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PSO BASED INTUITIONISTIC FUZZY OPTIMIZATION

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ABSTRACT:

Modeling of real life problems involving optimization process rolls out to be a multi-objective programming problem. In order to optimize a linear programming model, numerous approaches have been suggested so far. Problems of decision making with regard to multi-attribute have been carried out using Intuitionistic Fuzzy sets in which optimization was done by conventional methods. This paper intercalates an application of particle swarm optimization method to solve a linear programming problem. First, the theory of Intuitionistic Fuzzy Sets have been employed to formulate multi-objective linear programming problem by already existing methods and then Particle Swarm Optimization is introduced as a tool to optimize the problem. By considering the air condition selection problem, the results are compared and it is proved that the proposed method has a better performance than the conventional methods.

Keywords: *Intuitionistic Fuzzy set, Decision making, Intuitionistic fuzzy optimization, Particle Swarm Optimization.*

Mathematics Subject Classification: *03F55, 08A72.*

1. INTRODUCTION

Decision making is the process of identifying and choosing alternatives of the decision maker's values and preferences. A major part of decision-making involves the analysis of a finite set of alternatives described with respect to evaluative criteria. Then the task should be to rank these alternatives in terms of how attractive they are to the decision-maker(s) when all the criteria are considered simultaneously. Another task could be to find the best alternative or to determine the relative total priority of each alternative (for instance, if alternatives represent projects competing for funds, then all projects must be ranked and based on the ranks the best alternate will be selected) when all the criteria are considered simultaneously. Solving such problems is the focus of multiple-criteria decision analysis (MCDA). This area of decision-making, though very old, has attracted the interest of many researchers and practitioners and is still highly debated as there are many MCDA methods which may yield very different results when they are applied on exactly the same data. This leads to the formulation of a decision-making paradox.

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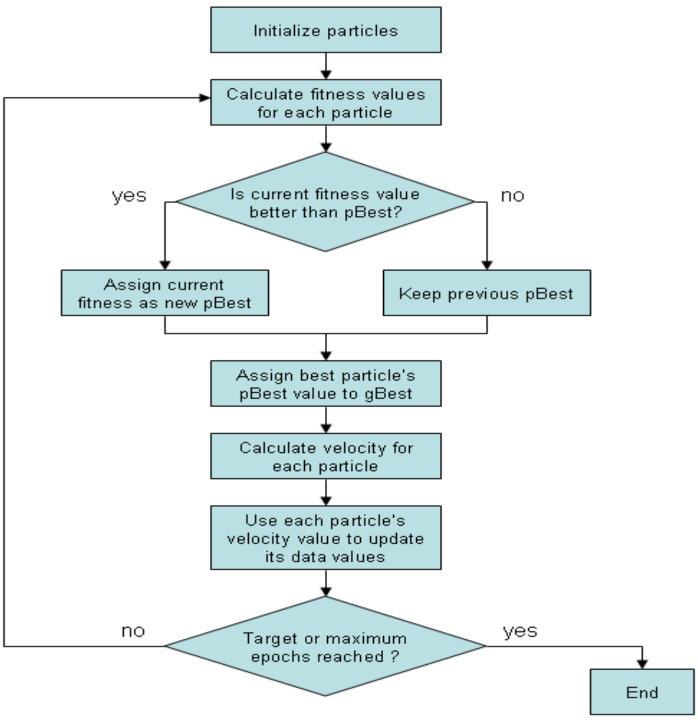
In 1965, Lofti A. Zadeh [20] introduced the notion of a fuzzy subset as a method for representing uncertainty in real world. The concept of intuitionistic fuzzy set was introduced by K. T. Atanassov [1] as a powerful extension of fuzzy set. Atanassov in his studies emphasized that in view of handling imprecision, vagueness or uncertainty in information both the degree of belonging and degree of non-belonging should be considered as two independent properties as these are not complement to each other. H-J .Zimmermann [22] designed crisp optimization models as fuzzy models and then solved it by using existing standard algorithms. As an extension of fuzzy optimization, Plamen G Angelov [16] defined some optimization problems in an Intuitionistic Fuzzy environment. He suggested a new approach for solving the problem of multi objective optimization in Air Conditioning systems through the comfort and discomfort IF definitions [17]. S. K. Bharati and S. R. Singh [4] implied a computational algorithm for solving multi-objective linear programming. Arindam Garai and Tapan Kumar Roy [2] used a technique which is an extension of intuitionistic fuzzy optimization technique, proposed by Plamen P. Angelov in 1997. Manish Agarwala, Kanad K. Biswas, Madasu Hanmandlu, used generalized Intuitionistic fuzzy softs sets in decision making [14]. Deng-Feng Li [5] investigated multi-attribute decision-making using intuitionistic fuzzy sets and constructed several linear programming models to generate optimal weights for criteria. But the method he put forward had to deal bigger calculation. After that Lin Lin, Xue-Hai Yuan, Zun-Quan Xia [11] introduced another method which allows the degrees of satisfiability and non-satisfiability of each alternative with respect to a set of criteria to be represented by intuitionistic fuzzy sets. There they used score function and accuracy function, intuitionistic indices etc. to convert intuitionistic fuzzy problem into LPP. Then by ranking method they identified a better solution. After that many researchers used IFS for multi-criteria decision making problems. Even though many methods are available like using similarity measures, interval valued IFS, Taylor’s series, hesitation index, etc., a better solution will be obtained through this proposed method. Moreover time consumption is less in this method compared to the existing methods.

Particle Swarm Optimization (PSO) is a computational & fast convergence method that optimizes a problem by iteratively trying to improve a candidate’s solution with regard to a given measure of quality. It solves a problem by having a population of candidate solutions, and moving these particles around in the search-space according to simple mathematical formulae over the particle's position and velocity. Each particle's movement is influenced by its local best known position but, is also guided toward the best known positions in the search-space, which are updated as better positions are found by other particles. This is expected to move the swarm toward the best solutions. Particle swarm optimization (PSO) was originally introduced by Kennedy and Eberhart in 1995 for the study of social and cognitive behavior (Eberhart & Kennedy, 1995a, 1995b). Currently, PSO algorithm is widely used in fields such as function optimization, combination optimization, Vehicle Scheduling, Graph coloring [8], Neuro Structure Optimization, network training, robot path programming, pattern recognition, fuzzy system control etc. [9].

In this paper several benchmark functions have been used to test the algorithm. The results disclose that the new algorithm performance are encouraging in optimization result and convergence characteristic, and can avoid premature phenomenon effectively. The detailed flow chart of PSO is followed as



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So far PSO has been used as a tool in Fuzzy mathematics such as Scheduling jobs on Computational Grids [6], economic dispatch problem [19], image segmentation [12], etc. Now we use it with intuitionistic Fuzzy set problems. Section-2 of this paper deals with the definitions and properties of intuitionistic fuzzy sets. In Section 3, the role of IFS in decision making through PSO is analyzed elaborately

2. INTUITIONISTIC FUZZY SETS

Definition 2.1: An Intuitionistic fuzzy set (IFS) A in a non-empty set X is defined as an object of the form $A = \{< x, \mu_A(x), \nu_A(x) > / x \in X\}$ where $\mu_A: X \to [0, 1]$ is the degree membership and $\nu_A: X \to [0, 1]$ is the degree of non - membership of the element $x \in X$ satisfying $0 \le \mu_A(x) + \nu_A(x) \le 1$.

In addition for each IFS A in X the degree of indeterminacy is defined by $\pi_A(x) = 1 - \mu_A(x) - \nu_A(x)$ which is called the degree of hesitancy of x to A. It is obvious that $0 \le \pi_A(x) \le 1$ for each $x \in X$. Especially, if $\pi_A(x) = 0$, for all $x \in X$ then the IFS A is reduced to a fuzzy set.

Definition 2.2: The operations of IFS are defined as follows, for every A, B $\in$ IFSs(X):

- $A \le B$ if and only if $\mu_A(x) \le \mu_B(x)$ and $\nu_A(x) \ge \nu_B(x)$ for all x in X.
- $A = B$ if and only if $A \le B$ and $B \le A$.
- $A \cap B = \{\langle x, \min(\mu_A(x),\mu_B(x)), \max(\nu_A(x), \nu_B(x))\rangle \mid x \in X\}$.
- $A \cup B = \{\langle x, \max(\mu_A(x),\mu_B(x)), \min(\nu_A(x), \nu B(x))\rangle \mid x \in X\}$.
- The complementary of an IFSA is $A^C = \{(x, \nu_A(x), \mu_A(x)) \mid x \in X\}$.

3. FORMULATION OF DECISION MAKING USING INTUITIONISTIC FUZZY VALUES

The formulation of the decision making problem as an intuitionistic Fuzzy problems [5] is as follows. Suppose that there exists an alternative set $X = \{x_1, x_2, ...x_n\}$ which consists of n non-inferior decision making alternatives from which a most preferred alternative is to be selected. Each alternative is assessed on m attributes. Let the set of all attributes be denoted by $A = \{a_1, a_2,.....a_m\}$. Assume that μ_{ij} and ν_{ij} are the degree of membership and the degree of non membership of the alternative $x_j \in X$ with respect to the attribute $a_i \in A$ to the fuzzy concept "excellence", respectively, where $0 \le \mu_{ij} \le 1$, $0 \le \nu_{ij} \le 1$, and $0 \le \mu_{ij} + \nu_{ij} \le 1$. That is the evaluation of the alternative $x_j \in X$ with respect to the attribute $a_i \in A$ is an intuitionistic fuzzy set denoted by $X_{ij} = \{\langle x_j, \mu_{ij}, \nu_{ij} \rangle\}$. The intuitionistic fuzzy indices $\pi_{ij} = 1 - \mu_{ij} - \nu_{ij}$ are such that the larger π_{ij} the higher a hesitation margin of the decision maker as to the "excellence" of the alternative $x_j \in X$ with respect to the attribute $a_i \in A$ whose intensity is given by μ_{ij}. From Intuitionistic indices we can calculate the best final result or worst one. During the process, the decision maker can increase his evaluation by adding the value of the intuitionistic index. Thus the evaluation lies in the closed interval $[\mu_{ij}^l, \mu_{ij}^u] = [\mu_{ij}, \mu_{ij} + \pi_{ij]}$, where $\mu_{ij}^l = \mu_{ij}$ and $\mu_{ij}^u = \mu_{ij} + \pi_{ij} = 1 - \nu_{ij}$. Clearly $0 \le \mu_{ij}^l \le \mu_{ij}^u \le 1$ for all $x_j \in X$ and $a_i \in A$.

Similarly, we assume that ρ_I and τ_I are the degree of membership and the degree of non-membership of the attribute $a_i \in A$ to the fuzzy concept of "importance" respectively where $0 \le \rho_I \le 1$, $0 \le \tau_I \le 1$ and $0 \le \rho_I + \tau_I \le 1$. The intuitionistic indices $\eta_I = 1 - \rho_I - \tau_I$ are such that the larger η_I, the higher a hesitation margin of decision maker as to the "importance" of the attribute $a_i \in A$ whose intensity is given by ρ_i. Intuitionistic indices allow us to calculate the biggest weight or the smallest one. As in the case of alternative evaluation the decision maker can increase his evaluating weights by adding the value of the intuitionistic index. Thus the weight lies in the interval $[\omega_i^l, \omega_i^u] = [\rho_i, \rho_i + \eta i]$, where $\omega_i^l = \rho_i$ and $\omega_i^u = \rho_{i+}\eta_I = 1 - \tau_i$. Clearly $0 \le \omega_i^l \le \omega_i^u \le 1$ for each attribute $a_i \in A$. In addition to this we assume that $\sum_{i=1}^m \omega_i^l \le 1$ and $\sum_{i=1}^m \omega_i^u \ge 1$ in order to find weights $\omega_i \in [0, 1]$ (I = 1,2,……m) satisfying $\omega_i^l \le \omega_i \le \omega_i^u$ and $\sum_{i=1}^m \omega_i = 1$.

Now we formulate the above problem into a linear programming problem by one of the conventional methods [5] as follows.

$$\max z = \frac{\sum_{j=1}^n \sum_{i=1}^m (\mu_{ij}^u - \mu_{ij}^l)\omega_i}{n}, \ \omega_i^l \le \omega_i \le \omega_i^u \ \text{(I = 1,2,….m)}, \ \sum_{i=1}^m \omega_i = 1.$$

To generate the optimal weights of the attributes PSO is used in place of conventional methods.

Example: Consider an air-condition system selection problem [5]. Suppose there exist three air-condition systems x_1, x_2 and x_3. Let the alternate set be $X = \{x_1, x_2, x_3\}$. Suppose three attributes a_1(economical), a_2(function), and a_3(being operative) are taken into consideration in the selection problem. Let the attributes set be $A = \{a_1, a_2, a_3\}$. Using statistical methods, the degrees μ_{ij} of membership and the degrees ν_{ij} of non-membership for the alternative $x_j \in X$ with respect to the attribute $a_i \in A$ to the fuzzy concept "excellence" can be obtained respectively. Namely,

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$$((\mu_{ij},\gamma_{ij}))_{3\times 3} = \begin{array}{c c} & \begin{array}{ccc} x_1 & x_2 & x_3 \end{array} \\ \begin{array}{c} a_1 \\ a_2 \\ a_3 \end{array} & \begin{pmatrix} (0.75, 0.10) & (0.80, 0.15) & (0.40, 0.45) \\ (0.60, 0.25) & (0.68, 0.20) & (0.75, 0.05) \\ (0.80, 0.20) & (0.45, 0.50) & (0.60, 0.30) \end{pmatrix} \end{array}$$

$$((\mu'_{ij},\gamma''_{ij}))_{3\times 3} = \begin{array}{c c} & \begin{array}{ccc} x_1 & x_2 & x_3 \end{array} \\ \begin{array}{c} a_1 \\ a_2 \\ a_3 \end{array} & \begin{pmatrix} (0.75, 0.90) & (0.80, 0.85) & (0.40, 0.55) \\ (0.60, 0.75) & (0.68, 0.80) & (0.75, 0.95) \\ (0.80, 0.80) & (0.45, 0.50) & (0.60, 0.70) \end{pmatrix} \end{array}$$

Similarly, the degrees ρ_i of membership and degrees τ_i of non-membership for the three attributes $a_i \in A$ to the fuzzy concept "importance" can be obtained, respectively. Namely

$$((\rho_i,\tau_i))_{1\times 3} = \begin{array}{ccc} a_1 & a_2 & a_3 \\ ((0.25, 0.25) & (0.35, 0.40) & (0.30, 0.65)) \end{array}$$

i) Now by intuitionistic indices method[5] we are converting the above problem into a linear programming problem as follows:

max z = $\frac{0.35\omega_1+0.47\omega_2+0.15\omega_3}{3}$ subject to the constraints

$0.25 \le \omega_1 \le 0.75$

$0.35 \le \omega_2 \le 0.60$

$0.30 \le \omega_3 \le 0.35$

$\omega_1 + \omega_2 + \omega_3 = 1$

Solving the above linear programming by conventional methods, its optimal solution can be obtained as

$\omega_1 = 0.25$, $\omega_2 = 0.40$, $\omega_3 = 0.35$

Then By Deng-Feng Li[5], the index for each alternative is given by

$\xi_1 = 0.7335$, $\xi_2 = 0.6563$, $\xi_3 = 0.6616$.

From this we conclude that the best alternative is x_1.

ii) Considering the same problem again, it is converted into a linear problem by another method [11] as follows:

max z = $1.41 * \omega 1 + 1.765 * \omega 2 + 0.925 * \omega 3$, subject to the constraints

$0.25 \le \omega_1 \le 0.75$

$0.35 \le \omega_2 \le 0.60$

$0.30 \le \omega_3 \le 0.35$

$\omega_1 + \omega_2 + \omega_3 = 1$

Solving the above linear programming by simplex method, its optimal solution can be obtained as,

$\omega_1 = 0.25$, $\omega_2 = 0.40$, $\omega_3 = 0.35$

Then by applying score function and accuracy function formula [11], the ranking of the alternatives is given by $R(a_1) = 0.5525$, $R(a_2) = 0.40425$ & $R(a_3) = 0.47125$ which shows the best alternative is x_1.

SIMULATION RESULTS AND DISCUSSIONS

The control parameters for the best result of PSO are:

Parameter	PSO
No. of variables	3
Population Size	1
No. of iterations	372
C_1	1.5
C_2	2.5

Optimum values of the variables

S. No.	C_1	C_2	ω_1	ω_2	ω_3	Max z	Time (sec.)	Iterations
1.	0.7	3.3	0.2712	0.4143	0.3145	1.4046	0.421624	263
2.	0.9	3.1	0.2525	0.4220	0.3256	1.4020	0.432950	353
3.	1.0	3.0	0.2911	0.4060	0.3030	1.4073	0.421167	331
4.	1.4	2.6	0.2525	0.4446	0.3030	1.4210	0.502841	527
5.	1.5	2.5	0.2525	0.4446	0.3030	1.4210	0.446970	372
6.	1.8	2.2	0.2525	0.4446	0.3030	1.4210	0.497333	514
7.	2.3	1.7	0.2934	0.4036	0.3030	1.4064	0.403399	216
8.	2.5	1.5	0.2525	0.4388	0.3087	1.4161	0.400890	195
9.	2.7	1.3	0.2525	0.4446	0.3030	1.4210	0.476420	437
10.	2.9	1.1	0.2525	0.4446	0.3030	1.4210	0.490540	497

Corresponding to these control variables it was found that all the variables satisfy the lower and upper limits and also the equality constraints.

Using conventional method we got $\omega_1 = 0.25$, $\omega_2 = 0.40$, $\omega_3 = 0.35$ and max z = 0.10933

Using PSO method we got $\omega_1 = 0.2525$, $\omega_2 = 0.4446$, $\omega_3 = 0.3030$ and **max z = 0.1143**.
And the index for each alternative is given by $\xi_1 = 0.7268$, $\xi_2 = 0.6676$, $\xi_3 = 0.6683$ which proves the best alternative is x_1.

Similarly by Lin Lin [11] method we have $\omega_1 = 0.25$, $\omega_2 = 0.40$, $\omega_3 = 0.35$ and max z = 1.38225

But using PSO method we get **max z = 1.4210**.

And the ranking of the alternatives are $R(a_1) = 0.5539$, $R(a_2) = 0.4029$ & $R(a_3) = 0.4680$ where the best alternative is a_1.

Comparison of results:

Table 3.2 and Table 3.3 show the comparison of the proposed method with other existing methods.

Table-3.2

Objective	Optimal solution[5]	PSO method	Improvement of Result
Max z = $\frac{0.35\omega_1+0.47\omega_2+0.15\omega_3}{3}$ Subject to $0.25 \le \omega_1 \le 0.75$ $0.35 \le \omega_2 \le 0.60$ $0.30 \le \omega_3 \le 0.35$ $\omega_1 + \omega_2 + \omega_3 = 1$	$\omega_1 = 0.25$, $\omega_2 = 0.40$, $\omega_3 = 0.35$ max z = **0.10933**	ω_1=0.2525, ω_2= 0.4446 $\omega_3 = 0.3030$ max z = **0.1143**	4.54%

Table-3.3

Objective	Optimal solution[11]	PSO method	Improvement of Result
Max z = $1.41*\omega_1+1.765*\omega_2+0.925*\omega_3$, Subject to $0.25 \le \omega_1 \le 0.75$ $0.35 \le \omega_2 \le 0.60$ $0.30 \le \omega_3 \le 0.35$ $\omega_1 + \omega_2 + \omega_3 = 1$	$\omega_1 = 0.25$, $\omega_2 = 0.40$, $\omega_3 = 0.35$ **max z = 1.38225**	ω_1=0.2525, ω_2= 0.4446 $\omega_3 = 0.3030$ **max z = 1.4210**	2.8%

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CONCLUSION

In this paper, PSO Algorithm is used for finding the optimal values of a decision making problem with less computation time. Simulation results are compared with the conventional methods. From the comparison, it was observed that the obtained optimal weights are better than that of conventional. Numerical results show the effectiveness of the proposed algorithm for solving optimization problem.

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