third method is Lambda-Max method, which is the direct fuzzification method by Csutora and Buckley in 2001. In this study, only Lambda-Max is used as it is found to be the most suitable method in determining the weight as well as the ranking process (Saadon et al., 2010).

The objectives of this paper are apply the Fuzzy Lambda-Max AHP method to find the criteria weights and to rank the criteria according to their importance so that the appropriate criteria can be used in clustering purposes.

Fuzzy Lambda-Max AHP for feature selection in clustering is described in this paper. The methodology is described in detail and its implementation in clustering HIV patients is illustrated to demonstrate the feasibility using Fuzzy Lambda-Max AHP for feature selection. Criteria weights found can be used to rank the importance of features to be used for clustering purposes.

LITERATURE REVIEW

Feature Selection

In many data analysis problems, one is often confronted with very high dimensional data. Feature selection techniques are invented to find the relevant feature subset of the original features, which can help clustering, classification and retrieval.

Feature selection has been widely used in the field of pattern recognition, machine learning, statistics and data mining tasks. The objective of feature selection is to choose a subset of input variables by eliminating features, which are irrelevant and have no predictive information. Feature selection has proven to be helpful in enhancing learning efficiency, increasing predictive accuracy and reducing complexity of learned results (Koller & Sahami, 1996). The supervised feature selection has the main goal of finding a feature subset that produces higher classification accuracy.

As the element of a domain increases, the number of features increases. Finding an optimal feature subset is difficult and it is even hard to find problems related to feature selection are d (Kohavi & John, 1997). At this stage, it is essential to describe conventional feature selection process, which consists of four basic steps: subset generation, subset evaluation, stopping criterion, and validation (Dash & Liu, 1997).

Fuzzy Lambda-Max Criteria Weight Determination

Fuzzy Lambda-Max is one of the methods in Analytics Hierarchy Process (AHP), often used for Multi Criteria Decision Making. Csutora and Buckley (2001) propose Lambda-Max which involves the direct fuzzification of the well-known Lambda-Max method which is used in Saaty's Analytical Hierarchy Process method. This method is easy to apply as it only uses basic computations (Csutora & Buckley, 2001).

This method works better than LLSM as it calculations take more time and hence, delay in solving the problem (Csutora & Buckley, 2001). Lambda-Max also is found to be the most appropriate method to use for finding criteria weights among all the Fuzzy AHP methods (Saadon et al., 2010), not only because the calculation is less complex, but also because it gives good results.

METHOD

The methodology for Fuzzy Lambda-Max AHP for criteria weight determination consists of four steps. Csutora and Buckley (2001) developed Lambda Max method to calculate the fuzzy weights as follows:

Step 1: Apply α-cut. Let α = 1 to obtain the positive matrix of decision maker k. $\widetilde{TM}_m^k = [\tilde{r}_{ij}]_m^k$, and let α = 0 to obtain the lower bound and upper bound positive matrices of decision maker k, $\widetilde{TL}_l^k = [\tilde{r}_{ij}]_l^k$ and $\widetilde{TU}_u^k = [\tilde{r}_{ij}]_u^k$. Calculate weight vector proposed in AHW$_m^k = (w_i)_m^k$, $W_l^k = (w_i)_l^k$, and $W_u^k = (w_i)_u^k$, $i = 1, 2, \ldots n$.

Step 2: Choose two constants QL_l^k and QU_u^k to minimise the fuzziness of the weight.

$$QL_l^k = \min\left\{\frac{w_{i_m}^k}{w_{i_u}^k}\right\}, 1 \le i \le n$$

$$QU_u^k = \max\left\{\frac{w_{i_m}^k}{w_{i_u}^k}\right\}, 1 \le i \le n$$

The upper bound and lower bound of the weight are defined as:

$$w_{i_l}^{*k} = QL_l^k w_{i_l}^k$$

$$w_{i_u}^{*k} = QU_u^k w_{i_u}^k$$

So, the lower and upper bound of the weight vectors are $(w_i)_l^k$ and $(w_i)_u^k$.

Step 3: Combine the lower bound, the middle, and the upper bound weight vectors. The fuzzy weight matrix for decision maker k can be obtained and is defined as

$$\widetilde{W}_l^{k*} = \left(w_{i_l}^{*k}, w_{i_m}^{*k}, w_{i_u}^{*k}\right), i = 1, 2, \ldots n.$$

Step 4: Repeat step 1, 2, and 3 to calculate the local fuzzy weights and global fuzzy weights.

Application of Lambda-Max in Finding the Criteria Weights

To investigate the feasibility, Fuzzy Lambda-Max is applied to find the criteria weight for the given example:

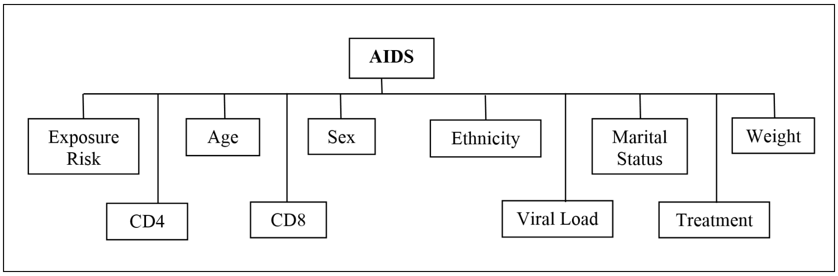

Figure 1. The criteria involved in determining AIDS survival

The Acquired Immune Deficiency Syndrome (AIDS) is a set of infections caused by the damage done to the human immune system affected by Human Immunodeficiency Virus (HIV). According to the San Francisco AIDS Foundation, HIV is transmitted through direct contact of the blood stream or the mucous membrane with a human fluid containing HIV (Dom et al., 2009).

Ten criteria are known factors that affect the potential of someone having AIDS. As shown in Figure 1, the 10 criteria are exposure risk, age, gender, ethnicity, marital status, weight, and level of CD4, level of CD8, HIV viral load and treatment.

The exposure risk means whether the patient is homosexual, heterosexual, bisexual, or getting HIV from their mother. It includes all ages. Gender is either female or male. Ethnicity is either the patient is a Malay, Chinese, Indian or other. Marital status includes single, married, divorced and widowed. There is no limit on weight in the data. The CD4 cells are a type of white blood cell which is important to the immune system while CD8 cells are the killer of abnormal body cells in human immune system. The last two factors are the HIV viral load in patient's body and the treatment received by the patients such as Didanoside (ddI) 100 mg -2, Didanosine (videx)-3, Kaletra (lopinavir/rit)-7 and many more.

Three experts have given their opinion on the level of effects of one criteria on the other criteria based on the rates of equal, moderate, strong and very strong (see Figure 2) towards the possibility of one having AIDS.

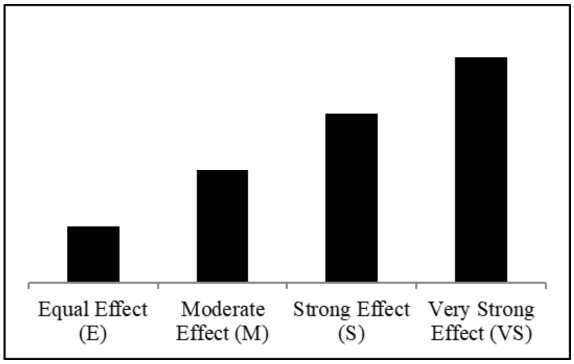

Figure 2. Rates of opinion

The inputs are in terms of pairwise comparison and are presented in matrix form. The comparison matrix of the three experts are shown in the following tables:

Table 1
Comparison matrix of 10 factors with respect to AIDS survival (Expert 1)

	E Risk	Age	Gender	Ethnic	Marital Stat	Weight	CD4	CD8	Viral Load	Treatment
E Risk	E	M	M	E	VS	E	M	M	M	E
Age		E	E	E	M					
Gender			E	M	E	E				
Ethnic				E	E					
Marital Stat		M		VS	E	E	E	E	E	E
Weight		M		VS		E	E	E	E	E
CD4		VS	M	M			E			
CD8		VS	M	VS			M	E	E	E
Viral Load		VS	M	M			M		E	E
Treatment		VS	VS	M			M			E

Table 2
Comparison matrix of 10 factors with respect to AIDS survival (Expert 2)

	E Risk	Age	Gender	Ethnic	Marital Stat	Weight	CD4	CD8	Viral Load	Treatment
E Risk	E	VS	VS	VS	VS	VS	VS	VS	VS	VS
Age		E	E	E	E	E	E	E	E	E
Gender			E	E	E	E	E	E	E	E
Ethnic				E	E	E	E	E	E	E
Marital Stat					E	S	M	M	M	E
Weight						E	E	E	E	E
CD4							E	E	E	M
CD8								E	E	E
Viral Load									E	S
Treatment										E

Table 3
Comparison matrix of 10 factors with respect to AIDS survival (Expert 3)

	E Risk	Age	Gender	Ethnic	Marital Stat	Weight	CD4	CD8	Viral Load	Treatment
E Risk	E	M	E	S	S	S	E	E	E	S
Age		E	M	E	E	E	E	E	E	
Gender			E	E		E	E	E		
Ethnic				E	E	E	E	E	E	E
Marital Stat			S		E	E	E	E	E	E
Weight						E	E	E	E	E
CD4							E	E	S	S
CD8								E	S	S
Viral Load			S						E	S
Treatment		S	S							E

Then, the rates of opinion are converted into triangular fuzzy numbers as given in Table 4.

Table 4
Fuzzy numbers for degree of importance (Wang, 2007)

Linguistic variable	Triangular Fuzzy Number
Equal	(1,1,1)
Moderate	(1,3,5)
Strong	(3,5,7)
Very Strong	(5,7,9)

Tables of pairwise comparison in triangular fuzzy number of the 10 factors that determine AIDS survival are as shown as follows:

Table 5
Fuzzy comparison matrix of 10 factors with respect to AIDS survival (Expert 1)

	E Risk	Age	Gender	Ethnic	Marital Stat	Weight	CD4	CD8	Viral Load	Treatment
E Risk	(1,1,1)	(1,3,5)	(1,3,5)	(1,1,1)	(5,7,9)	(1,1,1)	(1,3,5)	(1,3,5)	(1,3,5)	(1,1,1)
Age	(1/5,1/3,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,3,5)	(1/5,1/3,1)	(1/5,1/3,1)	(1/9,1/7,1/5)	(1/9,1/7,1/5)	(1/9,1/7,1/5)
Gender	(1/5,1/3,1)	(1,1,1)	(1,1,1)	(1,3,5)	(1,1,1)	(1,1,1)	(1/5,1/3,1)	(1/5,1/3,1)	(1/5,1/3,1)	(1/9,1/7,1/5)
Ethnic	(1,1,1)	(1/5,1/3,1)	(1/5,1/3,1)	(1,1,1)	(1,1,1)	(1/9,1/7,1/5)	(1/5,1/3,1)	(1/9,1/7,1/5)	(1/5,1/3,1)	(1/5,1/3,1)
Marital Stat	(1/9,1/7,1/5)	(1,3,5)	(1,1,1)	(5,7,9)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
Weight	(1,1,1)	(1,3,5)	(1,1,1)	(5,7,9)	(1 ,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
CD4	(1/5,1/3,1)	(5,7,9)	(1,3,5)	(1,3,5)	(1,1,1)	(1,1,1)	(1,1,1)	(1/5,1/3,1)	(1/5,1/3,1)	(1/5,1/3,1)
CD8	(1/5,1/3,1)	(5,7,9)	(1,3,5)	(5,7,9)	(1,1,1)	(1,1,1)	(1,3,5)	(1,1,1)	(1,1,1)	(1,1,1)
Viral Load	(1/5,1/3,1)	(5,7,9)	(1,3,5)	(1,3,5)	(1,1,1)	(1,1,1)	(1,3,5)	(1,1,1)	(1,1,1)	(1,1,1)
Treatment	(1,1,1)	(5,7,9)	(5,7,9)	(1,3,5)	(1,1,1)	(1,1,1)	(1,3,5)	(1,1,1)	(1,1,1)	(1,1,1)

Table 6
Fuzzy comparison matrix of 10 factors with respect to AIDS survival (Expert 2)

	E Risk	Age	Gender	Ethnic	Marital Stat	Weight	CD4	CD8	Viral Load	Treatment
E Risk	(1,1,1)	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)
Age	(1/9,1/7,1/5)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
Gender	(1/9,1/7,1/5)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
Ethnic	(1/9,1/7,1/5)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
Marital Stat	(1/9,1/7,1/5)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(3,5,7)	(1,3,5)	(1,3,5)	(1,3,5)	(1,1,1)
Weight	(1/9,1/7,1/5)	(1,1,1)	(1,1,1)	(1,1,1)	(1/7,1/5,1/3)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
CD4	(1/9,1/7,1/5)	(1,1,1)	(1,1,1)	(1,1,1)	(1/5,1/3,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,3,5)
CD8	(1/9,1/7,1/5)	(1,1,1)	(1,1,1)	(1,1,1)	(1/5,1/3,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
Viral Load	(1/9,1/7,1/5)	(1,1,1)	(1,1,1)	(1,1,1)	(1/5,1/3,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(3,5,7)
Treatment	(1/9,1/7,1/5)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1/5,1/3,1)	(1,1,1)	(1/7,1/5,1/3)	(1,1,1)

Table 7
Fuzzy comparison matrix of 10 factors with respect to AIDS survival (Expert 3)

	E Risk	Age	Gender	Ethnic	Marital Stat	Weight	CD4	CD8	Viral Load	Treatment
E Risk	(1,1,1)	(1,3,5)	(1,1,1)	(3,5,7)	(3,5,7)	(3,5,7)	(1,1,1)	(1,1,1)	(1,1,1)	(3,5,7)
Age	(1/5,1/3,1)	(1,1,1)	(1,3,5)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1/7,1/5,1/3)
Gender	(1,1,1)	(1/5,1/3,1)	(1,1,1)	(1,1,1)	(1/7,1/5,1/3)	(1,1,1)	(1,1,1)	(1,1,1)	(1/7,1/5,1/3)	(1/7,1/5,1/3)
Ethnic	(1/7,1/5,1/3)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
Marital Stat	(1/7,1/5,1/3)	(1,1,1)	(3,5,7)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
Weight	(1/7,1/5,1/3)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)
CD4	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(3,5,7)	(3,5,7)
CD8	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(1,1,1)	(3,5,7)	(3,5,7)
Viral Load	(1,1,1)	(1,1,1)	(3,5,7)	(1,1,1)	(1,1,1)	(1,1,1)	(1/7,1/5,1/3)	(1/7,1/5,1/3)	(1,1,1)	(3,5,7)
Treatment	(1/7,1/5,1/3)	(3,5,7)	(3,5,7)	(1,1,1)	(1,1,1)	(1,1,1)	(1/7,1/5,1/3)	(1/7,1/5,1/3)	(1/7,1/5,1/3)	(1,1,1)

Finally, from the fuzzy numbers, the criteria weights are calculated using Fuzzy Lambda-Max method as described in the previous section, to rank the criteria from the most important to the least important. The results will be presented in the next section.

RESULTS AND DISCUSSION

Based on the expert opinion, the criteria weights are calculated using the computations given in the previous section. The following table shows the final criteria weights obtained using Fuzzy Lambda-Max method.

Table 8
Final criteria weights

Criteria	Criteria weights
E Risk	(0.221, 0.318, 0.440)
Age	(0.063, 0.075, 0.102)
Gender	(0.061, 0.067, 0.100)
Ethnic	(0.064, 0.075, 0.097)
Marital Stat	(0.103, 0.128, 0.155)
Weight	(0.096, 0.108, 0.118)
CD4	(0.090, 0.129, 0.161)
CD8	(0.112, 0.154, 0.164)
Viral Load	(0.096, 0.127, 0.106)
Treatment	(0.085, 0.110, 0.137)

Then, the criteria are ranked. The criteria with the most weight is placed on top. The following table shows the ranking of criteria.

Table 9
Ranking of criteria

Rank	Criteria	Criteria weights
1	E Risk	(0.221, 0.318, 0.440)
2	CD8	(0.112, 0.154, 0.164)
3	CD4	(0.090, 0.129, 0.161)
4	Marital Stat	(0.103, 0.128, 0.155)
5	Viral Load	(0.096, 0.127, 0.106)
6	Treatment	(0.085, 0.110, 0.137)
7	Weight	(0.096, 0.108, 0.118)
8	Ethnic	(0.064, 0.075, 0.097)
9	Age	(0.063, 0.075, 0.102)
10	Gender	(0.061, 0.067, 0.100)

Ranking of criteria shows the importance of factors that indicate AIDS survival. The criteria that ranked first is the most important factor affecting the potential of the patient having AIDS. In this study, based on expert opinion and criteria weight obtained, it has been shown that the exposure risk, level of CD8 and CD4 cells are three most important factors towards the AIDS survival. Ethnicity, age and gender are found to be the least important factors. The ability of Fuzzy Lambda-Max AHP method in determining criteria weights and ranking the criteria is beneficial so that we know the important criteria to be used in clustering the patients whether they are likely to have AIDS or not. From the ranking of criteria, feature selection can be done by choosing only the important criteria.

CONCLUSION

The study has shown that Fuzzy Lambda-Max can be used for determining criteria weights. Hence, the criteria could be ranked according to importance. This is very useful for feature selection in clustering process. For future work, the accuracy of clustering result will be measured based on percentage accuracy by comparing actual and experimental clustering results. To further validate the method, comparison with existing methods of determining the criteria weights and their ranking can be carried out.

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