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# Computational Intelligence for Engineering and Management Applications

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 Springer

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# Preface

Regional Association for Security and Crisis Management, Serbia; Mathematical Institute of the Serbian Academy of Sciences and Arts; MCKV Institute of Engineering, West Bengal, India; and CT Institute of Engineering, Management and Technology, Punjab, India; presented CIEMA-2022, the 1st International Conference on Computational Intelligence for Engineering and Management Applications.

The fundamental goal of CIEMA-2022 was to create an international venue for academics, scholars, academicians, and industry professionals to present, discuss, and exchange knowledge regarding theoretical and applied computational intelligence research in all areas of engineering and management applications. Catholic University of the North in Chile, the European Centre for Operational Research (ECOR) in Serbia, Sultan Moulay Slimane University in Morocco, City University in Malaysia, The Institution of Green Engineers (IGEN), and the Society for Data Science (S4DS) in India supported in organizing CIEMA-2022.

Many excellent keynote addresses by notable speakers were delivered at the conference including Dr. Lazar Velimirovic, Mathematical Institute of the Serbian Academy of Sciences and Arts, Belgrade, Serbia; Prof. Valentina E. Balas, Department of Automatics and Applied Software, Faculty of Engineering, University Aurel Vlaicu, Arad, Romania; Prof. Dr. Bui Thanh Hung, Director of Artificial Intelligence Laboratory, Faculty of Information Technology, Ton Duc Thang University, Vietnam; Prof. Dr. Samarjit Kar, Department of Mathematics, National Institute of Technology Durgapur, India; and Dr. K. S. Ravichandran, Rajiv Gandhi Institute of Youth Development, Sriperumbudur, India.

Different application areas including computational intelligence for fundamental engineering applications; computational intelligence for advanced engineering applications and computational intelligence for management applications were the main tracks in CIEMA-2022. Researchers and professors from highly reputed international institutes and universities graced CIEMA by giving their consents to serve in different committees. All submitted abstracts of CIEMA-2022 were initially screen by internal committee members, and then, recommended abstracts were reviewed by conference committee members along with external reviewers. Full papers of CIEMA-2022 had undergone rigorous peer review process backed by experts in respective fields,

chosen from committee members and external reviewers. Each paper of CIEMA has been reviewed by at least two experts, and papers were selected purely on the basis of originality, significance of contribution, diversity of theme, approaches and reviewers' recommendations. CIEMA had received a total of 391 submissions, and finally, 155 papers were accepted by the reviewers. The overall acceptance rate was around only 39%. CIEMA-2022 received papers from 19 different countries across the globe including Albania, Bosnia and Herzegovina, Brazil, China, Chile, Ecuador, Ethiopia, Germany, India, Iran, Japan, Malaysia, Morocco, Nigeria, Serbia, South Korea, Turkey, Russia, and Vietnam.

The select proceedings of CIEMA-2022 includes some of the high-quality papers presented during CIEMA-2022. The volume is divided into the following parts based on themes and application domains considered in the papers.

- Computational Intelligence in Energy/Logistics/Manufacturing/Power Applications
- Computational Intelligence in Healthcare Applications
- Computational Intelligence in Image/Gesture Processing
- Reviews in Computational Intelligence
- Various Aspects of IOT, Machine Learning and Cyber-Network Security
- Computational Intelligence in Special Applications
- Computational Intelligence in Management Applications
- Computational Optimization for Decision Making Applications

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# **Computational Intelligence in Energy/Logistics/Manufacturing/Power Applications**

# An Integrated Approach for Robot Selection Under Utopia Environment



Bipradas Bairagi

**Abstract** In the constantly changing global scenario, modern industrial organizations are searching suitable automated manufacturing systems having industrial robot as an integrated part. Proper selection of robots for industrial purpose considering multiple conflicting criteria is very critical task for decision makers. An integrated approach for robot selection under utopia environment has been introduced in the current research work. This paper reflects the coefficient of decision-making attitude and employs Hurwicz Criterion to determine robot selection index (RSI) using cost index, utility index and relative closeness. The present work investigates the consistent in the consequence of robot selection problem obtained by the proposed method with that of existing method. To analyze the proposed algorithm, an illustrative example on selection of industrial robots having multiple conflicting criteria has been cited and solved using the proposed method. Consequently, sensitivity analysis of robot selection indices has been carried out for assisting the decision makers to make decision under varying decision-making attitude. Finally, the ranking of the robots under consideration is tabulated using the proposed methods.

**Keywords** Coefficient of decision-making attitude · Robot selection index · Hurwicz criterion · MCDM · TOPSIS · Cost index relative closeness

## 1 Introduction

Decision making is a selection process of the best possible alternative or action of course from a number of available alternatives. At every moment in our real life, decision is made for the selection of best alternatives on the basis of some selection criteria. Decision making starts from the selection of hospital before the birth of a child and is associated with selection of name, cloths, foods, school, college, university, tutors, profession, location selection of house and so on.

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The selection criteria on the basis of which all these decisions are made are objective, subjective and critical in nature. Objective criteria are those which are both measurable and quantitative such as cost, weight, speed, distance and lifecycles measured in suitable unit, reliability. Subjective criteria are those which are qualitative but neither measurable nor quantifiable. Subjective criteria are associated with imprecision and vagueness and realized by human perception such as looks of an alternative. Critical criteria are those which decide the requirement of further evaluation of data of an alternative. If critical criteria of an alternative are not satisfied, then the associated alternative is not considered for further evaluation or processing. Political stability, social or communal situation are examples of critical criteria.

In last few decades, extensive researches on industrial robot selection have been executed. Goswami and Behera applied two well-known MCDM approaches, ARAS and COPRAS, for the evaluation and selection of conveyors, AGV and robots as material handling equipment [1]. Soufi et al. introduced an AHP-based MCDM methodology for the evaluation and selection of material handling equipment to be utilized in manufacturing systems [2]. Satyam et al. applied a multi attribute decision making approach for evaluation and selection of conveyors as material handling equipment [3]. Nguyen et al. advocated a combined multi-criteria decision-making model for the evaluation and selection of conveyor as the material handling equipment based on fuzzy analytical hierarchy process and fuzzy ARAS with vague and imprecision information [4]. Mathewa and Saha made a comparison among the novel multi-criteria decision-making approaches by solving a problem on material handling equipment selection [5].

Shih [6] has evaluated performances of robots on their incremental benefit–cost ratio, and in this work, cost is shown in two representations. They have not demonstrated the effectiveness of their model. MCDM technique is widely used in ranking one or more alternatives from a set of available alternatives with respect to several criteria [7–12]. The study examines the modification in the most favorable result of a perturbation in a diversity of constraint or substitution rates, the criteria weights or the vagueness on performance procedures [13, 14].

Decision makers always like to know which option is best among a set of several feasible alternatives [15]. In order to determine the tactical decision-making about twofold market high machinery goods, a model on mixed integer goal programming is introduced to smooth the progress of the procedure of marketing media selection [16]. A framework is constructed using MCDM method for the sustainable technologies for generation of electricity in Greece to elaborate more realistic and transparent outcomes [17].

As per the global literature, the decision support framework formulation must be adequately flexible to consider variation in institutional settings, original capabilities and motivation as well as style of decision making [18, 19]. An integrated approach is introduced for considering the vendor selection procedure. In the beginning, the

authors formulated the vendor selection problem using multiple criteria decision-making methodology [20]. Then, the modified TOPSIS is used to select challenging products in terms of their general performances. TOPSIS is a constructive tool for working out multiple criteria decision making problems. In TOPSIS method, the optimal alternative is one which has the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution.

The gap analysis of the above literature survey clearly shows that there is still absolute necessity of further investigation for proper selection of the robots considering variable decision-making attitude with the objective of aiding managerial decision makers.

The rest of the paper is planned as follows. Section 2 is dedicated for representing integrated and extended algorithm. Section 3 gives the detailed description of a case study along with illustration, calculation and discussion. Section 4 is decorated with conclusion.

## 2 Integrated Algorithm with Extension

The following algorithm has been proposed to select the best alternative by solving the above problem.

**Step 1:** Establish a decision matrix ( $M_d^e$ ), where  $e$  = order of expert.  $M_d^e$  is represented as the following matrix.

$$M_d^e = \begin{matrix} & C_1 & C_2 & \dots & C_j & \dots & C_n \\ A_1 & \left[ \begin{array}{cccccc} x_{11}^e & x_{12}^e & \dots & x_{1j}^e & \dots & x_{1n}^e \\ x_{21}^e & x_{22}^e & \dots & x_{2j}^e & \dots & x_{2n}^e \\ \dots & \dots & \dots & \dots & \dots & \dots \\ x_{i1}^e & x_{i2}^e & \dots & x_{ij}^e & \dots & x_{in}^e \\ \dots & \dots & \dots & \dots & \dots & \dots \\ x_{m1}^e & x_{m2}^e & \dots & x_{mj}^e & \dots & x_{mn}^e \end{array} \right. & & & & & & \end{matrix} \quad (1)$$

where  $A_i$  =  $i$ th alternative,  $i = 1, 2, \dots, m$ ;  $m$  is number of alternatives;  $C_j$  =  $j$ th criterion,  $j = 1, 2, \dots, n$ ;  $n$  is the number of criteria;  $x_{ij}^e$  is the performance rating of alternative  $A_i$  with respect to criterion  $C_j$  by  $e$ th decision maker (expert),  $e = 1, 2, \dots, E$ ;  $E$  is the total number of decision makers or experts. The criteria are divided into two parts; one is benefit criteria, and the other is cost criteria; let the number of benefit criteria be ‘ $a$ ’ and the number of cost criteria be ‘ $b$ ’, so that  $a + b = n$ .

**Step 2:** Build normalized decision matrix  $M_{nd}^e$  from performance rating assigned by each expert,  $e = 1, 2 \dots E$ .

$$M_{nd}^e = \begin{matrix} A_1 \\ A_2 \\ \dots \\ A_i \\ \dots \\ A_m \end{matrix} \begin{bmatrix} y_{11}^e & y_{12}^e & \dots & y_{1j}^e & \dots & y_{1a}^e \\ y_{21}^e & y_{22}^e & \dots & y_{2j}^e & \dots & y_{2a}^e \\ \dots & \dots & \dots & \dots & \dots & \dots \\ y_{i1}^e & y_{i2}^e & \dots & y_{ij}^e & \dots & y_{ia}^e \\ \dots & \dots & \dots & \dots & \dots & \dots \\ y_{m1}^e & y_{m2}^e & \dots & y_{mj}^e & \dots & y_{ma}^e \end{bmatrix} \quad (2)$$

where  $y_{ij}^e$  = normalized value of  $x_{ij}^e$  and  $0 \leq y_{ij}^e \leq 1$ .  $y_{ij}^e$  is determined using the equation

$$y_{ij}^e = \frac{x_{ij}^e}{\sqrt{\sum_{i=1}^n x_{ij}^e}}, \quad \text{where } i = 1, \dots, m; \quad \text{and } j = 1, \dots, a. \quad (3)$$

**Step 3:** A weight vector  $W^e$  is assigned by each expert for the benefit

$$W^e = [w_1^e \dots w_j^e \dots w_a^e] \quad (4)$$

where  $\sum_{j=1}^a w_j^e = 1$  and  $j = 1, 2, \dots, a$ .

**Step 4:** Construct weighted normalized decision matrix  $U_b^h$ ,  $h = 1, 2 \dots H$  by each decision maker

$$M_{mnd}^e = \begin{matrix} A_1 \\ A_2 \\ \dots \\ A_i \\ \dots \\ A_m \end{matrix} \begin{bmatrix} y_{11}^e w_1^e & y_{12}^e w_2^e & \dots & y_{1j}^e w_j^e & \dots & y_{1n}^e w_n^e \\ y_{21}^e w_1^e & y_{22}^e w_2^e & \dots & y_{2j}^e w_j^e & \dots & y_{2n}^e w_n^e \\ \dots & \dots & \dots & \dots & \dots & \dots \\ y_{i1}^e w_1^e & y_{i2}^e w_2^e & \dots & y_{ij}^e w_j^e & \dots & y_{in}^e w_n^e \\ \dots & \dots & \dots & \dots & \dots & \dots \\ y_{m1}^e w_1^e & y_{m2}^e w_2^e & \dots & y_{mj}^e w_j^e & \dots & y_{mn}^e w_n^e \end{bmatrix}$$

$$= \begin{matrix} A_1 \\ A_2 \\ \dots \\ A_i \\ \dots \\ A_m \end{matrix} \begin{bmatrix} z_{11}^e & z_{12}^e & \dots & z_{1j}^e & \dots & z_{1n}^e \\ z_{21}^e & z_{22}^e & \dots & z_{2j}^e & \dots & z_{2n}^e \\ \dots & \dots & \dots & \dots & \dots & \dots \\ z_{i1}^e & z_{i2}^e & \dots & z_{ij}^e & \dots & z_{in}^e \\ \dots & \dots & \dots & \dots & \dots & \dots \\ z_{m1}^e & z_{m2}^e & \dots & z_{mj}^e & \dots & z_{mn}^e \end{bmatrix} \quad (5)$$

where  $z_{ij}^e = y_{ij}^e w_j^e$ ; that is product of  $y_{ij}^e$  and  $w_j^e$ ; and the value of  $z_{ij}^e$  lies between 0 and 1; that is,  $0 \leq z_{ij}^e \leq 1$ ,  $i = 1, 2, 3 \dots m, j = 1, 2, 3 \dots a$ .

**Step 5:** Determination of positive ideal solution  $V^{e+}$  (PIS) and negative ideal solution  $V^{e-}$  (NIS)

$$V^{e+} = [v_1^{e+} \dots v_a^{e+}] \{ \max v_{ij}^{e+}; i = 1, \dots, 2, \dots, m, j = 1, 2, \dots, a; \} \quad (6)$$

$$V^{e-} = [v_1^{e-} \dots v_a^{e-}] \{ \min v_{ij}^{e-}; i = 1, 2, \dots, m, j = 1, 2, \dots, a; \} \quad (7)$$

**Step 6:** Calculation of separation measures for each alternative  $S_i^{e+}$  and  $S_i^{e-}$  of the benefit criteria from PIS and NIS. Individual separation measures are calculated using the following formula.

$$S_i^{e+} = \left\{ \sum_{j=1}^n |v_{ij}^e - v_{ij}^{e+}|^2 \right\}^{1/2} \quad \text{where } i = 1, 2, \dots, m; \quad (8)$$

$$S_i^{e-} = \left\{ \sum_{j=1}^n |v_{ij}^e - v_{ij}^{e-}|^2 \right\}^{1/2} \quad \text{where } i = 1, 2, \dots, m; \quad (9)$$

**Step 7:** Determination of group separation measure  $\bar{S}_{bi}^{h+}$  and  $\bar{S}_{bi}^{h-}$  from the above-calculated value of individual separation measure of alternatives. As number of decision makers is  $e$ , so each of  $S_i^{e+}$  and  $S_i^{e-}$  is a set of  $e$  number of alternatives. For group separation measures, the following formulas are used.

$$\bar{S}_i^{e+} = S_i^{1+} \otimes S_i^{2+} \otimes \dots \otimes S_i^{e+} \quad \text{where } i = 1, 2, \dots, m; \quad (10)$$

$$\bar{S}_i^{e-} = S_i^{1-} \otimes S_i^{2-} \otimes \dots \otimes S_i^{e-} \quad \text{where } i = 1, 2, \dots, m; \quad (11)$$

Geometrical mean (GM) is preferred to arithmetic mean (AM) for performing the above operation. If geometrical mean (GM) is followed, then the abovementioned operations take the forms.

$$\bar{S}_i^+ = \left\{ \prod_{k=1}^{k=e} S_i^{k+} \right\}^{1/e}; \quad \text{where } i = 1, \dots, m; \quad (12)$$

$$\bar{S}_i^- = \left\{ \prod_{k=1}^{k=e} S_i^{k-} \right\}^{1/e}; \quad \text{where } i = 1, \dots, m. \quad (13)$$

If arithmetic mean (AM) is followed, then expression takes the forms

$$\bar{S}_i^+ = \frac{1}{e} \sum_{k=1}^{k=e} S_i^{k+}; \quad \text{where } i = 1, \dots, m; \quad (14)$$

$$\bar{S}_i^- = \frac{1}{e} \sum_{k=1}^{k=e} S_i^{k-}; \quad \text{where } i = 1, \dots, m. \quad (15)$$