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A Direct Method to Solve Double Refined Indeterminate Triangular Neutrosophic Linear Programming Problem

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Abstract:

Double Refined Indeterminate Triangular Neutrosophic Number (DRITrNN) provides the additional possibility to represent with sensitivity and accuracy the uncertain, imprecise, incomplete and inconsistent information. In this article a Linear programming problem is considered in DRITrNN situation and an efficient novel algorithm is proposed to solve the LPP with variables in the form of DRITrNN and its efficiency is validated with Numerical illustration.

Keywords:

Single valued triangular neutrosophic number , Double Refined Indeterminate Triangular Neutrosophic Number , Linear Programming Problem, Algorithm.

1. Introduction

Triangular fuzzy number has diverse application in varied areas like decision-making [3,9,15], risk evaluation [8], performance evaluation [12], forecast [13], matrix games [6], k-dimensional space representation [17], collaborative filtering recommendation system [18] and ranking and evaluating information systems quality[14]. As an improvement of the fuzzy number, Intuitionistic fuzzy number was defined to suitably describe the vagueness and lack of precision of data. Mahapatra and Roy [10] evaluated system reliability by considering reliability of components as triangular intuitionistic fuzzy number.

Single valued triangular neutrosophic number (SVTrNN) is the generality of triangular fuzzy numbers and triangular intuitionistic fuzzy numbers. It is used to specify the information in a more flexible manner. Avishek Chakraborthy et.al; [2] defined different forms of linear, non-linear generalized triangular neutrosophic numbers that has great significance in uncertainty theory. He used it to solve imprecise project evaluation review technique and route selection problem. Deli.I and Subas.Y [4,5] developed hybrid geometric operator for single valued triangular neutrosophic number and solved multi criteria decision making problem. Abdel-Basset, M.et.al; [1] derived preference relations of triangular neutrosophic and used in the algorithm of group decision-making problem.

Smarandache Florentin et. al; [16] derived an algorithm for CPM whose parameters are vague and denoted by triangular neutrosophic numbers. Mehmet Sahin et.al; [11] defined single valued triangular neutrosophic number in general form and applied it for group decision making with multi attributes.

As an extension to provide the added opportunity to denote the inconsistent information with greater accuracy Gokilamani and Sahayasudha [7] proposed the definition of Double Refined Indeterminate Triangular Neutrosophic Number and used ranking method to solve the Linear programming Problem. In this article a novel algorithm is developed to solve the LPP with the variables in the form of DRITrNN.

2.Preliminaries

Definition:

A DRITrN number $\bar{\bar{A}}_{Nt} = \langle (a,b,c); p_{\bar{A}_{Nt}}, q_{\bar{A}_{Nt}}, r_{\bar{A}_{Nt}}, s_{\bar{A}_{Nt}} \rangle$ is a neutrosophic set on the real number set R, whose truth membership function $T_{\bar{A}_{Nt}}(x)$, indeterminacy leaning towards truth membership function $I_{F\bar{A}_{Nt}}(x)$, indeterminacy leaning towards falsity membership function $I_{F\bar{A}_{Nt}}(x)$ and falsity membership function $F_{\bar{A}_{Nt}}(x)$ are defined as follows:

$T_{\bar{A}_{Nt}}(x) = \begin{cases} \dfrac{(x-a)p_{\bar{A}_{Nt}}}{b-a} & a \le x < b \\ p_{\bar{A}_{Nt}} & x = b \\ \dfrac{(c-x)\,p_{\bar{A}_{Nt}}}{c-b} & b < x \le c \\ 0 & Otherwise \end{cases}$	$I_{F\bar{A}_{Nt}}(x) \begin{cases} \dfrac{b-x+r_{\bar{A}_{Nt}}(x-a)}{b-a} & a \le x < b \\ r_{\bar{A}_{Nt}} & x = b \\ \dfrac{x-b+r_{\bar{A}_{Nt}}(c-x)}{c-b} & b < x \le c \\ 1 & Otherwise \end{cases}$
$I_{T\bar{A}_{Nt}}(x) = \begin{cases} \dfrac{(x-a)q_{\bar{A}_{Nt}}}{b-a} & a \le x < b \\ q_{\bar{A}_{Nt}} & x = b \\ \dfrac{(c-x)\,q_{\bar{A}_{Nt}}}{c-b} & b < x \le c \\ 0 & Otherwise \end{cases}$	$F_{\bar{A}_{Nt}}(x) \begin{cases} \dfrac{b-x+s_{\bar{A}_{Nt}}(x-a)}{b-a} & a \le x < b \\ s_{\bar{A}_{Nt}} & x = b \\ \dfrac{x-b+s_{\bar{A}_{Nt}}(c-x)}{c-b} & b < x \le c \\ 1 & Otherwise \end{cases}$

3.Algorithm to Solve DRITrN LPP

An approach is framed with the assumption that the variable in LPP is in the form of double refined indeterminate triangular neutrosophic number and the algorithm is illustrated with numerical example.

3.1 Algorithm:

Consider the following Double refined indeterminate triangular neutrosophic linear programming with *m* constraints and *n* variables

(Maximize) or (Minimize) Z = $\sum_{j=1}^{n} C_j \, (\bar{\bar{x}}_{Nt})_j$

subject to,

$\sum_{j=1}^{n} a_{ij} \; (\bar{\bar{x}}_{Nt})_j \leq \; or \; = \; or \; \geq \; (\bar{\bar{b}}_{Nt})_j$, i=1,2…m

$(\bar{\bar{x}}_{Nt})_j \geq 0$, j=1,2…n

Let $\bar{\bar{b}}_{Nt}$= $\langle (\; b^l, \; b^m, \; b^r); \; p_{\bar{\bar{b}}_{Nt}}, q_{\bar{\bar{b}}_{Nt}}, r_{\bar{\bar{b}}_{Nt}}, s_{\bar{\bar{b}}_{Nt}} \rangle$ and

$\bar{\bar{x}}_{Nt}$= $\langle (\; {x_j}^l, \; {x_j}^m, \; {x_j}^r); \; p_{\bar{\bar{x}}_{Nt}}, q_{\bar{\bar{x}}_{Nt}}, r_{\bar{\bar{x}}_{Nt}}, s_{\bar{\bar{x}}_{Nt}} \rangle$

The following are the steps involved in solving DRITrN LPP.

Step1:

Consider the LPP

Maximize(Minimize) Z = $\sum_{j=1}^{n} c_j \; \langle (\; {x_j}^l, \; {x_j}^m, \; {x_j}^r); \; p_{\bar{\bar{x}}_{Nt}}, q_{\bar{\bar{x}}_{Nt}}, r_{\bar{\bar{x}}_{Nt}}, s_{\bar{\bar{x}}_{Nt}} \rangle$

subject to

$\sum_{j=1}^{n} (\bar{\bar{a}}_{Nt})_{ij} \; \langle (\; {x_j}^l, \; {x_j}^m, \; {x_j}^r); \; p_{\bar{\bar{x}}_{Nt}}, q_{\bar{\bar{x}}_{Nt}}, r_{\bar{\bar{x}}_{Nt}}, s_{\bar{\bar{x}}_{Nt}} \rangle \leq \langle (\; b^l, \; b^m, \; b^r); \; p_{\bar{\bar{b}}_{Nt}}, q_{\bar{\bar{b}}_{Nt}}, r_{\bar{\bar{b}}_{Nt}}, s_{\bar{\bar{b}}_{Nt}} \rangle \; \forall \, i$

$\langle (\; {x_j}^l, \; {x_j}^m, \; {x_j}^r); \; p_{\bar{\bar{x}}_{Nt}}, q_{\bar{\bar{x}}_{Nt}}, r_{\bar{\bar{x}}_{Nt}}, s_{\bar{\bar{x}}_{Nt}} \rangle \; \geq 0 \;\; \forall$ j

Step 2:

The LPP in step 1 can be transformed in to an LPP as ,

Maximize(Minimize) Z = $\langle (\; z^l, \; z^m, \; z^r); \; p, q, r, s \rangle$

subject to

$\langle (\; a^l, a^m, a^r); \; p, q, r, s \rangle \; \leq \langle (\; {b_i}^l, \; {b_i}^m, \; {b_i}^r); \; p_{\bar{\bar{b}}_{i_{Nt}}}, q_{\bar{\bar{b}}_{i_{Nt}}}, r_{\bar{\bar{b}}_{i_{Nt}}}, s_{\bar{\bar{b}}_{i_{Nt}}} \rangle \; \forall \, i$

$p \; \leq Mini \; (p_{\bar{\bar{b}}_{i_{Nt}}}) \;\; , \;\; q \; \leq Mini \; (q_{\bar{\bar{b}}_{i_{Nt}}}) \;\; , \; r \; \geq Maxi \; (r_{\bar{\bar{b}}_{i_{Nt}}}) \;\; , s \; \geq Maxi \; (s_{\bar{\bar{b}}_{i_{Nt}}})$

Where
$p = Mini \; \left(p_{\bar{\bar{x}}_{j_{Nt}}} \right), \;\; q = Mini(q_{\bar{\bar{x}}_{j_{Nt}}}) \;\; , \;\; r = Maxi \; (r_{\bar{\bar{x}}_{j_{Nt}}}) \;\; , \;\; s = Maxi \; (s_{\bar{\bar{x}}_{j_{Nt}}})$

Step 3:

LPP in step 2 can be transformed into an multi objective linear programming Problem

$Maximize(Minimize) z^l$,

$Maximize(Minimize) z^m$,

$Maximize(Minimize)z^r$,

$Maximize(Minimize)\sum_{j=1}^{n} p_{\bar{\bar{x}}_{j_{Nt}}}$,

$Maximize(Minimize)\sum_{j=1}^{n} q_{\bar{\bar{x}}_{j_{Nt}}}$,

$Minimize(Maximize)\sum_{j=1}^{n} r_{\bar{\bar{x}}_{j_{Nt}}}$,

$Minimize(Maximize)\sum_{j=1}^{n} s_{\bar{\bar{x}}_{j_{Nt}}}$,

subject to

$a^l \leq b_i^{\,l} \ \forall\, i$

$a^m \leq b_i^{\,m} \ \forall\, i$

$a^r \leq b_i^{\,r} \ \forall\, i$

$$\sum_{j=1}^{n} p_{\bar{\bar{x}}_{j_{Nt}}} \leq n\, Mini(p_{\bar{\bar{b}}_{i_{Nt}}})$$

$\sum_{j=1}^{n} q_{\bar{\bar{x}}_{j_{Nt}}} \leq n\, Mini\,(q_{\bar{\bar{b}}_{i_{Nt}}})$

$$\sum_{j=1}^{n} r_{\bar{\bar{x}}_{j_{Nt}}} \geq n\, Maxi\,(r_{\bar{\bar{b}}_{i_{Nt}}})$$

$$\sum_{j=1}^{n} s_{\bar{\bar{x}}_{j_{Nt}}} \geq n\, Maxi\,(s_{\bar{\bar{b}}_{i_{Nt}}})$$

$x_j^{\,l} \geq 0, \quad x_j^{\,m} - x_j^{\,l} \geq 0 \quad , \quad x_j^{\,r} - x_j^{\,m} \geq 0$

$p_{\bar{\bar{x}}_{j_{Nt}}} + q_{\bar{\bar{x}}_{j_{Nt}}} + r_{\bar{\bar{x}}_{j_{Nt}}} + s_{\bar{\bar{x}}_{j_{Nt}}} \leq 4$

$0 \leq p_{\bar{\bar{x}}_{j_{Nt}}} \leq 1, \quad 0 \leq q_{\bar{\bar{x}}_{j_{Nt}}} \leq 1, \quad 0 \leq r_{\bar{\bar{x}}_{j_{Nt}}} \leq 1, \quad 0 \leq s_{\bar{\bar{x}}_{j_{Nt}}} \leq 1$

$p_{\bar{\bar{x}}_{j_{Nt}}} \geq s_{\bar{\bar{x}}_{j_{Nt}}}, \quad p_{\bar{\bar{x}}_{j_{Nt}}} \geq r_{\bar{\bar{x}}_{j_{Nt}}} \quad , \quad p_{\bar{\bar{x}}_{j_{Nt}}} \geq q_{\bar{\bar{x}}_{j_{Nt}}}$

Step 4:
Combining all the objective function in to a single objective function the LPP can be represented as

$$Maximize(Minimize)w = z^l + z^m + z^r + \sum_{j=1}^{n} p_{\bar{\bar{x}}_{j_{Nt}}} + \sum_{j=1}^{n} q_{\bar{\bar{x}}_{j_{Nt}}} - \sum_{j=1}^{n} r_{\bar{\bar{x}}_{j_{Nt}}} - \sum_{j=1}^{n} s_{\bar{\bar{x}}_{j_{Nt}}}$$

subject to

$a^l \leq b_i^{\,l} \ \forall\, i$

$a^m \leq b_i^{\,m} \ \forall\, i$

$a^r \leq b_i^r \ \forall i$

$$\sum_{j=1}^{n} p_{\bar{\bar{x}}_{j_{Nt}}} \leq n\, Mini(p_{\bar{\bar{b}}_{i_{Nt}}})$$

$$\sum_{j=1}^{n} q_{\bar{\bar{x}}_{j_{Nt}}} \leq n\, Mini\,(q_{\bar{\bar{b}}_{i_{Nt}}})$$

$$\sum_{j=1}^{n} r_{\bar{\bar{x}}_{j_{Nt}}} \geq n\, Maxi\,(r_{\bar{\bar{b}}_{i_{Nt}}})$$

$$\sum_{j=1}^{n} s_{\bar{\bar{x}}_{j_{Nt}}} \geq n\, Maxi\,(s_{\bar{\bar{b}}_{i_{Nt}}})$$

$x_j^l \geq 0, \quad x_j^m - x_j^l \geq 0 \ , \ x_j^r - x_j^m \geq 0$

$p_{\bar{\bar{x}}_{j_{Nt}}} + q_{\bar{\bar{x}}_{j_{Nt}}} + r_{\bar{\bar{x}}_{j_{Nt}}} + s_{\bar{\bar{x}}_{j_{Nt}}} \leq 4$

$0 \leq p_{\bar{\bar{x}}_{j_{Nt}}} \leq 1, \quad 0 \leq q_{\bar{\bar{x}}_{j_{Nt}}} \leq 1, \quad 0 \leq r_{\bar{\bar{x}}_{j_{Nt}}} \leq 1, \quad 0 \leq s_{\bar{\bar{x}}_{j_{Nt}}} \leq 1$

$p_{\bar{\bar{x}}_{j_{Nt}}} \geq s_{\bar{\bar{x}}_{j_{Nt}}}, \quad p_{\bar{\bar{x}}_{j_{Nt}}} \geq r_{\bar{\bar{x}}_{j_{Nt}}}, \quad p_{\bar{\bar{x}}_{j_{Nt}}} \geq q_{\bar{\bar{x}}_{j_{Nt}}}$

Step 5:

Find the optimal solution $\bar{\bar{x}}_{Nt}$ of LPP in step 4 by using TORA software and then find the neutrosophic optimal value. The obtained solution are in the form of DRITrNN.

3.2 Numerical Illustration:

Maximize Z = 5 $\bar{\bar{x}}_{1_{Nt}}$ + 4 $\bar{\bar{x}}_{2_{Nt}}$

subject to

6 $\bar{\bar{x}}_{1_{Nt}}$ + 4 $\bar{\bar{x}}_{2_{Nt}}$ $\leq <(3,5,6); 0.6,0.3,0.2,0.2>$

$\bar{\bar{x}}_{1_{Nt}}$ + 2 $\bar{\bar{x}}_{2_{Nt}}$ $\leq <(5,8,10); 0.7,0.4,0.3,0.1>$

$\bar{\bar{x}}_{1_{Nt}}$ + $\bar{\bar{x}}_{2_{Nt}}$ $\leq <(12,15,19); 0.6,0.2,0.1,0.2>$

$\bar{\bar{x}}_{2_{Nt}} \leq <(14,17,21); 0.8,0.3,0.2,0.1>$

$\bar{\bar{x}}_{1_{Nt}}, \bar{\bar{x}}_{2_{Nt}} \geq 0$

Solution:

Considering $\bar{\bar{x}}_{1_{Nt}} = \langle (x_1^l, x_1^m, x_1^r);\ p_{\bar{\bar{x}}_{1_{Nt}}}, q_{\bar{\bar{x}}_{1_{Nt}}}, r_{\bar{\bar{x}}_{1_{Nt}}}, s_{\bar{\bar{x}}_{1_{Nt}}} \rangle$ and

$\bar{\bar{x}}_{2Nt} = \langle (x_2{}^l, x_2{}^m, x_2{}^r); p_{\bar{\bar{x}}_{2Nt}}, q_{\bar{\bar{x}}_{2Nt}}, r_{\bar{\bar{x}}_{2Nt}}, s_{\bar{\bar{x}}_{2Nt}} \rangle$ the LPP can be transformed in to an LPP as

$$\text{Maximize } Z = \begin{cases} 5 \langle (x_1{}^l, x_1{}^m, x_1{}^r); p_{\bar{\bar{x}}_{1Nt}}, q_{\bar{\bar{x}}_{1Nt}}, r_{\bar{\bar{x}}_{1Nt}}, s_{\bar{\bar{x}}_{1Nt}} \rangle + \\ 4 \langle (x_2{}^l, x_2{}^m, x_2{}^r); p_{\bar{\bar{x}}_{2Nt}}, q_{\bar{\bar{x}}_{2Nt}}, r_{\bar{\bar{x}}_{2Nt}}, s_{\bar{\bar{x}}_{2Nt}} \rangle \end{cases}$$

subject to

$6 \langle (x_1{}^l, x_1{}^m, x_1{}^r); p_{\bar{\bar{x}}_{1Nt}}, q_{\bar{\bar{x}}_{1Nt}}, r_{\bar{\bar{x}}_{1Nt}}, s_{\bar{\bar{x}}_{1Nt}} \rangle +$
$4 \langle (x_2{}^l, x_2{}^m, x_2{}^r); p_{\bar{\bar{x}}_{2Nt}}, q_{\bar{\bar{x}}_{2Nt}}, r_{\bar{\bar{x}}_{2Nt}}, s_{\bar{\bar{x}}_{2Nt}} \rangle \leq < (3,5,6); 0.6,0.3,0.2,0.2 >$

$\langle (x_1{}^l, x_1{}^m, x_1{}^r); p_{\bar{\bar{x}}_{1Nt}}, q_{\bar{\bar{x}}_{1Nt}}, r_{\bar{\bar{x}}_{1Nt}}, s_{\bar{\bar{x}}_{1Nt}} \rangle +$
$2 \langle (x_2{}^l, x_2{}^m, x_2{}^r); p_{\bar{\bar{x}}_{2Nt}}, q_{\bar{\bar{x}}_{2Nt}}, r_{\bar{\bar{x}}_{2Nt}}, s_{\bar{\bar{x}}_{2Nt}} \rangle \leq < (5,8,10); 0.7,0.4,0.3,0.1 >$

$\langle (x_1{}^l, x_1{}^m, x_1{}^r); p_{\bar{\bar{x}}_{1Nt}}, q_{\bar{\bar{x}}_{1Nt}}, r_{\bar{\bar{x}}_{1Nt}}, s_{\bar{\bar{x}}_{1Nt}} \rangle + \langle (x_2{}^l, x_2{}^m, x_2{}^r); p_{\bar{\bar{x}}_{2Nt}}, q_{\bar{\bar{x}}_{2Nt}}, r_{\bar{\bar{x}}_{2Nt}}, s_{\bar{\bar{x}}_{2Nt}} \rangle \leq <$
$(12,15,19); 0.6,0.2,0.1,0.2 >$

$\langle (x_2{}^l, x_2{}^m, x_2{}^r); p_{\bar{\bar{x}}_{2Nt}}, q_{\bar{\bar{x}}_{2Nt}}, r_{\bar{\bar{x}}_{2Nt}}, s_{\bar{\bar{x}}_{2Nt}} \rangle \leq < (14,17,21); 0.8,0.3,0.2,0.1 >$

$\langle (x_j{}^l, x_j{}^m, x_j{}^r); p_{\bar{\bar{x}}_{j_{Nt}}}, q_{\bar{\bar{x}}_{j_{Nt}}}, r_{\bar{\bar{x}}_{j_{Nt}}}, s_{\bar{\bar{x}}_{j_{Nt}}} \rangle \geq 0 \;\; \forall$ j

Using the proposed method the above LPP can be converted as

Maximize $Z = 5x_1{}^l + 4\, x_2{}^l + 5\, x_1{}^m + 4\, x_2{}^m + 5\, x_1{}^r + 4\, x_2{}^r + \; p_{\bar{\bar{x}}_{1Nt}} + p_{\bar{\bar{x}}_{2Nt}} + q_{\bar{\bar{x}}_{1Nt}} + q_{\bar{\bar{x}}_{2Nt}} - r_{\bar{\bar{x}}_{1Nt}} - r_{\bar{\bar{x}}_{2Nt}} - s_{\bar{\bar{x}}_{1Nt}} - s_{\bar{\bar{x}}_{2Nt}}$

subject to

$6x_1{}^l + 4\, x_2{}^l \leq 3, \quad x_1{}^l + 2\, x_2{}^l \leq 5, \quad x_1{}^l + x_2{}^l \leq 12, x_2{}^l \leq 14$

$6x_1{}^m + 4\, x_2{}^m \leq 5, \quad x_1{}^m + 2\, x_2{}^m \leq 8, \quad x_1{}^m + x_2{}^m \leq 15, x_2{}^m \leq 17$

$6x_1{}^r + 4\, x_2{}^r \leq 6, \quad x_1{}^r + 2\, x_2{}^r \leq 10, \quad x_1{}^r + x_2{}^r \leq 19, x_2{}^r \leq 21$

$p_{\bar{\bar{x}}_{1Nt}} + p_{\bar{\bar{x}}_{2Nt}} \leq 1.2, \quad q_{\bar{\bar{x}}_{1Nt}} + q_{\bar{\bar{x}}_{2Nt}} \leq 0.4, r_{\bar{\bar{x}}_{1Nt}} + r_{\bar{\bar{x}}_{2Nt}} \geq 0.6, s_{\bar{\bar{x}}_{1Nt}} + s_{\bar{\bar{x}}_{2Nt}} \geq 0.4$

$x_j{}^l \geq 0, \quad x_j{}^m - x_j{}^l \geq 0 \quad , \quad x_j{}^r - x_j{}^m \geq 0$ for j=1,2

$p_{\bar{\bar{x}}_{j_{Nt}}} + q_{\bar{\bar{x}}_{j_{Nt}}} + r_{\bar{\bar{x}}_{j_{Nt}}} + s_{\bar{\bar{x}}_{j_{Nt}}} \leq 4$ for j=1,2

$0 \leq p_{\bar{\bar{x}}_{j_{Nt}}} \leq 1, \quad 0 \leq q_{\bar{\bar{x}}_{j_{Nt}}} \leq 1, \quad 0 \leq r_{\bar{\bar{x}}_{j_{Nt}}} \leq 1, \quad 0 \leq s_{\bar{\bar{x}}_{j_{Nt}}} \leq 1$ for j=1,2

$p_{\bar{\bar{x}}_{j_{Nt}}} \geq s_{\bar{\bar{x}}_{j_{Nt}}}, \quad p_{\bar{\bar{x}}_{j_{Nt}}} \geq r_{\bar{\bar{x}}_{j_{Nt}}}, \quad p_{\bar{\bar{x}}_{j_{Nt}}} \geq q_{\bar{\bar{x}}_{j_{Nt}}}$ for j=1,2

The optimal solution is obtained using TORA,

$\bar{\bar{x}}_{1Nt} = < (0, 0, 0); 1, 0.2, 0.4, 0.2 >$

$\bar{\bar{x}}_{2_{Nt}} = < (0.75, 1.25, 1.5); 0.2, 0.2, 0.2, 0.2 >$

4. Conclusion

In this paper a new algorithm is developed to solve Linear Programming Problem with variables in the form Double Refined Indeterminate Triangular Neutrosphic number .This direct approach is used to solve the LPP effectively. The efficacy of the approach is verified by implementing it to a numerical example.

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