Application of Multi-Attribute Decision Making Method to Solve Robot Selection Problem

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ABSTRACT

The selection of best alternative in fuzzy problem is the difficult task for design engineer. To get the accurate result for selection of best alternative the study of multi-attribute decision makingmethods are taking attention of world. The aim of the present study is to solve fuzzy robot selection problem by using Technique of Order Preference by Similarity to Ideal Solutionmethodto rank alternatives. This study helps the decision maker for selection of a best robot that will meet all the requirement of the design engineer. A jointed-arm robot is to be selected for supporting numerical control machines. The result obtained using this method shows that the twelve number robotfulfil all requirement of engineer and customer.

Keywords:Robot selection, Technique of order preference by similarity to ideal solution.

I. INTRODUCTION

The design engineers always face the problem in deciding the best robot among the various that are available in market in huge quantity. They need to fix one among all available alternatives which will satisfy the all requirement of that application at any situation so that operational failure of the system may not occur. Therefore, the comprehensive evaluation and optimized robot selection for NC machine particularly important. As the decision making process is found to be unstructured, characterized by domain dependent knowledge, there is a need to apply an efficient multi –attribute decision making (MADM) tool to help the decision makers in making correct decisions. These methods consist of finding the most preferred alternative from given set of alternatives.In this paper the Technique of Order Preference by Similarity to Ideal Solution (TOPSIS) method is applied to solve twelve alternatives and five attribute robot selection for problem. This method is based on the concept that the chosen alternative should have the shortest distance from positive ideal solution and longest distance from the negative ideal solution.

II. LITERATURE REVIEW

Designer used various MADM methods for selection problems of different industrial and daily applications. Shivanand [1] define robot as automatically controlled, reprogrammable, multi-purpose manipulators programmable in three or more axes.Azami et al. [2] studied the polygon area method for robot selection problem. Also two numerical robot selection examples are taken to indicate the validation and advantages of the proposed method in comparison with the other four methods.

Lai et al. [3] used a TOPSIS method to identify solutions from a finite set of alternatives based on minimum distance from an ideal point and maximum distance from a negative ideal point. Atai [4]try to use of MADM approaches in solving a layout design problem by using TOPSIS method.Wanke et al. [5]the study reports on the performance assessment of Asian airlines using TOPSIS, to compute efficiency and increases the discriminatory power of the analysis against the efficient frontier. Gok [6] presents a new fuzzy TOPSIS method of choosing optimal cutting parameters requires for best surface roughness which directly affect performance of material.Mohammad [7] proved the results of performance,exergy analysis and TOPSIS steps, the optimum operation conditions for hypothetical cooling tower were gained. Hassani et al. [8] proposed the Comparative analysis between TOPSIS and PSI method of materials selection to achieve a desirable combination of strength and workability in Al/SiC composite where the weights are calculated by AHP method. Chamoli [9] in this paper the performance of the V down perforated baffle roughened rectangular channel is carried out under similar operating conditions. Author used the PSI method to solve this V down perforated baffle roughened channel problem and proved that PSI method proved is rapid and vigorous technique for assessment of the optimum roughness parameter.Madic et al. [10] discusses the application of the preference selection index (PSI) method for discrete optimization of the CO2 laser cutting of stainless steel. Kamble and Rao [11] explained that selection procedure of cricket players from a set of six level players in complex situations using analytical hierarchy process and it helps to rank the players.

III.TOPSIS METHOD

The MADM methods are most useful while dealing with fuzzy robot/material selection problem in which designer needs to select best alternative among the set of choices. The solution of many complex decision problems involves combinatorial optimization, i.e. obtaining the optimal solution among a finite set of alternatives. However, number of researcher presents their methods and theory to solve such fuzzy problem.

TOPSIS is aone of the most widely used MADM technique which was introduced by Yoon and Hwang [12]. It is a way to finding the alternative that is closest to the positive ideal solution and farthest from negative ideal solution. Like an option is more similar to an ideal solution, it has a higher priority. In this method the relative closeness is calculated from the ideal solution by using separation measure formula. With the maximum value of relative closeness we can select optimal alternative from the set of choices. TOPSIS method is a technique for order preference by similarity to ideal solution that maximizes the benefit criteria/attributes and minimizes the cost criteria/attributes, whereas the negative ideal maximizes the cost criteria/attributes and minimizes the benefit criteria/attributes.

The TOPSIS method is conducted as follows:

Step 1: Construct the normalized decision matrix. The normalized value r_{ij} is calculated as:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum x_{ij}^2}} \quad \text{for } i=1\dots m;\ j = 1\dots n$$

Step 2: Construct the weighted normalized decision matrix.

 ISBN : 978-93-87793-14-9

Assume we have a set of weights for each criteria w_j for j = 1.....n. Multiply each column of the normalized decision matrix by its associated weight.

$V_{ij} = w_j * r_{ij}$

Step 3: To determine positive-ideal solution (PIS) and negative-ideals solutions (NIS).

Positive ideal (best) solution: (Maximum value for beneficial and minimum for non-beneficial)

$$V^+ = \{(\sum_i^{max} V_{ij} / j \in J) \left(\sum_i^{min} V_{ij} / j \in J\right) / \, i = 1,2,3 \ldots \ldots\} = \{V_1^+, V_2^+, V_3^+, V_4^+, V_5^+\}$$

Negative ideal (worst) solution: (Minimum value for beneficial and maximum for non-beneficial)

$$V^- = \{(\sum_i^{min} V_{ij} / j \in J) \left(\sum_i^{max} V_{ij} / j \in J\right) / \, i = 1,2,3 \ldots \ldots\} = \{V_1^-, V_2^-, V_3^-, V_4^-, V_5^-\}$$

Step 4: Obtain the separation measures by using the n-dimensional Euclidean distance. The separation of each alternative can be calculated from the positive ideal solution and negative ideal solution is given as:

Positive separation measures Negative separation measures

$$S_i^+ = \sqrt{\sum (V_{ij} - V_j^+)^2} \quad S_i^- = \sqrt{\sum (V_{ij} - V_j^-)^2}$$

Step 5: Calculate the relative closeness to the ideal solution. The relative closeness of the alternative Aij can be defined as:

$$D_i = \frac{S_i^-}{(S_i^- + S_i^+)}$$

Step 6: Rank the preference order. Select an alternative with maximum D_i or rank alternatives in the descending order based on the value of D_i.

IV. PROBLEM STATEMENT

Robot Selection for supporting NC machines

In this example, a jointed-arm robot is to be selected for supporting Numerical Control (NC) machines.The actual data was provided by the manufactures [Rao, 13, 14]. Karasak and Ahiska [15], Rao[13,14] and Singh and Rao[16]]solved this example using MCDM methods. The decision matrix with twelve alternative robots and five attributes is given in Table 1. The attributes are Purchasing Cost (PC) in US$, Handling Coefficient (HC), Load Capacity (HC) in kg, 1/ REepeatability (RE) in 1/mm, and VElocity (VE) (m/s), among which HC, LC, RE, and VE are beneficial attributes (where higher values are desirable); whereas, PC is non-beneficial type (where lower values are preferable).

Table 1: Decision Matrix

ROBOT	PC	HC	LC	RE	VE
R1	100000	0.995	85	1.7	3
R2	75000	0.933	45	2.65	3.6
R3	56250	0.875	18	5	2.2
R4	28125	0.409	16	1.7	1.5
R5	46875	0.818	20	5	1.1

R6	78125	0.664	60	2.5	1.35
R7	87500	0.88	90	2	1.4
R8	56250	0.633	10	8	2.5
R9	56250	0.653	25	4	2.5
R10	87500	0.747	100	2	2.5
R11	68750	0.88	100	4	1.5
R12	43750	0.633	70	5	3

V. SOLUTION USING TOPSIS METHOD

In this section, one example of robot selection problem is considered to demonstrate the methodology of TOPSIS method. This example is earlier illustrated by Azami[2] using Polygon area method. The quantitative and qualitative data of robot selection problem is shown in Table 1.

The step by step solution involved in the application of TOPSIS method for selecting optimal robot for the given application are described below:

Step 1: Calculate the normalized decision matrix. Some normalized methods for TOPSIS is summarized byHassani and Khorshidi [8]. For simplify a vector normalization method is introduced whose normalized value r_{ij} is calculated asgiven formula. For example-r_{12}, r_{11} and all values are shown in Table 2:

$r_{ij} = \frac{x_{ij}}{\sqrt{\sum x_{ij}^2}}$ i) For beneficial $r_{12} = \frac{0.995}{\sqrt{7.23804}} = 0.3698.$

ii) For non-beneficial $r_{11} = \frac{100000}{\sqrt{5.616 * 10^{10}}} = 0.42197.$

Table 2: Normalized decision matrix.

ROBOT	PC	HC	LC	RE	VE
R1	0.42197	0.3698	0.3897	0.1208	0.3748
R2	0.31648	0.3467	0.2063	0.1883	0.4498
R3	0.23736	0.3252	0.0825	0.3552	0.2749
R4	0.11868	0.1520	0.0733	0.1208	0.1874
R5	0.1978	0.3040	0.0917	0.3552	0.1374
R6	0.32966	0.2468	0.2751	0.1776	0.1686
R7	0.36922	0.3270	0.4127	0.1421	0.1749
R8	0.23736	0.2352	0.0458	0.5684	0.3124
R9	0.23736	0.2427	0.1146	0.2842	0.3124
R10	0.36922	0.2776	0.4585	0.1421	0.3124
R11	0.2901	0.3270	0.4585	0.2842	0.1874
R12	0.18461	0.2352	0.321	0.3552	0.3748

Step 2: Construct the weighted normalized decision matrix as shown in Table 3:

$V_{ij} = w_j * r_{ij}$ i) For beneficial $V_{12} = 0.09853 * 0.369 = 0.0364.$

ii) For non-beneficial $V_{11} = 0.3702 * 0.4219 = 0.1562$..

Table 3: Weighted normalized decision matrix.

ROBOT	PC	HC	LC	RE	VE
R1	0.1562	0.0364	0.0168	0.0270	0.0992
R2	0.1172	0.0342	0.0089	0.0421	0.1191
R3	0.0879	0.0320	0.0036	0.0794	0.0728
R4	0.0439	0.0150	0.0032	0.0270	0.0496
R5	0.0732	0.0300	0.0039	0.0794	0.0364
R6	0.1220	0.0243	0.0118	0.0397	0.0447
R7	0.1367	0.0322	0.0178	0.0317	0.0463
R8	0.0879	0.0232	0.0020	0.1270	0.0827
R9	0.0879	0.0239	0.0049	0.0635	0.0827
R10	0.1367	0.0274	0.0197	0.0317	0.0827
R11	0.1074	0.0322	0.0197	0.0635	0.0496
R12	0.0683	0.0232	0.0138	0.0794	0.0992

Step 3: To determine positive-ideal and negative-ideals solutions. For PIS minimum of non-beneficial criteria as (PC=0.0439) and maximum value of beneficial criteria as (HC=0.0364).

For NIS maximum of non-beneficial as (PC=0.1562) and minimum of beneficial as (HC=0.0150).

Table 4: Positive ideal solution

0.0439	**0.0364**	**0.0197**	**0.1270**	**0.1191**

Table 5: Negative ideal solution

0.1562	**0.0150**	**0.0020**	**0.0270**	**0.0364**

Step 4: Findsthe Positive separation measures (S_i^+) and Negative separation measures (S_i^-).

The separation of each alternative from the ideal solution (P_1) and the negative ideal solution (N_1) are given below, respectively in Table 6:

$$S_i^+ = \sqrt{\sum (V_{ij} - V_j^+)^2} S_1^+ = \sqrt{0.0230} = 0.1517.$$

$$S_i^- = \sqrt{\sum (V_{ij} - V_j^-)^2} S_1^- = \sqrt{0.0046} = 0.0023.$$

Step 5: Calculate the relative closeness to the ideal solution (P_i). Calculate the relative closeness of each alternative to the ideal solution. The relative closeness of the alternative A_{ij} with respect to P_1 is defined as follows and all values of alternatives are shown in Table 6:

$$D_1 = \frac{S_i^-}{(S_i^- + S_i^+)} D_1 = \frac{0.0023}{0.1517 + 0.0023} = 0.0149.$$

Step 6: Rank the preference order is given in Table 6:

Table 6: Rank

Robot	S_i^+	S_i^-	D_i	RANK
1	0.1517	0.0023	0.0149	9
2	0.1127	0.0045	0.0384	7
3	0.0685	0.0045	0.0618	3
4	0.1247	0.0064	0.0487	4
5	0.1013	0.0049	0.0464	5
6	0.1395	0.0008	0.0056	11
7	0.1516	0.0005	0.0034	12
8	0.0612	0.0084	0.1212	2
9	0.0875	0.0041	0.0449	6
10	0.1381	0.0015	0.0108	10
11	0.1136	0.0023	0.0194	8
12	0.0346	0.0073	0.1742	1

VI. CONCLUSION

This paper has demonstrated the application of TOPSIS technique in evaluating robot options for numerical control machine.In this method a better evaluation of the alternative robots is achieved. The top-ranked robot as obtained using TOPSIS method exactly matches with those derived by the past researchers. This method can be efficiently applied to any type of real fuzzy problems involving any number of qualitative and quantitative criteria, and any number of alternatives.

The problem selected for this paper study have total five criteria in which four are beneficial and one is non-beneficialcriteria, and twelve alternative robots. We applied TOPSIS method to select best alternative i.e. best robot for supporting NC machine. The preferenceof robot selection obtained by using TOPSIS is R12>R8>R3>R4>R5>R9>R2>R11>R1>R10>R6>R7. And we come to the conclusion that we can achieve the best result if robot number 12 is used through TOPSIS method.

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