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Determination System of Single Tuition Group Using a Combination of Fuzzy C-Means Clustering and Simple Additive Weighting Methods

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Abstract. Single Tuition is a single tuition fee that is borne by each student every semester based on their economic ability while Single Tuition fee is the total operational cost of each student every semester in the Study Program at State Universities. Determination of these fees is calculated based on several criteria such as the work of the father, the work of the mother, the income of the father and mother, the number of dependents of parents, the status of parents, the vehicle owned, taxes borne by parents, and several other criteria. How to calculate and determine the single tuition fee for each student is done manually, so that problems arise that are not efficient with time and cost. Therefore, in this study, a computerized single money determination system was created by making a decision support system that was able to automatically determine the Single Tuition group. Several studies have been conducted relating to this decision-making system, including the methods used such as Multi-Attribute Decision Making, Data Mining, and AHP. In this study using a combination of Fuzzy C-Means and Simple Additive Weighting methods to determine the Single Tuition Fee. Fuzzy C-Means groups the same data into one group, while Simple Additive Weighting performs a weighted sum with a performance rating on each alternative on all attributes. The study used 13 criteria and 62 sub-criteria as parameters in determining the Single Tuition group. From the results of testing 73 test data, it is known the results that in this test the number of clusters is 8 pieces, the number of weights is 2, the iteration is maximum 100, the smallest iteration is 0.01 and the initial iteration 1. The result is known that the decision-making system succeeded in ranking with a margin error 0 - 0.01.

1. Introduction

The Group of Single Tuition or Uang Kuliah Tunggal (UKT) is currently stipulated in government regulations for all State Universities in Indonesia to better help and reduce the cost of student education. The requirement is stated in the Minister of Education and Culture Regulation No. 55 of 2013 [1]. Every State University has different UKT rates, this is done by education and is based on its study program [2]. Single and Small Tuition borne by each student based on their economic abilities. Single tuition fees are all operational costs for each student per semester in study programs at State Universities and UKT which are determined by folding Single and Small Tuition with costs borne by the government.

So far in determining the selection of UKT is still done manually so that this is not time efficient. But along with current technological developments, various problems can be resolved quickly and easily by utilizing technology, namely by using a Decision Support System. The problems that can be overcome with this system include determining scholarships for poor students, determining in choosing study programs, determining to choose outstanding students and others. Several methods used by this system include the Analytic Hierarchy Process (AHP), data mining, Multiple Attribute Decision Making (MADM) and others.

Some researchers have conducted research on the decision making of Single Tuition, including [3], who conducted the study using data mining methods with the results of the accuracy of 50% for the amount of data 80, while the amount of data 115 then the results of accuracy were 52.63. Reference [4] who conducted a study on the size of the Single Tuition using the MADM method with the results of 87.5% strongly agree that the application did not error.
Therefore, in this study, an application was made to determine a single tuition group on the Lhokseumawe State Polytechnic campus. The method used in this study is the Fuzzy C-Means (FCM) method and Simple Additive Weighting (SAW). The FCM method is used to group data by clustering. The Clustering function is to determine the same data into one group, while SAW is used to find the number of weights with performance ratings on each alternative for all attributes. The results of this study can be used as a reference for policymakers of the State Polytechnic of Lhokseumawe so that this application can increase the efficiency and productivity of institutions in determining single tuition for each student.

2. Research Methodology

Based on the introduction, the first thing to do in this study is to identify the problems faced in making the system. These problems are the many variations in student data input and the number of assessment criteria in determining the single tuition group. To create a system for determining the single tuition group, 7 design tables and 17 forms of user interfaces (UI) are needed. The designed tables include study program tables, student tables, criteria tables, sub-criteria tables, value tables, single tuition tables, and operator tables. Furthermore, the UI form designed is a login form, home admin form, form home (student), student data input form, attachment input form, student card form, criteria form, sub-criteria form, student data form, study program data form, determinant form values, Fuzzy C-Means display form, decision form, setting form, operator data form, and operator profile form. The data source in this study is the form of prospective students who register online on State Polytechnic of Lhokseumawe.

2.1. Decision Support System (DSS)

A system that can help make decisions in solving problems that are not structured by utilizing data and models is a Decision Support System [5]. Decisions taken are seen from the structure which is divided into [6]:

1) Structured decisions are decisions made repeatedly and are routine, the decision-making procedure is very clear, the decision is mainly made at the lower level management.
2) Partially structured decisions are decisions that have two properties, some of which can be handled by a computer and the other must still be done by decision makers, procedures in the decision maker are outlined, but there are some things that still require policy from decision makers. Usually, such decisions are taken by middle-level managers in an organization.
3) Unstructured decisions are decisions that are complicated because there is no repetition or does not always occur, the decision requires experience and various external sources. Such decisions generally occur in upper-level management.

2.2. Fuzzy C-Means

Fuzzy C-Means or abbreviated as FCM is a technique for determining the center of a cluster that will mark the average location of each cluster. This technique was first introduced in [7]. In this technique, the initial condition of the cluster center is still not accurate. Each data point has membership degrees for each cluster formed. By improving the cluster center and the degree of membership of each data point repeatedly, the cluster center will shift towards the right location. This looping is based on minimizing objective functions that describe the distance from the data points given to the cluster center which is weighted by the degree of membership of the data point [8]. The FCM algorithm is as follows [8]:

1) Input data to be clustered in the matrix m x n, with m as is the amount of data to be clustered and n is the attribute of each data. For example, \(X_{ij} = i\)-data (i = 1,2, ... m), j-attribute (j = 1,2, ... n).
2) Set FCM calculations such as: many clusters (c), weighting conditions (w), maximum iterations (Maxiter), maximum error (E), objective functions (Po = 0) and initial iterations (iter = 1).
3) Generate Uik values randomly (with i = 1,2, ... m and k = 1,2, ... c) as the element of the initial U partition matrix, with Xi is the i data. To be clearer the U matrix can be seen in the equation (2.1)
\[ U = \begin{bmatrix}
\mu_{11}(X_1) & \mu_{21}(X_1) & \cdots & \mu_{c1}(X_1) \\
\mu_{12}(X_2) & \mu_{22}(X_2) & \cdots & \mu_{c2}(X_2) \\
\vdots & \vdots & \ddots & \vdots \\
\mu_{1i}(X_i) & \mu_{2i}(X_i) & \cdots & \mu_{ci}(X_i)
\end{bmatrix} \quad (2.1) \]

The total random value for each data period is always worth 1, to be more clearly seen in the equation (2.2)

\[ \sum_{i=1}^{c} \mu_{ci} = 1 \quad (2.2) \]

4) Calculate the center value of the k-cluster, with the \( V_{kj} \) symbol, with \( k = \text{many criteria} \) and \( j = \text{many attributes} \). For \( k = 1, 2, \ldots, c \) and \( j = 1, 2, \ldots, n \). To calculate the cluster center can be seen in the equation (2.3).

\[ V_{kj} = \frac{\sum_{i=1}^{m} (\mu_{ik})^w X_{ij}}{\sum_{i=1}^{m} (\mu_{ik})^w} \quad (2.3) \]

5) Calculate the objective function in the t-iteration, then the \( P_t \) value will be obtained as shown in equation (2.4)

\[ P_t = \sum_{i=k}^{m} \sum_{k=1}^{c} \left[ \left( \sum_{j=1}^{n} (X_{ij} - V_{kj})^2 \right) (\mu_{ik})^w \right] \quad (2.4) \]

6) Calculate changes in the degree of membership of each data in each cluster by fixing the \( U \) partition matrix, to be more clearly seen in equation (2.5).

\[ \mu_{ik} = \frac{\left[ \sum_{i=1}^{n} (X_{ij} - V_{kj})^2 \right]^{\frac{1}{w-1}}}{\sum_{k=1}^{c} \left[ \sum_{j=1}^{n} (X_{ij} - V_{kj})^2 \right]^{\frac{1}{w-1}}} \quad (2.5) \]

7) The last step, check the stop condition:
   a) if: \(|P_t - P_{t-1}| < E\) or (Iter>maxiter).
   b) if not, Iter= Iter + 1, repeat step 4.

2.3. Simple Additive Weighting

The Simple Additive Weighting method is known as the weighted addition method. The basic concept of this method is to find a weighted sum of performance ratings on each alternative on all attributes. The essence of the concept of the saw method is to determine the value of weight on each attribute and then perform a ranking process that will select the alternatives given [9]. Steps of the SAW method [9]:

1) Determine the \( Z \) decision matrix that measures \( m \times n \), where \( m = \text{the alternative that will be selected} \) and \( n = \text{criteria} \).

2) Give the \( x \) value of each alternative (i) on each criterion (j) that has been determined, where, \( i = 1, 2, \ldots, m \) and \( j = 1, 2, \ldots, n \) in the \( Z \) decision matrix according to the equation (2.6).

\[ Z = \begin{bmatrix}
x_{11} & x_{12} & \cdots & x_{1j} \\
\vdots & \vdots & \ddots & \vdots \\
x_{11} & x_{12} & \cdots & x_{ij}
\end{bmatrix} \quad (2.6) \]

3) Give the preference weight (\( W \)) by the decision maker for each of the criteria that have been determined according to the equation (2.7).

\[ W = [W_1 W_2 W_3 \cdots W_j] \quad (2.7) \]
4) Normalize the Z decision matrix by calculating the normalized performance rating value \((r_{ij})\) of the alternative \(A_i\) in the \(C_j\) attribute according to the equation (2.8).

\[
r_{ij} = \begin{cases} 
\frac{x_{ij}}{\text{MAX}(x_{ij})} & \text{if } j \text{ is attribute of interest.} \\
\frac{x_{ij}}{\text{MIN}(x_{ij})} & \text{if } j \text{ is attribute of cost.}
\end{cases}
\]  

(2.8)

Where:
- \(r_{ij}\) = normalized performance rating
- \(\text{MAX}(x_{ij})\) = the maximum value of each row and column
- \(\text{MIN}(x_{ij})\) = minimum value for each row and column
- \(x_{ij}\) = row and column of the matrix

5) The results of the normalized performance rating value \((r_{ij})\) form a normalized matrix \((N)\) according to the equation (2.9).

\[
N = \begin{bmatrix} 
r_{11} & r_{12} & \cdots & r_{1j} \\
r_{21} & \vdots & \ddots & \vdots \\
& \ddots & \ddots & \vdots \\
& & \ddots & r_{nj}
\end{bmatrix}
\]  

(2.9)

6) Perform the ranking process by multiplying the normalized matrix \((N)\) with the preference weight value \((W)\).

7) Determine the preference value for each alternative \((V_i)\) by summing the results between the normalized matrix \((N)\) and the preference weight \((W)\) according to the equation (2.10).

\[
V_i = \sum_{j=1}^{n} w_j r_{ij}
\]  

(2.10)

Where:
- \(V_i\) = preference value
- \(w_j\) = heavy ranking
- \(r_{ij}\) = normalized performance rating

2.4. Parameters for Determining UKT Groups

In determining the student UKT group a number of parameters are needed which will become a reference in the calculation using the FCM and SAW methods. Based on data from the academic section of the Lhokseumawe State Polytechnic campus, the parameters used as input in filling in new student data consist of 13 criteria and 62 sub-criteria. To be more clearly shown in table 1.

In table 1, it can be seen that the determinants of the UKT consist of 13 criteria for father's job, mother's job, father's monthly income, parent's salary, number of families, residence status, PLN fees, PDAM fees, car tax, and motorcycle tax. For the first and second criteria, there are 9 sub-criteria while the third to thirteenth criteria have each of the four sub-criteria. Score scores are given in the range 1 to 4.
### Table 1. Parameters for Determining UKT Groups

<table>
<thead>
<tr>
<th>No</th>
<th>Criteria</th>
<th>Sub-Criteria</th>
<th>Score</th>
<th>No</th>
<th>Criteria</th>
<th>Sub-Criteria</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Father's Jobs</td>
<td>PNS GOL.III-IV</td>
<td>1</td>
<td>6</td>
<td>Parents Status</td>
<td>Complete</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TNI-POLRI (Officer)</td>
<td>1</td>
<td></td>
<td></td>
<td>Widower</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Big Entrepreneurs</td>
<td>1</td>
<td></td>
<td></td>
<td>Widow</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PNS GOL.I-I</td>
<td>2</td>
<td></td>
<td></td>
<td>Orphan</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TNI-POLRI (Tamtama-Bintara)</td>
<td>2</td>
<td>7</td>
<td>Number of Childern</td>
<td>1 Person</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Small Entrepreneur</td>
<td>2</td>
<td></td>
<td></td>
<td>2-4 Person</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Employee</td>
<td>2</td>
<td></td>
<td></td>
<td>5-6 Person</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Laborer</td>
<td>3</td>
<td></td>
<td></td>
<td>&gt;7 Person</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Does not work</td>
<td>4</td>
<td>8</td>
<td>Number of families</td>
<td>3 Person</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Mother's Jobs</td>
<td>PNS GOL.III-IV</td>
<td>1</td>
<td></td>
<td></td>
<td>4-6 Person</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TNI-POLRI (Officer)</td>
<td>1</td>
<td></td>
<td></td>
<td>7-8 Person</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Big Entrepreneurs</td>
<td>1</td>
<td></td>
<td></td>
<td>&gt;9 Person</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PNS GOL.I-I</td>
<td>2</td>
<td>9</td>
<td>Residential Status</td>
<td>Annual rent</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TNI-POLRI (Tamtama-Bintara)</td>
<td>2</td>
<td></td>
<td></td>
<td>Monthly rent</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Small Entrepreneur</td>
<td>2</td>
<td></td>
<td></td>
<td>Stay awhile **)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Employee</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Laborer</td>
<td>3</td>
<td>10</td>
<td>PLN Fees</td>
<td>&gt; Rp.200.000</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Does not work</td>
<td>4</td>
<td></td>
<td></td>
<td>Rp.100.000 &lt;= n &lt; Rp.200.000</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Father's Monthly Income</td>
<td>&gt;Rp.2 Million</td>
<td>1</td>
<td></td>
<td></td>
<td>Rp.75.000 &lt;= n &lt; Rp.100.000</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rp.1.5 Million &lt;= n &lt;= Rp.2 Million</td>
<td>2</td>
<td></td>
<td></td>
<td>&lt;= Rp.75.000</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rp.50.000 &lt; n &lt;= Rp.1.5 Million</td>
<td>3</td>
<td>11</td>
<td>PDAM Fees</td>
<td>&lt; Rp.75.000</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No Income</td>
<td>4</td>
<td></td>
<td></td>
<td>&gt; Rp.50,000 and &lt;75,000</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Amount of Dependents</td>
<td>1-2 Person</td>
<td>1</td>
<td></td>
<td>Till</td>
<td>Rp.50.000</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3-5 Person</td>
<td>2</td>
<td></td>
<td></td>
<td>Well Water</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6-7 Person</td>
<td>3</td>
<td>12</td>
<td>Car Tax</td>
<td>&gt; Rp.2 Million</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;8 Person</td>
<td>4</td>
<td></td>
<td></td>
<td>Rp.150.000 &lt;= n &lt;= Rp.2 Million</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Parents's Salary</td>
<td>&gt; Rp.450.000</td>
<td>1</td>
<td></td>
<td></td>
<td>Rp.500.000 &lt;= n &lt; Rp.1.5 Million</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rp.301.000 &lt; n &lt;= Rp.450.000</td>
<td>2</td>
<td></td>
<td></td>
<td>Do not have</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rp.150.000 &lt; n &lt;= Rp.300.000</td>
<td>3</td>
<td>13</td>
<td>Motorcycle Tax</td>
<td>&gt; Rp.200.000</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 &lt; n &lt;= Rp.150.000</td>
<td>4</td>
<td></td>
<td></td>
<td>Rp.150.000 &lt;= n &lt;= Rp.200.000</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 &lt; n &lt;= Rp.150.000</td>
<td></td>
<td></td>
<td></td>
<td>Do not have</td>
<td>4</td>
</tr>
</tbody>
</table>
2.5. Designing the ERD (Entity Relationship Diagram)

ERD is a model that explains the relationship between data in a database that is based on basic data objects that have relationships between relations. The ERD in the system for determining the UKT group can be seen in figure 1.

![ERD System for Determining UKT Groups](image)

In figure 1, it can be seen that each student has registration data, name, gender, birth date, religion, study program, address, parent's name, Parent's Phone Number, and Parents' Income. Each student has a relationship with 13 criteria.

2.6 Flowchart Combination Method

The UKT group determination system uses the FCM and SAW methods. The combination flowchart of Fuzzy C-Means Clustering and Simple Additive Weighing methods as shown in Figure 2. Figure 2 is a detailed description of the combination of FCM and SAW methods, it can be seen that the combination of the two methods requires input in the form of data to be clustered and then made a partition matrix and calculated center cluster and objective function. After the partition matrix is improved, it is grouped based on the degree of membership so as to produce the best data cluster. The flowchart describes the flow of a combination of methods that produce alternative recommendations by performing several processes such as ranking and forming preference values.
3. Result and Discussion

In the FCM method process, there are several steps taken, first the calculation of the UKT process is based on criteria and family data that has been filled in by students. The output of the UKT calculation process can be seen in Figure 3.

Next step 2 is obtained from the X matrix calculation based on student family data input criteria, which will then be followed by giving a value to variable $c = 8$, $w = 2$, $\text{Maxiter} = 100$, $\epsilon = 0.01$, $P0 = 0$ and $\text{iter} = 1$. Value given to the 6 variables used as a reference for calculating the initial steps. To be clearer, the process of assigning values to these variables can be seen in table 2.
In step 3, form a random value assuming the total random value in each row of data is always 1. This is in accordance with the calculation of the formula in equation (2.2). The variable $i$ is the amount of data while the variable $k$ is the number of clusters. The results of step 3 can be seen in figure 4.

Table 2. Giving Initial Variable Value

<table>
<thead>
<tr>
<th>Many clusters</th>
<th>$c$</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>$w$</td>
<td>2</td>
</tr>
<tr>
<td>Maximum iteration</td>
<td>$\text{maxiter}$</td>
<td>100</td>
</tr>
<tr>
<td>Smallest error</td>
<td>$e$</td>
<td>0.01</td>
</tr>
<tr>
<td>Objective function</td>
<td>$P_0$</td>
<td>0</td>
</tr>
<tr>
<td>Initial Iteration</td>
<td>$\text{iter}$</td>
<td>1</td>
</tr>
</tbody>
</table>

Next step 4 is to calculate the center value of the vector with $k$ = many criteria, and $j$ many attributes. Based on equation (2.3), the calculation results are obtained as shown in figure 5.

Figure 4. Result based on equation 2.2

Figure 5. Calculation based on equation 2.3
Based on Figure 5, it can be seen that the calculated data is 73 students with 13 clusters. The results of the cluster center calculation can be seen in the Vkj variable such as shown in table 3.

Table 3, Vkj variable values

<table>
<thead>
<tr>
<th>Vkj</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.71</td>
<td>2.36</td>
<td>1.77</td>
<td>1.6</td>
<td>1.4</td>
<td>1.38</td>
<td>2</td>
<td>1.82</td>
<td>1.41</td>
<td>2.26</td>
<td>2.76</td>
<td>2.88</td>
<td>1.81</td>
</tr>
<tr>
<td>2</td>
<td>1.71</td>
<td>2.36</td>
<td>1.77</td>
<td>1.6</td>
<td>1.4</td>
<td>1.38</td>
<td>2</td>
<td>1.82</td>
<td>1.41</td>
<td>2.26</td>
<td>2.76</td>
<td>2.88</td>
<td>1.81</td>
</tr>
</tbody>
</table>

Table 3 is the result of calculating the cluster center for 13 criteria. Next, the fifth step is calculating the objective function using equation (2.4), then the P1 value is 0.1764. After calculating the FCM method, then the calculation uses the SAW method by determining the weight of each criterion. The calculation weights can be seen in Figure 6. The calculation using the SAW method consists of 3 stages, namely determining the weights on the criteria, determining normalized and ranking matrices. The complete process of SAW calculation is shown in figure 6.

Figure 6. Completed SAW calculation

In figure 6, it can be seen that the student data displayed on the form are 10 people from 73 data entered. The data in the red box is the weight generated from the calculation using the SAW method but is still in the form of grouping so the results of the determination of the UKT are unknown. In this step, there is only a multiplication process between weight 1 and the next weight.
Figure 7. Result on normalizing matrix

Based on Figure 7, it can be seen that the red box is the result of the calculation in the form of matrix data, this is because this step is the step of normalizing the matrix where the matrix is formed from the results of multiplying the normalization matrix then forming the normalization process. The results of this normalized matrix will be used as the determination of the next results in step 3 in figure 8.

Figure 8. Step 3 in the SAW method

Based on Figure 8 it can be seen that the final result of the calculation of the Simple Additive Weighting method is in the form of ordered data starting from the data with the largest value to the smallest data. This result is obtained from the calculation of the ranking process by multiplying the normalized matrix (N) with the preference weight value (W). These results indicate that UKTs 1 through 8 start from the highest value to the smallest UKT value.
Based on Figure 9, it can be seen that the final value with UKT 1 starts from students who have a high final score, and so on with the value that decreases until the smallest final score has a UKT decision 8. The final value is the final result of the Simple Additive Weighting method.

4. Conclusions
Based on the results and discussion, it can be concluded that the number of data input as many as 73 students with 13 criteria that describe the family economic conditions of prospective students and using a combination of FCM and SAW methods can determine the ranking of Single Tuition with a margin of error 0 - 0.01. This system can help the campus to fulfill a sense of justice in determining the UKT group for prospective new students. The testing of this system uses a reference calculation with the number of clusters of 8 pieces, the number of weights 2, the maximum iteration of 100, the smallest iteration of 0.01 and the initial iteration of 1.

References
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