



Selection Of Industrial Robots using Complex Proportional Assessment Method

Dayanand Gorabe¹, Dnyaneshwar Pawar², Nilesh Pawar³
^{1, 2, 3} Students (Department of Mechanical Engineering),
Sinhgad Institute of Technology, Lonavala,
Maharashtra, INDIA.

Abstract: A Multi Attributes Decision Making (MADM) methods are gaining importance for selection of best robot among the available robots by considering the important attributes of robot. Manufactures are continuously incorporated advanced features and facilities into the robots due to increasing complexity. It has become more complicated to select a robot for specific industrial application. In this problem seven robots each having five attributes are considered and solved by Complex Proportional assessment (COPRAS) method. The rank of the robots are calculated and it is found that the Unimation PUMA 500/600 is the best robot among the other robots.

Keywords: Robot selection, COPRAS, MADM, Preference ranking method, Ranking, etc.

I. Introduction

Robots can perform repetitious, difficult and hazardous tasks with precision. Therefore, it is an important tool for diverse industrial applications like material handling, spray painting, welding and machine loading. Industrial robots are usually costly and have many characteristics, their selection calls for a careful examination and assessment of the requirements. The recent growth of information technology and engineering sciences have been the key reason for the increased utilization of robots. The control resolution, accuracy, repeatability, load carrying capacity, degrees of freedom, man-machine interfacing ability, maximum tip speed, memory capacity and supplier's service quality are the most important attributes to be taken into consideration while selecting an industrial robot for a particular application [1]. The selection of the robot to suit a particular application and production environment, from the large number of robots available in the market today has become a difficult task. In order to evaluate the overall effectiveness of the candidate alternatives and to select the best option, the multicriteria decision making method requires decomposing the problem into step such as defining a set of attributes which mostly influence the alternative, preparing a decision matrix, weighing the criteria based on past experience or using an appropriate method, evaluating the alternatives and ranking them from best to worst. The literature shows some applications in the field of multi criteria analysis in material selection. Multiple attribute decision making (MADM) addresses the problem of choosing an optimum choice containing the highest degree of satisfaction from a set of alternatives which are characterized in terms of their attributes [2]. Voogd established Environmental planning used to site sludge processing plants, to organize water resource plans, to develop groundwater management strategies, to prioritize watersheds for implementation of watershed restoration measures [3, 4], state of-art survey for MCDA proposed by Martel and Matarazoo. [5], comparison of various alternatives in water resource management carried by Hajkowicz and Higgins Water resource management decisions are typically guided by multiple objectives measured in a range of financial and non-financial units. Often the outcomes are highly intangible and may include items such as biodiversity, recreation, scenery and human health. [6], attributes based specification, comparison and selection of a robot by P.P. Bhangale The selection of the robot to suit a particular application and production environment, from the large number of robots available in the market today has become a difficult task. [7]. This paper presents selection of industrial robots using COPRAS method and rankings of the robot are found out.

II. Complex Proportional assessment method

This method selects the best decision considering both the ideal and the ideal-worst solutions. It takes into the account the performance of the alternatives with respect to different criteria and also the corresponding criteria weights. The COPRAS (Complex Proportional Assessment) method assumes direct and proportional dependences of the significance and utility degree of available alternatives under the presence of mutually conflicting criteria (Kaklauskas et al. 2006; Kaklauskas et al. 2007; Zavadskas et al. 2008.) [8]. The COPRAS method which is used here for evaluating and selecting the alternative flexible manufacturing systems adopts a stepwise ranking and evaluating procedure of the alternatives in terms of their significance and utility degree.

III. Problem statement and solution

Selection of a robot for a specific industrial application is one of the most challenging problems in real time manufacturing environment. It has become more and more complicated due to increase in complexity, advanced features and facilities that are continuously being incorporated into the robots by different manufacturers. Manufacturing environment, product design, production system and cost involved are some of the most influencing factors that directly affect the robot selection decision. The decision maker needs to identify and select the best suited robot in order to achieve the desired output with minimum cost and specific application ability.

This example deals with the selection of the most appropriate industrial robot for some pick-n-place operations where it has to avoid certain obstacles. Performance of an industrial robot is often specified using different attributes. Repeatability, accuracy, load capacity and velocity are observed to be the most important attributes affecting the robot selection decision. In this example five different robot selection attributes are considered as load capacity (LC), maximum tip speed (MTS), repeatability (RE), memory capacity (MC) and manipulator reach (MR), among which load capacity, maximum tip speed, memory capacity and manipulator reach are the beneficial attributes (where higher values are desirable), whereas repeatability is a non-beneficial attribute (where lower value is preferable). Thus, the industrial robot selection problem consists of five criteria and seven alternative robots. Rao [9] estimated the criteria weights as $W_{LC} = 0.036$, $W_{RE} = 0.192$, $W_{MTS} = 0.326$, $W_{MC} = 0.326$, $W_{MR} = 0.120$ using analytic hierarchy process (AHP).

Table I Quantitative data for the Industrial Robot selection problem

SR NO.	Robot	Load Capacity (Kg)	Repeatability (mm)	Max. tip speed (mm/s)	Memory capacity (point)	Manipulator reach (mm)
1	ASEA-IRB 60/2	60	0.4	2540	500	990
2	Cincinnati Milacrone T3-726	6.35	0.15	1016	3000	1041
3	Cybotch V15 Electric Robot	6.8	0.10	1727.2	1500	1676
4	Hitachi American Process Robot	10	0.2	1000	2000	965
5	Unimation PUMA 500/600	2.5	0.10	560	500	915
6	United States Robots Maker110	4.5	0.08	1016	350	508
7	Yaskawa Electric Motoman	3	0.1	1778	1000	920

COPRAS method are presented as below:

Step 1: Normalize the decision matrix using linear normalization procedure. (kaklauskas.et.al.....2006)

$$r_{ij} = x_{ij} / \sum x_{ij} \quad (1)$$

Table II Normalized decision matrix

Robot	LC	RE	MTS	MC	MR
1	0.6441	0.3539	0.2635	0.0564	0.1411
2	0.0681	0.1327	0.1054	0.3389	0.1483
3	0.0730	0.0884	0.1792	0.1694	0.2389
4	0.1073	0.1769	0.1037	0.2259	0.1375
5	0.0268	0.0884	0.0581	0.0564	0.1304
6	0.0483	0.0707	0.1054	0.0395	0.0724
7	0.0322	0.0884	0.1844	0.1129	0.1311

Step 2: Determine the weighted normalized decision matrix, D.

$$D = [y_{ij}] \text{ m x n} = r_{ij} \times w_j \quad (2)$$

$$\sum_{i=1}^m Y_{ij} \quad (i=1, 2, 3, \dots, m; j=1, 2, 3, \dots, n)$$

Table III Weighted Normalized decision matrix

Robot	LC	RE	MTS	MC	MR
1	0.0232	0.0679	0.0859	0.0184	0.0169
2	0.0024	0.0254	0.0343	0.1105	0.0178
3	0.0026	0.0169	0.0584	0.0552	0.0286
4	0.0038	0.0339	0.0338	0.0736	0.0165
5	0.0009	0.0169	0.0189	0.0184	0.0156
6	0.0017	0.0135	0.0343	0.0128	0.0086
7	0.0011	0.0169	0.0601	0.0368	0.0157

Step 3: The sum of weighted normalized values are calculated for both the beneficial attributes and non-beneficial attributes. Using the following equation:

$$S_{+i} = \sum_{j=1}^n y_{+ij} \quad (3)$$

$$S_{-i} = \sum_{j=1}^n y_{-ij} \quad (4)$$

$$S_{+} = \sum_{i=1}^m S_{+i} = \sum_{i=1}^m \sum_{j=1}^n y_{+ij} \quad (5)$$

$$S_{-} = \sum_{i=1}^m S_{-i} = \sum_{i=1}^m \sum_{j=1}^n y_{-ij} \quad (6)$$

Table IV Sums of the Weighted normalized values

Robots	S_{+i}	S_{-i}
1	0.1444	0.0679
2	0.1651	0.0254
3	0.1449	0.0169
4	0.1278	0.0339
5	0.0539	0.0169
6	0.0576	0.0135
7	0.1187	0.0169

Step 4: Determine the significance of the attributes on the basis of defining the positive alternative S_{+i} and negative alternative S_{-i} characteristic.

Step 5: Determine the relative significance or priorities (Q_i) of the alternative.

$$Q_i = S + i + \frac{S - \min \sum_{i=1}^m S_{-i}}{S - i \sum_{i=1}^m (S - \frac{\min}{S - i})} \quad (7)$$

Step 6: Calculate the quantitative utility (U_i) for i^{th} alternative.

$$U_i = \left[\frac{Q_i}{Q_{\max}} \right] \times 100\% \quad (8)$$

Table V Q_i and U_i values

Robots	Q_i	U_i	Rank
1	0.1529	81.4659	3
2	0.1877	100.0000	1
3	0.1788	95.2772	2
4	0.1448	77.1402	5
5	0.0878	46.8031	7
6	0.1000	53.2918	6
7	0.1477	78.7103	4

IV. Conclusion

For the robot end user or purchaser it will help to select and buy the correct robot from the market. The suggested methodology can be used for any type of selection problem having any number of attributes. Therefore, alternative Unimation PUMA 500/600 is the first choice, Hitachi American Process Robot is the second choice, Cincinnati Milacron T3-726 is the third choice, ASEA-IRB 60/2 is the fourth choice and United States Robots Maker110 is the fifth choice, Yaskawa Electric Motoman L3C is the sixth choice, Cybotch V15 Electric Robot is the seventh choice. Thus, the problem helps to understand the importance of multi criteria decision making and proper ranking of the alternatives from a set of attribute for industrial robot selection. The methodology is capable of taking into account important requirements of gas cylinder and it strengthens the existing procedure by proposing a logical and rational method of evaluation and selection rather than a selection which is done groundlessly.

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