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SOLVING FUZZY LINEAR PROGRAMMING PROBLEM USING A FUZZY LOGARITHMIC BARRIER METHOD

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Abstract

In this paper, we focus a fuzzy logarithmic barrier function for solving a fuzzy linear programming problem. An algorithm the method gives a better rate of convergence to achieve the fuzzy optimal solution to the problem. Some numerical examples are included to exhibit the efficiency of the new algorithmic procedure.

1. Introduction

The fuzzy set theory has been useful to control theory and management sciences, mathematical modelling. A decision-making problems are often uncertain (or) vague in some ways to apply real-world. In 1965, Zadeh fuzzy set theory was introduced while the concept of fuzzy linear programming problem at the general level is first proposed by Tanaka and Asai [17]. D. Dubois and H. Prade [2] introduced the notion of fuzzy numbers. The function principle was introduced by Hsieh and Chen [9] to treat fuzzy arithmetical operations. This principle is used for the operation of addition, multiplication, subtraction, and division of fuzzy numbers we describe fuzzy basic solution

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(FBFS) for the FLP problems which established by [10] and [11], Mahdavi-Amiri and Nasseri for the FVLP problem and also describe the duality of the fuzzy linear programming problems. Defuzzification is the process of transforming fuzzy values to crisp values. Defuzzification methods have been widely studied for some years and are applied to fuzzy systems. The principal idea behind these methods was to obtain a typical value from a given set according to some specified characters. Defuzzification method provides a correspondence from the set of all fuzzy sets into the set of all real numbers. The Logarithmic barrier function method was introduced by Frisch [5] and then developed by Fiacco [3] and Mc Cormick [4]. Wright [18], and Parwardi et al [14] give high cost to infeasible points. The Fuzzy Logarithmic Barrier method is an alternative class of algorithms for fuzzy constrained optimization. The Fuzzy Logarithmic Barrier method is an alternative method to solve the fuzzy linear programming problem. In fact, the Fuzzy Logarithmic Barrier method is a procedure for approximating fuzzy constrained problems by adding the fuzzy objective function a term that prescribes a high cost for violation of the fuzzy constraints. A continuous fuzzy barrier function whose point value increases to infinity as the point approaches the boundary of the feasible region of the fuzzy optimization problem. Associated with this method is a positive decreasing parameter σ or η that determines the fuzzy barrier; consequently, the extent to which the fuzzy unconstrained problem approaches the original fuzzy constrained problems.

In this paper, section 2, we give some basic concepts of fuzzy set theory and fuzzy linear programming problem. In section 3, we develop a fuzzy linear programming problem using the fuzzy logarithmic barrier method and an algorithm. In section 4, a numerical example is included.

2. Preliminaries

2.1. Fuzzy Sets

A fuzzy set A is defined by $\tilde{A} = \{(x, \mu_A(x)) : x \in A, \mu_A(x) \in [0, 1]\}$. A pair $(x, \mu_A(x))$, the first element x belongs to the classical set A, and the second element $\mu_A(x)$ belongs to the interval [0, 1], called the membership function.

A fuzzy set can also be denoted by $\tilde{A} = \{\mu_A(x)/x : x \in A, \mu_A(x) \in [0, 1]\}$. Here the symbol '/' does not represent the division sign. It indicates that the top number $\mu_A(x)$ is the membership value of the element *x* on the bottom.

2.2. Fuzzy Number

2.2.1. Generalized Fuzzy Number

Any fuzzy subset of the real line *R*, whose membership function satisfies the following conditions, is a generalised fuzzy number

i. $\mu_{\tilde{A}}(x)$ is a continuous. A mapping from *R* to [0, 1],

ii. $\mu_{\tilde{A}}(x) = 0, -\infty < x \le a_1$,

iii. $\mu_{\tilde{A}}(x) = L(x)$ is strictly increasing on $[a_1, a_2]$,

iv. $\mu_{\tilde{A}}(x) = 1, a_2 \le x \le a_3$,

v. $\mu_{\tilde{A}}(x) = R(x)$ is strictly decreasing on $[a_3, a_4]$,

vi. $\mu_{\tilde{A}}(x) = 0, a_4 \le x < \infty$,

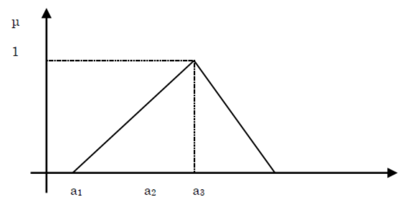
where a_1, a_2, a_3, a_4 are real numbers.

There are different fuzzy numbers. In the present research, the researchers and have confined themselves only to the triangular fuzzy number and the trapezoidal fuzzy number.

2.3. Triangular Fuzzy Number

The fuzzy set $\tilde{A} = (a_1, a_2, a_3)$ where $a_1 \le a_2 \le a_3$ and defined on *R*, is called the triangular fuzzy number if the membership function of $\tilde{A}$ is given by

$$\mu_{\tilde{A}}(x) = \begin{cases} \dfrac{x - a_1}{a_2 - a_1}, & a_1 \le x \le a_2 \\ \dfrac{a_3 - x}{a_3 - a_2}, & a_2 \le x \le a_3 \\ 0, & \text{otherwise} \end{cases}$$



Triangular fuzzy number $\tilde{A} = (a_1, a_2, a_3)$.

2.4. Fuzzy Linear Programming Problem

Consider the following fuzzy linear programming problem:

Maximum (or Minimum) $\tilde{Z} = \tilde{c}x_i$.

Constraints of the form

$$Ax_i (\leq, =, \geq) \tilde{b}_j, \qquad j = 1, 2, \ldots, m$$

and the nonnegative conditions of the fuzzy variables $\tilde{x} \geq (0, 0, 0)$ where $\tilde{c}^T = (\tilde{c}_1, \ldots, \tilde{c}_n)$ is an n-dimensional constant vector, $A \in R^{m \times n}$, $\tilde{x} = (\tilde{x}_i)$, $i = 1, 2, \ldots, n$ and $\tilde{b}_j$ are non-negative fuzzy variable vectors such that $\tilde{x}_i$ and $\tilde{b}_j \in F(R)$ for all $1 \leq i \leq n, 1 \leq j \leq m$, is called a fuzzy linear programming (FLP) problem.

2.5. Feasible solution: We say that vector $\tilde{x} \in F(R)^n$ is a feasible solution if and only if $\tilde{x}$ satisfies the constraints of the problem.

2.6. Optimal Solution: A feasible solution $\tilde{x}^*$ is an optimal solution if for all feasible solution $\tilde{x}$, we have $\tilde{c}\tilde{x}^* \geq \tilde{c}\tilde{x}$.

2.7. Fuzzy basic feasible solution: Here, we describe fuzzy basic solution (FBFS) for the FLP problems which established by Mahdavi-Amiri and Nasseri [17] for the fuzzy variable linear programming problem (FVLP). Consider the system $A\tilde{x} = \tilde{b}$ and $\tilde{x} \geq \tilde{0}$. Let $A = [a_{ij}]_{m \times n}$. Assume that $rank\ (A) = m$. Partition A as $[B, N]$ where B is nonsingular. It is evident that rank $(\tilde{L}) = m$. Let y_j be the solution to $B_y = a_j$. It is apparent that the basic solution $\tilde{x}_L = (\tilde{x}_{L_1}, \tilde{x}_{L_2}, \ldots, \tilde{x}_{L_m})^T = L^{-1}\tilde{b}, \tilde{x}_N = 0$ is a solution of $A\tilde{x} = \tilde{b}$. We call $\tilde{x}$, accordingly partitioned as $(\tilde{x}_L^T\ \tilde{x}_N^T)^T$, a fuzzy basic solution corresponding to the basis B. If $\tilde{x}_L \geq \tilde{0}$, then the fuzzy basic solution is feasible, and the corresponding fuzzy objective value is $\tilde{z} = \tilde{c}_L, \tilde{x}_L$, where $\tilde{c}_L = (\tilde{c}_{L_1}, \ldots, \tilde{c}_{L_m})$. Now corresponding to every fuzzy non-basic variable $\tilde{x}_j, 1 \leq j \leq n, j \neq L_i$, and $i = 1, \ldots, m$, define $z_j = c_L y_j = c_L L^{-1} a_j)$. If $\tilde{x}_L > \tilde{0}$, then $\tilde{x}$ is called non-degenerate fuzzy basic feasible solution.

3. Fuzzy Logarithmic Barrier Method

Consider the primal Fuzzy linear programming problem

Minimize $\tilde{Z} = \tilde{f}(\tilde{x})$

Subject to $M_i\tilde{x} \geq \tilde{N}_i, i = 1, 2$.

where

$$M \in R^{m \times n}, \tilde{f}, x \in R^n, \tilde{N} \in R^m, \tilde{f} = (f_1, f_2, f_3), \tilde{N} = (n_1, n_2, n_3). \tag{1}$$

Consider the dual fuzzy linear programming problem

Maximize $\tilde{Z} = \tilde{N}_j(\tilde{y})$

$M_j(\tilde{y}) \leq \tilde{f}(\tilde{y}), j = 1, 2$. Where M_j and $\tilde{N}_j$ the fuzzy transpose of matrices M and N respectively.

Without loss of generality, assume that M has full rank m. The notation ~ denotes the fuzzy quantity described a triangular fuzzy number.

Assume that the problem (1) has at least one feasible solution.

For any scalar, $\eta > 0$ we define the fuzzy logarithmic barrier function $\tilde{L}(x, \eta)$ for the fuzzy linear programming problem.

Define $\tilde{L}(\tilde{x}, \eta) : R^n \to R$ by the fuzzy logarithmic barrier function

$$\tilde{L}(\tilde{x}, \eta) = \tilde{f}(\tilde{x}) - \frac{1}{\eta}\sum_{i=1}^{m} \log(-(M_i\tilde{x} - \tilde{N}_i)). \quad (2)$$

Where M_i and $\tilde{N}_i$ the i^{th} row of fuzzy matrices M and N respectively.

The Fuzzy Logarithmic Barrier function (2) is convex. Hence $\tilde{L}(\tilde{x}, \eta)$ is a global minimum and η is a positive decreasing value of the fuzzy logarithmic barrier parameter.

Define the function $\tilde{L} : R^n \to (-\infty, \infty)$ by

$$\tilde{L}(\tilde{x}) = M_i\tilde{x} - \tilde{N}_i \leq 0, \text{ if } M_i\tilde{x} - \tilde{N}_i = 0 \text{ for all } i,$$

$$\tilde{L}(\tilde{x}) = M_i\tilde{x} - \tilde{N}_i > 0, \text{ if } M_i\tilde{x} - \tilde{N}_i \neq 0 \text{ for all } i.$$

Convert the fuzzy equation into two weak fuzzy inequalities.

A fuzzy logarithmic barrier function defined the interior of the boundary region, such that

(i) $\tilde{L}$ is continuous.

(ii) $\tilde{L}(\tilde{x}) \geq 0$.

(iii) $\tilde{L}(\tilde{x}) \to \infty$ as x approaches the boundary of the set.

The Fuzzy Logarithmic Barrier function with fuzzy linear programming problem is given by

$$\tilde{L}(\tilde{x}, \eta) = \tilde{f}(\tilde{x}) - \frac{1}{\eta}\sum_{i=1}^{m} \log(-(M_i\tilde{x}^k - \tilde{N}_i)).$$

Where $\tilde{g}(\tilde{x}) = (M_i\tilde{x}^k - \tilde{N}_i)$, η is a positive decreasing parameter.

Fuzzy Logarithmic barrier methods are also they called as fuzzy interior methods.

3.1. Fuzzy Logarithmic Barrier Lemma

(i) $\tilde{L}(\tilde{x}^k, \eta^k) \geq \tilde{L}(\tilde{x}^{k+1}, \eta^{k+1})$

(ii) $\tilde{L}(\tilde{x}^k) \leq \tilde{L}(\tilde{x}^{k+1})$

(iii) $\tilde{f}(\tilde{x}^k) \geq \tilde{f}(\tilde{x}^{k+1})$

(iv) $\tilde{f}(\tilde{x}^*) \leq \tilde{f}(\tilde{x}^k) \leq \tilde{L}(\tilde{x}^k, \eta^k)$.

Proof.

(i).

$$\tilde{L}(\tilde{x}^k, \eta^k) = \tilde{f}(\tilde{x}^k) - \frac{1}{\eta^k}\sum_{i=1}^{m} \log\ (-(M_i(\tilde{x}^k - \tilde{N}_i)) \geq \tilde{f}(\tilde{x}^k) - \frac{1}{\eta^{k+1}}(-(M_i(\tilde{x}^k - \tilde{N}_i))$$

$$\geq \tilde{f}(\tilde{x}^{k+1}) - \frac{1}{\eta^{k+1}}\sum_{i=1}^{m} \log\ (-(M_i(\tilde{x}^{k+1} - \tilde{N}_i)) = \tilde{L}(\tilde{x}^{k+1}, \eta^{k+1}).$$

$$\tilde{L}(\tilde{x}^k, \eta^k) \geq \tilde{L}(\tilde{x}^{k+1}, \eta^{k+1}).$$

(ii)

$$\tilde{f}(\tilde{x}^k) - \frac{1}{\eta^k}\sum_{i=1}^{m} \log\ (-M_i(\tilde{x}^k - \tilde{N}_i)) \leq \tilde{f}(\tilde{x}^{k+1}) - \frac{1}{\eta^k}\sum_{i=1}^{m} \log\ (-(M_i(\tilde{x}^{k+1} - \tilde{N}_i)) \quad (4)$$

$$\tilde{f}(\tilde{x}^{k+1}) - \frac{1}{\eta^{k+1}}\sum_{i=1}^{m} \log\ (-(M_i\tilde{x}^{k+1} - \tilde{N}_i)) \leq \tilde{f}(\tilde{x}^k) - \frac{1}{\eta^{k+1}}$$

$$\sum_{i=1}^{m} \log\ (-(M_i\tilde{x}^k - \tilde{N}_i)) \quad (5)$$

Adding the fuzzy equations (4) and (5), we get

$$\tilde{f}(\tilde{x}^k) - \frac{1}{\eta^k}\sum_{i=1}^{m} \log\ (-(M_i\tilde{x}^k - \tilde{N}_i)) + \tilde{f}(\tilde{x}^{k+1}) - \frac{1}{\eta^{k+1}}\sum_{i=1}^{m} \log\ (-(M_i(\tilde{x}^{k+1} - \tilde{N}_i))$$

$$\leq \tilde{f}(\tilde{x}^{k+1}) - \frac{1}{\eta^k}\sum_{i=1}^{m} \log\ (-(M_i\tilde{x}^{k+1} - \tilde{N}_i)) + \tilde{f}(\tilde{x}^k) - \frac{1}{\eta^{k+1}}\sum_{i=1}^{m} \log\ (-(M_i\tilde{x}^k - \tilde{N}_i)).$$

$$(\tilde{f}(\tilde{x}^k) + \tilde{f}(\tilde{x}^{k+1})) - (\tilde{f}(\tilde{x}^{k+1}) + \tilde{f}(\tilde{x}^k))$$

$$-\left(\frac{1}{\eta^k}\sum_{i=1}^{m}\log(-(M_i\tilde{x}^k-\tilde{N}_i))+\frac{1}{\eta^{k+1}}\sum_{i=1}^{m}(-(M_i\tilde{x}^k-\tilde{N}_i))\right)$$

$$\le -\frac{1}{\eta^k}\sum_{i=1}^{m}\log(-(M_i\tilde{x}^{k+1}-\tilde{N}_i))+\frac{1}{\eta^{k+1}}\sum_{i=1}^{m}\log(-(M_i\tilde{x}^{k+1}-\tilde{N}_i)).$$

But $(\tilde{f}(\tilde{x}^k)+\tilde{f}(\tilde{x}^{k+1}))-(\tilde{f}(\tilde{x}^{k+1})+\tilde{f}(\tilde{x}^k))=0.$

Then

$$\left(\frac{1}{\eta^k}-\frac{1}{\eta^{k+1}}\right)\sum_{i=1}^{m}\log(-(M_i(\tilde{x}^k-\tilde{N}_i))\le\left(\frac{1}{\eta^k}-\frac{1}{\eta^{k+1}}\right)\sum_{i=1}^{m}\log(-(M_i(\tilde{x}^{k+1}-\tilde{N}_i)).$$

Since $\eta^k\le\eta^{k+1}$, $\tilde{L}(\tilde{x}^k)\le\tilde{L}(\tilde{x}^{k+1})$.

(iii) From the proof of (i)

$$\tilde{f}(\tilde{x}^k)-\frac{1}{\eta^{k+1}}\sum_{i=1}^{m}\log(-(M_i\tilde{x}^k-\tilde{N}_i))\ge\tilde{f}(\tilde{x}^{k+1})-\frac{1}{\eta^{k+1}}\sum_{i=1}^{m}\log(-(M_i\tilde{x}^{k+1}-\tilde{N}_i)).$$

$\tilde{L}(\tilde{x}^k)\le\tilde{L}(\tilde{x}^{k+1})$. Then $\tilde{f}(\tilde{x}^k)\ge\tilde{f}(\tilde{x}^{k+1})$.

(iv). From the proof of (ii)

$$\sum_{i=1}^{m}\log(-(M_i\tilde{x}^k-\tilde{N}_i))\le\sum_{i=1}^{m}\log(-(M_i\tilde{x}^{k+1}-\tilde{N}_i)),\ \tilde{f}(\tilde{x}^k)\ge\tilde{f}(\tilde{x}^{k+1}).$$

$$\tilde{f}(\tilde{x}^*)\le\tilde{f}(\tilde{x}^k)\le\tilde{f}(\tilde{x}^k)-\frac{1}{\eta^k}\sum_{i=1}^{m}\log(-(M_i\tilde{x}^k-\tilde{N}_i))=\tilde{L}(\tilde{x}^k,\eta^k).$$

3.2. Fuzzy Logarithmic Barrier Convergence Theorem

A fuzzy linear programming problem an increasing sequence of positive fuzzy Logarithmic barrier parameter $\{\eta^k\}$ such that $\eta^k\ge 1$, $\eta^k\to\infty$, $k\to\infty$. Suppose $\tilde{f}(x)$, $M_i\tilde{x}-\tilde{N}_i$ and $\tilde{L}(\tilde{x})$ is a continuous function an optimal solution exists x^* of $\tilde{Z}$. $N(\in, x^*)\cap\{x : M_i\tilde{x}-\tilde{N}_i<0\}\ne\varnothing$, for every $\varepsilon>0$. Then any limit point of $\tilde{x}$ of $\{\tilde{x}^k\}$.

Proof. Let $\tilde{x}$ be any limit point of $\{\tilde{x}^k\}$.

$$\tilde{L}(\tilde{x}^k, \eta^k) = \tilde{f}(\tilde{x}) - \frac{1}{\eta^k}\sum_{i=1}^{m} \log(-(M_i\tilde{x}^k - \tilde{N}_i)) \geq f(\tilde{x}^*). \quad (6)$$

From the continuity of $\tilde{f}(\tilde{x}) - M_i\tilde{x}^k - \tilde{N}_i$, we get,

$$\lim_{k \to \infty} \tilde{f}(\tilde{x}^k) = \tilde{f}(\tilde{x}), \lim_{k \to \infty} \log(-(M_i\tilde{x}^k - \tilde{N}_i)) \leq 0$$

From the fuzzy logarithmic barrier lemma (iv) we get,

$$\lim_{k \to \infty} \tilde{L}(\tilde{x}^k, \eta^k) = \tilde{f}(x^*)$$

$\tilde{x}$ is feasible.

3.3. Algorithm

1. Identify the fuzzy objective function, constraints of the problem and rewrite in standard forms. Write Min $\tilde{Z} = \tilde{f}(\tilde{x})$. Subject to $(M_i\tilde{x}^k - \tilde{N}_i) \leq 0$.

2. Convert fuzzy log barrier function defined $\tilde{L}(\tilde{x}, \eta) = \tilde{f}(\tilde{x}) - \frac{1}{\eta}\sum_{i=1}^{m} \log(-(M_i\tilde{x}^k - \tilde{N}_i))$. Log of a number is always positive.

3. Log Barrier functions is a smooth approximation of the indicator function. Given a problem with inequality constraints to Minimize

$$Min \ \tilde{L}(\tilde{x}, \eta) = \tilde{f}(\tilde{x}) - \frac{1}{\eta}\sum_{i=1}^{m} \log(-(M_i\tilde{x}^k - \tilde{N}_i)).$$

As $\eta \to \infty$, the approximation becomes closer to the indicator function.

4. Applying the first-order necessary condition for optimality, taking the limit $\eta \to \infty$ we get the optimal value of the given fuzzy linear programming problem.

5. Compute $\tilde{L}(\tilde{x}^k, \eta^k) = \min_{x \geq 0} \tilde{L}(\tilde{x}, \eta^k)$, then minimize $\tilde{x}^k$ and $\eta = 10$, $k = 1, 2, \ldots, k = I$ then stop.

Otherwise, go to step 5.

The above algorithm to apply the same procedure of Dual Fuzzy linear programming problem in fuzzy logarithmic barrier method.

4. Numerical Example

Problem 1. Consider the primal fuzzy linear programming problem

$$Min \ \tilde{z} = (3.75, 4, 4.25)\tilde{x}_1 + (2.75, 3, 3.25)\tilde{x}_2 \ 2\tilde{x}_1 + 3\tilde{x}_2 \geq (5.75, 6, 6.25),$$

$$4\tilde{x}_1 + \tilde{x}_2 \geq (3.75, 4, 4.25).$$

Solution:

The Logarithmic barrier function defined by

$$\tilde{L}(\tilde{x}) = -\log(2\tilde{x}_1 + 3\tilde{x}_2 - (5.75, 6, 6.25)) - \log(4\tilde{x}_1 + \tilde{x}_2 - (3.75, 4, 4.25)).$$

The Fuzzy linear programming problem can be changed into the standard form of unconstrained problems

$$Min \ \tilde{L}(\tilde{x}, \eta) = (3.75, 4, 4.25)\tilde{x}_1 + (2.75, 3, 3.25)$$

$$\tilde{x}_2 - \frac{1}{\eta}\log(2\tilde{x}_1 + 3\tilde{x}_2 - (5.75, 6, 6.25)) - \frac{1}{\eta}\log(4\tilde{x}_1 + \tilde{x}_2 - (3.75, 4, 4.25)).$$

Applying the first-order necessary condition we get,

$$\tilde{x}_1 = \frac{1}{\eta}(-3.50, 0.76, 8.53) + (0.25, 0.60, 0.95),$$

$$\tilde{x}_2 = \frac{1}{\eta}(-1.66, 0.16, 1.34) + (1.45, 1.60, 1.75).$$

Taking the limit $\eta \to \infty$ we get, the optimal value of the given primal fuzzy linear programming problem. $\tilde{x}_1 = (0.25, 0.60, 0.95)$, $\tilde{x}_2 = (1.45, 1.60, 1.75)$.

Table 1

No.	η^k	$\tilde{x}_1$	$\tilde{x}_2$
1	10	(-0.10,0.68,1.80)	(1.28,1.62,1.88)

2	10^2	(0.22,0.61,1.04)	(1.43,1.60,1.76)
3	10^3	(0.25,0.60,0.96)	(1.45,1.60,1.75)
4	10^4	(0.25,0.60,0.95)	(1.45,1.60,1.75)

The optimal value of the given primal fuzzy linear programming problem Min $\tilde{z} = (4.93, 7.20, 9.73)$.

Dual of the fuzzy linear programming problem solutions are

$$\tilde{y}_1 = \frac{1}{\eta}(-0.14, 0.08, 0.48) + (0.68, 0.80, 0.93),\ \tilde{y}_2 = \frac{1}{\eta}(0.69, 0.38, 0.01)$$

$$+(0.47, 0.6, 0.72).$$

Dual fuzzy linear programming problem of the optimal values are $\tilde{y}_1 = (0.68, 0.80, 0.93)$, $\tilde{y}_2 = (0.47, 0.6, 0.72)$.

When we look at the few iterations of the optimal of the problems are given as follows: The table below shows the value of $\tilde{y}_1(\eta)$ and $\tilde{y}_2(\eta)$ for a sequence of parameters. We see that $Y = (\tilde{y}_1(\eta), \tilde{y}_2(\eta))$ exhibits a linear rate of convergence to the optimal solution.

Table 2.

No.	η^k	$\tilde{y}_1$	$\tilde{y}_2$
1	10	(0.67,0.81,0.98)	(0.54,0.64,0.72)
2	10^2	(0.68,0.80,0.93)	(0.48,0.60,0.72)
3	10^3	(0.68,0.80,0.93)	(0.47,0.60,0.72)

The optimal value of the given fuzzy dual linear programming problem Max $\tilde{z} = (5.96, 7.20, 8.46)$.

5. Conclusion

In this paper, the fuzzy logarithmic Barrier function with the fuzzy Logarithmic Barrier parameter for solving the primal-dual fuzzy linear programming problem by using the proposed algorithm to obtain a better optimal solution is discussed. The table for the problems considered above shows that the computational procedure for the primal-dual algorithm developed by us when η is the fuzzy logarithmic barrier parameter gives a better the rate of convergence to the optimal solution.

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