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An Efficient Algorithm for Fuzzy Linear Fractional Programming Problems via Ranking Function

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Abstract:

In many applications such as production, planning, the decision maker is important in optimizing an objective function that has fuzzy ratio two functions which can be handed using fuzzy fractional programming problem technique. A special class of optimization technique named fuzzy fractional programming problem is considered in this work when the coefficients of objective function are fuzzy. New ranking function is proposed and used to convert the data of the fuzzy fractional programming problem from fuzzy number to crisp number so that the shortcoming when treating the original fuzzy problem can be avoided. Here a novel ranking function approach of ordinary fuzzy numbers is adopted for ranking of triangular fuzzy numbers with simpler and easier calculations as well as shortening in the procedures. The fuzzy fractional programming problem is the first reduced to a fractional programming problem and then solved with the technique to obtain the optimal solution. It has a power to give a best solution for supporting the solution theory proposed in this work, some numerical fuzzy fractional programming problem are included to ensure the advantage, efficiency and accuracy of the suggested algorithm. In addition, this research paper describes a comparison between our optimal solutions with other existing solutions for inequalities constrains fuzzy fractional program.

Keywords: Fuzzy fractional programming, Fuzzy set, Generalized triangular fuzzy number, Membership function, Triangular fuzzy number.

Introduction:

Fractional programming problem (FPP) is a special kind of non-linear programming problems in which the objective function is a ratio two functions with the constraints. Fractional model arises in decision making such as construction planning, economic, and commercial planning, health care and hospital planning [1].

Recently, Charnes and Kooper [2] established a method for transforming the fractional programming (FP) to an equivalent model program. Effati and Pakdaman [3] introduced a technique obtain the solution of the interval valued fractional programming (FP). Tantawy [4] proposed an iterative method for treating fraction programming problem with sensitivity analysis. The fractional programming (FP) problem with interval coefficients in the objective function was invented by Borza1 et al.[5]. Many researches proposed some techniques depending on integer solution for FP Problem [6-8] while multi-objective integer FP problems are treated with the help of an improved method by Mehdi et al.[9].

The fuzzy fractional programming problem is interested and has applications in many important fileds [10, 11].

Some researchers suggested some algorithms to obtain the approximate solution for fuzzy programming (FP) problem such as proposed technique introduced by Kabiraj et al.[12]. A new method presented by Malathi et al. [13] to solve special fuzzy programming (FP) problem.

Another way to solve the fuzzy programming (FP) problem is established by using ranking function to convert the fuzzy programming (FP) problem into an equivalent crisp programming problem [14,15].

Furthermore, the ranking function is utilized to solve fuzzy fractional programming (FFP) problem by [16], fully fuzzy multi-objective programming problem (FFMOPP), fuzzy rough fractional programming (FP) problem, fuzzy fractional transportation problem and multi-objective fractional programming (MOFP) are also solved using different method [17-23].

Here, an efficient ranking method is suggested to obtain an optimal solution for FFP problem by reducing it into a crisp programming. The presented technique is explained through illustrations. This article is organized as follows: some important preliminaries concerning triangular fuzzy number and ranking function are listed is Section 2. In Section 3, a ranking function is adopted while its application to solve FFP problem is derived in Section 4. Two examples of FFP problem are included in Section 5. In order to demonstrate the efficiency of the proposed approach, a comparison with other obtains result is also listed in this section. Section 6 describes the conclusion of our obtain results.

Preliminaries

Some necessary background and definitions are recalled throughout this section.

Definition 1 [24]

Let X be a collection of objects denoted by x. A fuzzy set $\tilde{A}$ in X can be defined as a set of ordered pairs:

$\tilde{A} = \{ (x, M_{\tilde{A}}(X)) : x \in X\}$

where $M_{\tilde{A}}(X)$ is named the membership function of x in a set $\tilde{A}$. The function $M_{\tilde{A}}(X)$ maps each element of a set X to a membership grade (or membership value) between 0 and 1.

Definition 2 [24]

A fuzzy number $\tilde{A}$ is a convex normalized fuzzy set on **R** such that:

(i) A least one x_0 exists in R w$here\ M_{\tilde{A}}(x_0) = 1$,

(ii) $M_{\tilde{A}}(X)$ is piecewise continuous.

Definition 3 [25]

A fuzzy number $\tilde{A} = (a, b, c)$, $a \le b \le c$ $(a, b, c \ge 0)$ is called a triangular fuzzy number if $M_{\tilde{A}}(X)$ is defined by

$$M_{\tilde{A}}(X) = \begin{cases} \frac{(x-a)}{b-a} & a \le x \le b \\ 1 & x = b \\ \frac{(c-x)}{c-b} & b \le x \le c \end{cases}$$

In general, the fuzzy number $\tilde{A}$ = (a, b, c; w) can be defined to be a generalized triangular fuzzy number if $M_{\tilde{A}}(X)$ is defined by

$$M_{\tilde{A}}(X) = \begin{cases} \frac{w(x-a)}{b-a} & a \le x \le b \\ w & x = b \\ \frac{w(c-x)}{c-b} & b \le x \le c \end{cases}$$

The Suggested New Ranking Function

In fact, an efficient scheme for ordering the elements is to give a ranking function $R: D(R) \to R$ which maps for each fuzzy number into R, and exists a natural order. The orders on is defined by:

$\tilde{A} \le \tilde{B}$ if and only if $R(\tilde{A}) \le R(\tilde{B})$

$\tilde{A} = \tilde{B}$ if and only if $R(\tilde{A}) = R(\tilde{B})$

where $\tilde{A}\ and\ \tilde{B}$ are in $D(R)$

The proposed ranking of fuzzy numbers can be defined as

Consider the generalized triangular membership function

$$M_{\tilde{A}}(X) = \begin{cases} \frac{w(x-a)}{b-a} & a \le x \le b \\ w & x = b \\ \frac{w(c-x)}{c-b} & b \le x \le c \end{cases}$$

Using the $\alpha -$ cut when $0 \le \alpha \le 1$, yields

$$\frac{w(x-a)}{b-a} = \alpha \to x = a + \frac{\alpha}{w}(b-a) = inf\ \tilde{A}(\alpha).$$

$$\frac{w(c-x)}{c-b} = \alpha \to x = c - \frac{\alpha}{w}(c-b) = sup\ \tilde{A}(\alpha).$$

Now applying the following ranking function $R(\tilde{A})$:

$$R(\tilde{A}) = \frac{[\frac{1}{2} \int_0^w \alpha^6 \left[inf \left(\tilde{A}(\alpha)\right) + sup\left(\tilde{A}(\alpha)\right)\right] d\alpha]}{\alpha^6 \ d\alpha}$$

then $R(\tilde{A})$ becomes the equation:

$$R(\tilde{A}) = \frac{[\frac{1}{2} \int_0^w \alpha^6 \left[a + \frac{\alpha}{w}(b-a) + c - \frac{\alpha}{w}(c-b)\right] d\alpha]}{\alpha^6 \ d\alpha}$$

$$R(\tilde{A}) = \frac{[\frac{1}{2} [\frac{\alpha^7}{7} a + \frac{\alpha^8}{8w}(b-a) + \frac{\alpha^7}{7} c - \frac{\alpha^8}{8w}(c-b)]\Big|_0^w]}{\frac{\alpha^7}{7}}$$

$$R(\tilde{A}) = \frac{\left[\frac{1}{2}\left[\frac{w^7}{7} a + \frac{w^8}{8w}(b-a) + \frac{w^7}{7} c - \frac{w^8}{8w}(c-b)\right]\right]}{\frac{w^7}{7}}$$

$$R(\tilde{A}) = \frac{\frac{w^7}{2}[\frac{a}{7} + \frac{(b-a)}{8} + \frac{c}{7} - \frac{(c-b)}{8}]}{\frac{w^7}{7}}$$

$$R(\tilde{A}) = \frac{a + 14 * b + c}{16}$$

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Application of the Proposed Ranking Function to Solve Fuzzy Fractional Programming (FFP) Problems

The Technical is suggested to solve a problem of fuzzy fractional programming utilizing fuzzy programming technique where the objective function coefficients are represented by triangular fuzzy numbers but the values of the right hand sides and the left hand sides variables are real numbers. Ranking approach is used in fuzzy fractional programming (FFP) problem to convert it in fuzzy programming (FP) problem. The approach of ranking algorithm for fuzzy fractional programming (FFP) problem is summarized as below:

Consider fuzzy fractional programming (FFP) problems is

Maximize $Z(X) = \frac{\tilde{c}\, X+ \alpha}{\tilde{d}\ \ X+\beta}$

subject to,

$Ax \leq b$

$x \geq 0.$

where $A = (A1, A2, \ldots\ldots, An)$ is an m by n matrix;

$c, d\ and\ \ x \in \mathbb{R}^{n}\ , b\ , \gamma\ and\ \beta\ \ are\ scalars.$

The proposed algorithm can be summarized as below:

1. Convert the fuzzy fractional programming problem into the following FP problem via new ranking function of triangular fuzzy number.

Maximize $Z(X) = \frac{c\, X+ \alpha}{d\ \ X+\beta}$

subject to,

$Ax \leq b$

$x \geq 0.$

2. Transform the obtained FP problem into a model problem by using Charnes-Cooper transformation method

Maximize $Z(x) = \tilde{c}\, y + \alpha t$

subject to,

$\tilde{d}\ \ y + \beta t = 1$

$Ay - bt\ \leq 0$

$y \geq 0\ , t \geq 0.$

3. Find the optimal solution y in step 2.
4. Obtain the optimal solution x using the value y in step 2.
5. The above algorithm is illustrated by numerical examples given in the next section a mathematical programming will utilize to get the optimal solution.
6. Compare a new ranking function with other ranking function type triangular fuzzy numbers to obtain the optimal solution of problems.

Numerical Examples

Two numerical fuzzy fractional programming problems are solved in this section with triangular fuzzy numbers, with the help of the suggested ranking functions. The FFP problems are transformed into a crisp programming model.

Example 1:- Consider the fuzzy fractional programming (FFP) problem

$$Max\ Z = \frac{(3.6,4\ ,5.6)x_1\ + (7.6,8,9.6)\ x_2}{(0.6,1,2.6)\ x_1\ + (1.6,2,3.6)\ x_2 + (2.6,3,4.6)}$$

subject to

$2x_1 + x_2 \leq 10$

$3x_1 + 4\ x_2 \leq 26$

$x_1\ ,\ \ x_2 \geq 0.$

Applying the proposed algorithm, Convert fuzzy programming problem into the following FFP problem using new ranking function of triangular fuzzy number

1. $R(\tilde{A})\ = \frac{a+14*b+c}{16}$

We first substitute the ranking function of each fuzzy number in objective function, which leads to an equivalent FP problem

$$Max\ Z\ = \frac{4\ .0750x_1\ + 8.0750\ x_2}{1.0750x_1\ + 2.0750x_2 + 3.0750}$$

subject to

$2x_1 + x_2 \leq 10$

$3x_1 + 4\ x_2 \leq 26$

$x_1\ ,\ \ x_2 \geq$

Now, transformed this fractional programming problem into model programming problem via transformation of charnes cooper, express this model programming form as

$Max\ Z = \ 4.0750\ y_1 + 8.0750\ y_2$

subject to

$1.0750y_1\ + 2.0750y_2 + 3.0750\ t = 1$

$2y_1 + y_2 - 10\ t\ \ \leq 0$

$3y_1 + 4\ y_2 - 26\ t\ \ \leq 0$

$y_1\ ,\ \ y_2 \geq\ 0$

The standard form of programming problem as follows:

$Max\ Z = \ 4.0750\ y_1 + 8.0750\ y_2$

subject to

$1.0750y_1\ + 2.0750y_2 + 3.0750\ t = 1$

$2y_1 + y_2 - 10\ t + y_4 = 0$

$3y_1 + 4\ y_2 - 26\ t\ + y_5\ = 0$

$y_1\ ,\ \ y_2 \geq\ 0$

Thus using step 4, the optimized solution here is

$y_1 = 0\ ,\ y_2 = 0.3925\ ,\ t = 0.0604$

$x_1 = \frac{y_1}{t} = 0\ , x_2 = \frac{y_2}{t} = 6.4983$

In step 5, the objective function value is z=3.1691.

In addition, using the ranking function (26) for a comparison between the above methods is made to show that the suggested method gives satisfactory

better results. A comparison can be also made using the following ranking function

$R(\tilde{A}) = \frac{a+6*b+c}{8}$

The ranking function of each fuzzy number in objective function, which leads to an equivalent FP problem

$$Max\ Z = \frac{4.1500x_1 + 8.1500\, x_2}{1.1500x_1 + 2.1500x_2 + 3.1500}$$

subject to

$2x_1 + x_2 \le 10$

$3x_1 + 4\, x_2 \le 26$

$x_1\ ,\ \ x_2 \ge$

Now the FP problem is reduced to model programming problem via transformation of charnes cooper, express this model programming form as

$Max\ Z = 4.1500\, y_1 + 8.1500\, y_2$

subject to

$1.1500y_1 + 2.1500y_2 + 3.1500\, t = 1$

$2y_1 + y_2 - 10\, t \le 0$

$3y_1 + 4\, y_2 - 26\, t \le 0$

$x_1\ ,\ \ x_2 \ge 0$

The standard form of model programming problem as follows:

$Max\ Z = 4.1500\, y_1 + 8.1500\, y_2$

subject to

$1.1500y_1 + 2.1500y_2 + 3.1500\, t = 1$

$2y_1 + y_2 - 10\, t + y_4 = 0$

$3y_1 + 4\, y_2 - 26\, t + y_5 = 0$

$x_1\ ,\ \ x_2 \ge 0$

thus using step 4, the optimized solution here is

$y_1 = 0\ ,\ y_2 = 0.3796\ ,\ t = 0.0584$

$x_1 = \frac{y_1}{t} = 0\ , x_2 = \frac{y_2}{t} = 6.500$

In step 5, the objective function value $z = 3.0934$. Afterwards, comparing optimized solution in Table 1.

Table 1. optimal value of example 1

Value of the function	The solution of new ranking function	Exact error	[26]	Exact error
3.2501	3.1691	0.0810	3.0934	0.1567

Note that, the new ranking function is more optimized than the ranking function [25].

Example 2:- Consider the fuzzy fractional programming (FFP) problem

$$Max\ Z = \frac{(3.3,4,5.2)x_1 + (5.3,6,7.2)\, x_2}{(4.3,5,6.2)\, x_1 + (3.3,4,5.2)\, x_2 + (0.3,1,2.2)}$$

subject to

$2x_1 + x_2 \le 10$

$3x_1 + 4\, x_2 \le 26$

$x_1\ , x_2 \ge 0.$

Applying the proposed algorithm, Convert fuzzy programming problem into the following FFP problem using new ranking function of triangular fuzzy number

2. $R(\tilde{A}) = \frac{a+14*b+c}{16}$

The first step is to substitute the ranking function of each fuzzy number in objective function, which leads to an equivalent FP problem

$$Max\ Z = \frac{4.0313x_1 + 6.0313\, x_2}{5.0313x_1 + 4.0313\, x_2 + 1.0313}$$

subject to

$2x_1 + 4x_2 \le 12$

$x_1 + 4\, x_2 \le 9$

$x_1\ ,\ \ x_2 \ge 0$

Now, transformed this FP problem into model programming problem via transformation of charnes cooper, express this model programming form as

$Max\ Z = 4.0313\, y_1 + 8.0313\, y_2$

subject to

$5.0313y_1 + 4.0313y_2 + 1.0313\, t = 1$

$2y_1 + 4\, y_2 - 12\, t \le 0$

$y_1 + 4\, y_2 - 9\, t \le 0$

$y_1\ ,\ \ y_2 \ge 0$

The standard form of model programming problem as follows:

$Max\ Z = 4.0313\, y_1 + 8.0313\, y_2$

subject to

$5.0313y_1 + 4.0313y_2 + 1.0313\, t = 1$

$y_1 + 4\, y_2 - 12\, t + y_4 = 0$

$y_1 + 4\, y_2 - 9\, t + y_5 = 0$

$y_1\ ,\ \ y_2 \ge 0$

thus using step 4, the optimized solution is obtained

$y_1 = 0\ ,\ y_2 = 0.2227\ ,\ t = 0.099$

$x_1 = \frac{y_1}{t} = 0\ , x_2 = \frac{y_2}{t} = 2.2495$

In step 5, the objective function value $z = 1.3434$ is solved.

Moreover, using the ranking function [26], a comparison between the above methods is made to show that the suggested method gives satisfactory better results. A comparison using the following ranking function

$$R(\tilde{A}) = \frac{a + 6 * b + c}{8}$$

The fuzzy number in objective function is converting into a crisp fractional programming (CFP) problem by ranking function

$$Max\ Z = \frac{4.0625x_1 + 6.0625x_2}{5.0625x_1 + 4.0625x_2 + 1.0625}$$

subject to
$2x_1 + 4x_2 \leq 12$
$x_1 + 4\, x_2 \leq 9$
$x_1\, , x_2 \geq 0$
Now, transform this FP problem into model programming problem via transformation of charnes cooper. Express this model programming form as
$Max\ Z = 4\,.0625\, y_1 + 6.0625\, y_2$
subject to
$5.0625y_1 + 4.0625y_2 + 1.0625\, t = 1$
$2y_1 + 4\, y_2 - 12\, t \leq 0$
$y_1 + 4\, y_2 - 9\, t \leq 0$
$y_1\, ,\ y_2 \geq 0$

The standard form of model programming problem as follows:
$Max\ Z = 4\,.0625\, y_1 + 6.0625\, y_2$
subject to
$5.0625y_1 + 4.0625y_2 + 1.0625\, t = 1$
$2y_1 + 4y_2 - 12\, t + y_4 = 0$
$y_1 + 4\, y_2 - 9\, t + y_5 = 0$
$y_1\, ,\ y_2 \geq 0$
thus using step 4, the optimized solution is obtained
$y_1 = 0\, ,\ y_2 = 2.205\, ,\ t = 0.0980\, ,$
$x_1 = \frac{y_1}{t} = 0\, , x_2 = \frac{y_2}{t} = 2.2500$
In step 5, the objective function value $z = 1.3369$ is solved.
Afterwards, comparing optimized solution in Table 2.

Table 2. optimal value of example 2

Value of the function	The solution of new ranking function	Exact error	[26]	Exact error
1.3500	1.3434	0.0066	1.3369	0.0131

Note that, the new ranking function is more optimized than the suggested ranking function in [26].

Conclusion

An efficient algorithm is proposed to solve the fuzzy fractional programming problem together with triangular fuzzy numbers. In this paper a novel ranking function has been used to convert fuzzy fractional programming problems to crisp fractional programming problems with simpler and easier calculations.

Author's declaration:

- Conflicts of Interest: None.
- I hereby confirm that all the Figures and Tables in the manuscript are mine. Besides, the Figures and images, which are not mine, have been given the permission for re-publication attached with the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in University of Technology.

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خوارزمية فعالة لمشكلات البرمجة الكسرية الخطية الضبابية عبر الدالة الرتبية

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الخلاصة :

في العديد من التطبيقات مثل الإنتاج ، يعد التخطيط لصانع القرار أمرًا مهمًا في تحسين دالة الهدف الضبابية للمسالة حيث تحتوي على نسبة دالتين ضبابيتين ، والتي يمكن ان تسلم باستخدام تقنية مسالة البرمجة الكسرية الضبابية . يتم النظر في فئة خاصة من تقنية التحسين تسمى مسالة البرمجة الكسرية الضبابية في هذا العمل عندما تكون معاملات دالة الهدف للمسالة ضبابية. تم اقتراح دالة الترتيب الجديدة واستخدامها لتحويل بيانات مسالة البرمجة الكسرية الضبابية من رقم غامض إلى رقم واضح بحيث يمكن تجنب العيب عند معالجة المسالة الضبابية الأصلية. هنا يتم اعتماد نهج وظيفة الترتيب الجديدة للأرقام الضبابية العادية لترتيب الأرقام الضبابية المثلثية مع حسابات أبسط وأسهل بالإضافة إلى تقصيرها في الإجراءات. يتم تقليل مشكلة البرمجة الكسرية الضبابية أولاً إلى مشكلة البرمجة الكسرية ثم حلها باستخدام التقنية للحصول على الحل الأمثل. لديها القدرة على إعطاء أفضل حل لدعم نظرية الحل المقترحة في هذا العمل ، يتم تضمين بعض مسائل البرمجة الكسرية الضبابية لضمان ميزة وكفاءة ودقة الخوارزمية المقترحة. بالإضافة إلى ذلك ، تصف هذه الورقة البحثية مقارنة بين حلولنا المثالية مع الحلول الأخرى القائمة لعدم المساواة للقيود في مسائل البرمجة الكسرية الضبابية.

الكلمات المفتاحية: البرمجة الكسرية الضبابية، المجموعة الضبابية، العدد الضبابي الثلاثي المعمم، دالة الانتماء، العدد الضبابي الثلاثي.