A Study of Algorithmic Approaches for Fuzzy Pattern Quadratic Fraction

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Abstract - Nonlinear problems like this one can have a lot of different types of goals, but they all have one thing in common: the goal is to get the rate of two quadratic objective functions, which are both subject to linear constraints, to be as high as possible. When a lot of rates have to be done at the same time for the optimization, there are problems. Among these are financial and corporate planning, planning for a hospital and health care plan as well as for production. In the literature, quadratic fractional optimization has been getting a lot of attention. It is the most important problem in both optimization theory and practise. There were a lot of different results on quadratic fractional optimization. Ranking function is used to make the nonlinear problem into a crisp one, and then fuzzy programming is used to solve the crisp problem. 2014 was the year that Lachhwani looked into a multi-objective quadratic fuzzy optimization problem. This is a way to make sure that you're getting the best out of a lot of different goal functions, in the form of a numerator and denominator function. Abdulrahim (2013) looked into how to solve a quadratic fuzzy optimization problem through feasible direction development and a modified simplex method. Sen (2013) came up with a piecewise linear approximation method that could help solve a Fuzzy separable quadratic optimization problem.

Keywords - Algorithmic Approaches, Fuzzy Pattern, Quadratic Fraction, Nonlinear problems, optimization theory.

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INTRODUCTION

Fuzzy goal programming was used by Pramanik et al. (2011) to solve the quadratic optimization problem. Gani and Kumar (2013) came up with a new way to solve fuzzy quadratic programming problems. They called it the principal pivoting method. Ghadle and Pawar (2016) came up with a new way to solve a Quadratic fractional programming problem in a special case. Kheirfam (2011) came up with a way to solve fully fuzzy Quadratic programming problems. Linear fractional programming problems were solved by Pandian and Jayalakshmi in 2013. Sharma and Singh (2014) came up with a way to solve Quadratic fractional optimization through the FGP method. Jain et al. (2011) came up with a way to solve the fuzzy linear fractional programming problem.A lot of application problems can be thought of as a mathematical problem that can be written with uncertainty. Bellman and Zadeh (1970) came up with the idea of maximising a decision in a fuzzy situation. Tanaka and others came up with a way to solve fuzzy mathematical programming in 1973. If you want to solve an optimization problem, you can use linear programming. This branch of math is used to solve problems where all of the constraints and the goal functions are linear functions. How do you figure out the best answer from a wide range? Linear programming is a method for doing this. Classical linear programming and fuzzy linear programming are two types of linear programming problems. Classical linear programming is when you solve a simple linear programming problem. Fuzzy linear programming is when you solve a fuzzy linear programming problem. Zimmermann came up with the idea of fuzzy linear programming problems (1978). Vansant et al. (2004) used linear programming with fuzzy parameters to help them make decisions about industrial production. It was in 1989 that Campos and Verdegay came up with a way to solve linear programming with fuzzy coefficients in both the matrix and on the right hand side of the constraint, which is why they are so important. Gani et al. (2009) came up with a fuzzy linear programming problem based on the L-R fuzzy number. Jimenez et al. (2007) came up with a way to solve linear programming problems where all the coefficients are fuzzy numbers and the linear ranking method is used. Decision-makers are made up of non-symmetrical trapezoidal fuzzy numbers, and they can be solved by using a ranking function. Hashem (2013) came up with this idea.

PRELIMINARIES

Trapezoidal and triangular fuzzy numbers

If the membership function $f_{\tilde{A}}(x)$ is piecewise linear, then is said to be a trapezoidal fuzzy number. The membership function of a trapezoidal fuzzy number is given by

$$\mu_{\tilde{a}}(x) = \begin{cases} \frac{w(x-a_1)}{a_2-a_1}, a_1 \le x \le a_2 \\ w, \quad a_2 \le x \le a_3 \\ \frac{w(a_4-x)}{a_4-a_3}, a_3 \le x \le a_4 \\ 0 \quad , otherwise \end{cases}$$

If w=1, then $\tilde{a} = (a_1, a_2, a_3, a_4; 1)$ is a normalized trapezoidal fuzzy number and $\tilde{a}$ is a generalized or non-normal trapezoidal fuzzy number if $0 < w < 1$. the image of $\tilde{a} = (a_1, a_2, a_3, a_4; w)$ is given by $-\tilde{a} = (-a_4, -a_3, -a_2, -a_1; w)$.

In particular case if $a_2 = a_3$ the trapezoidal fuzzy number reduces to a triangular fuzzy number given by $\tilde{a} = (a_1, a_2, a_4; w)$. The value of 2 a corresponds with the mode or core and [1 4 aa,] with the support. If w=1, then $\tilde{a} = (a_1, a_2, a_4)$ is a normalized triangular fuzzy number a % is a generalized or non-normal triangular fuzzy number if $0 < w < 1.$

Properties of trapezoidal fuzzy number

Let $\tilde{a} = (a_1, a_2, a_3, a_4)$ and $\tilde{b} = (b_1, b_2, b_3, b_4)$ be two trapezoidal fuzzy numbers, then the fuzzy numbers addition and fuzzy numbers subtraction are defined as follows:

i. Fuzzy numbers addition of $\tilde{a}$ and $\tilde{b}$ is denoted by $\tilde{a} + \tilde{b}$ and is given by $\tilde{a} + \tilde{b} = (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4)$

ii. Fuzzy numbers subtraction of $\tilde{a}$ and $\tilde{b}$ is denoted by $\tilde{a} - \tilde{b}$ and is given by $\tilde{a} - \tilde{b} = (a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1)$

AN APPROACH FOR RANKING OF TRAPEZOIDAL FUZZY NUMBERS

Method of magnitude (Mag)

If $\tilde{a} = (a_1, a_2, a_3, a_4)$ is a trapezoidal fuzzy number, then the defuzzified value or the crisp number of $\tilde{a}$ is given by $\tilde{a} = \frac{a_1+2a_2+2a_3+a_4}{6}$. We need the following definitions of ordering on the set of the fuzzy numbers based on the magnitude of a fuzzy number.

The magnitude of the trapezoidal fuzzy number,

$\tilde{u} = (x_0 - \sigma, x_0, y_0, y_0 - \beta)$ with parametric form $\tilde{u} = (\underline{u}(r), \overline{u}(r))$

where $\underline{u} = x_0 - \sigma + \sigma r$ and $\overline{u} = y_0 + \beta - \beta r$ is defined as

$$\text{Mag}(u) = \frac{1}{2}\left(\int_0^1 (\underline{u}(r) + \overline{u}(r) + x_0 + y_0) f(r) dr\right),$$

Where the function f(r) is a non-negative and increasing function

on [0,1], with f(0)=0,f(1)=1 and $\int_0^1 f(r)dr = \frac{1}{2}$.

Clearly, the function f(r) can be thought of as a weighting function. In real-life applications, the function f(r) can be chosen based on the situation. The size of a trapezoidal fuzzy number u, which is defined by (1), shows how much information there is about each membership level, and the meaning of this size is visual and natural. The resulting scalar value is used to rank the fuzzy numbers. In the other words Mag $(\tilde{u})$ is used to rank fuzzy numbers. The larger Mag $(\tilde{u})$ means the larger fuzzy number.

The magnitude of the trapezoidal fuzzy number

$\tilde{a} = (a_1, a_2, a_3, a_4)$ is given by $Mag(\tilde{a}) = \frac{a_1 + 5a_2 + 5a_3 + a_4}{12}$ or

$$Mag(\tilde{a}) = \frac{5}{12}(a_2 + a_3) + \frac{1}{12}(a_1 + a_4).$$

Let $\tilde{u}$ and $\tilde{v}$ be two trapezoidal fuzzy numbers. The ranking of $\tilde{u}$ and $\tilde{v}$ by the $\text{Mag}(\tilde{u})$, the set of trapezoidal fuzzy numbers is defined as follows:

i. $Mag(\tilde{u}) > Mag(\tilde{v})$ *if and only if* $\tilde{u} > \tilde{v}$;

ii. $Mag(\tilde{u}) < Mag(\tilde{v})$ *if and only if* $\tilde{u} < \tilde{v}$ and

iii. $Mag(\tilde{u}) = Mag(\tilde{v})$ *if and only if* $\tilde{u} = \tilde{v}$;

The ordering ≥ and ≤ between any two trapezoidal fuzzy numbers $\tilde{u}$ and $\tilde{v}$ are defined as follows:

i. $\tilde{u} \geq \tilde{v}$; *if and only if* $\tilde{u} > \tilde{v}$ *or* $\tilde{u} = \tilde{v}$ *and*

ii. $\tilde{u} \leq \tilde{v}$; *if and only if* $\tilde{u} < \tilde{v}$ *or* $\tilde{u} = \tilde{v}$.

The mathematical properties of the "magnitude" method for ranking fuzzy numbers are shown here. It doesn't require a lot of computer work, and it doesn't need to know what all the other options are before start.

PROBLEM FORMULATION

The quadratic programming method is one of the most important ways to improve operations research. Quadratic programming models are usually used in real-world situations to figure out what to do next. In real-life situations, there may be a lot of uncertainty about the parameters. In this case, fuzzy numbers can be used to show the parameters of quadratic programming problems. There is a special quadratic programming problem that we look at. In this case, the quadratic fractional objective function can be changed into a linear fractional objective function with fuzzy variables. Mathematically, consider the special case of quadratic fuzzy fractional programming problem (QFFPP):

$$\text{Maximize } Z=\frac{(C_B x_B \oplus \alpha)(C'_B x_B \oplus \beta)}{(D_B x_B \oplus \gamma)(D'_B x_B \oplus \delta)}$$

Subject to constraints: $Ax \leq b, x \geq 0$

Where all $C_B, C'_B, D_B, D'_B, \alpha, \beta, \gamma, \delta$ are trapezoidal fuzzy number variable.

ALTERNATIVE ALGORITHM FOR SPECIAL CASE OF FUZZY QUADRATIC FRACTIONAL PROGRAMMING PROBLEM

Find optimal solution of special case of QFFPP by an alternative method, algorithm is given as follows:

Step 1 Convert all fuzzy numbers into crisp value by using proposed ranking method.

Step 2 Check objective function of QFFPP is of maximization. If it is to be minimization type than convert it into maximization.

Step 3 Convert quadratic fractional objective function to the product of linear fractional objective functions.

Step 4 Check whether all bi (RHS) are non- negative. If any bi is negative then convert it to positive.

Step 5 Express the given QFFPP in standard form then obtain an initial basic feasible solution.

Step 6 Find net evaluation Δ j for each variable j x by the formula:

$$\Delta_j = \sum_{i=1}^{4} z^i \Delta_{ij}$$

$$z^1 = (C_B x_B + \alpha), z^2 = (C'_B x_B + \beta), z^3 = (D_B x_B + \gamma), z^4 = (D'_B x_B + \delta)$$

$$\Delta_{1j} = (C_B x_B - C_j), \Delta_{2j} = (C'_B x_B + C'_j), \Delta_{3j} = (D_B x_B + D_j), \Delta_{4j} = (D'_B x_B + D'_j)$$

Step 7 Use simplex method for this table and go to next step.

Step 8 Check solution for optimality if all Δ≥ 0 ij , then current solution is an optimal solution, otherwise go to step 6 and repeat the same procedure.

Thus optimum solution of special type of QFFPP is obtained.

NUMERICAL EXAMPLE

$$Max\ Z = \frac{\{(0,1,1,2)x_1 + (2,2,2,2)\}\{(0,1,1,2)x_1 + (1,1,1,1)x_2 + (1,1,1,1)\}}{\{(-3,1,1,5)x_1 + (-2,2,2,6)x_2 + (3,3,3,3)\}\{(0,1,1,2) + (3,3,3,3)\}}$$

Subject to

$$(-2,2,6,10)x_1 + (-2,2,2,6)x_2 \leq (2,6,10,14)$$

$$(0,1,1,2)x_1 + (2,2,2,2)x_2 \leq (0,4,8,12)$$

$$x_1, x_2 \geq 0$$

By using the method for defuzzyfing the trapezoidal fuzzy numbers

$$mag(u) = \frac{5}{12}(b+c) + \frac{1}{12}(a+d)$$

$$R(0,1,1,2) = \frac{5}{12}(1+1)\frac{1}{12}(0+2) = 1$$

$$R(2,2,2,2) = 2$$

$$R(1,1,1,1) = 1$$

$$R(-3,1,1,5) = 1$$

$$R(-2,2,2,6) = 2$$

$$R(3,3,3,3) = 3$$

$$R(2,6,10,14) = 8$$

$$R(0,4,8,12) = 6$$

$$Max\ Z = \frac{(x_1+2)(x_1+x_2+1)}{(x_1+2x_2+3)(x_2+3)}$$

Subject to

$$4x_1 + 2x_2 \leq 8$$

$$x_1 + 2x_2 \leq 6$$

$$x_1, x_2 \geq 0$$

Now solving the above problem by an alternative method the detailed process of the solution is as follows. QFFPP is in standard form

$$Max\ Z = \frac{(x_1+2)(x_1+x_2+1)}{(x_1+2x_2+3)(x_2+3)}$$

Subject to

$$4x_1 + 2x_2 + s_1 = 8$$
$$x_1 + 2x_2 + s_2 = 6$$
$$x_1, x_2, s_1, s_2 \geq 0$$

Where s_1, s_2 are slack variables.

By solving above problem, we obtain the following final simplex table.

Table 1

						1	0	0	0
						1	1	0	0
						1	2	0	0
						0	1	0	0
C_B	C'_B	D_B	D'_B	X_B	b	x_1	x_2	s_1	s_2
1	1	1	0	x_1	2/3	1	0	1/3	-1/3
0	1	2	1	x_2	8/3	0	1	-1/6	2/3
				$z^1 = 8/3$		0	0	1/3	-1/3
				$z^2 = 13/3$		0	0	1/6	1/3
				$z^3 = 0$		0	0	0	1
				$z^4 = 17/3$		0	0	-1/6	2/3
				Δ_j		0	0	2/3	40/3

$\because$ All $\Delta_j \geq 0$ current solution is an optimal solution.

$\therefore$ Optimum solution is $x_1 = \frac{2}{3}, x_2 = \frac{8}{3}$ $Z = 0.226$.

ARITHMETIC OPERATION

Interval Arithmetic

If want to limit rounding errors and measure errors in mathematical computations, you can use interval math, interval analysis, interval computation, or interval arithmetic. This way, you can come up with numerical methods that work. In this way, each value is shown as a range of possible values. The following are the basic operation of interval arithmetic for two variable [a,b] and [c,d] that are subsets of the real line (-∞,∞) .

i. Addition: $[a,b] + [c,d] = [\,a+c\,, b+d\,]$

ii. Subtraction: $[a,b] - [c,d] = [\,a-d\,, b-c\,]$

iii. Multiplication: $[a,b] \times [c,d] = [\ \min\ (ac,ad,bc,bd)\ ,\ \max\ (ac,ad,bc,bd)]$

iv. Division: $\left[\frac{[a,b]}{[c,d]}\right] = [\min\left(\frac{a}{c},\frac{a}{d},\frac{b}{c},\frac{b}{d}\right), \max\left(\frac{a}{c},\frac{a}{d},\frac{b}{c},\frac{b}{d}\right)]$, where 0 is not in $[c,d]$

ARITHMETIC OPERATION OF FUZZY NUMBERS USING α–CUT METHOD

In this section we consider addition, subtraction, multiplication and division of fuzzy numbers using α-cut method.

Let $\tilde{a} = (a_1, a_2, a_3, a_4)$ and $\tilde{b} = (b_1, b_2, b_3, b_4)$ be two fuzzy numbers whose membership function are defined by

$$\mu_{\tilde{a}}(x) = \begin{cases} \frac{x-a_1}{a_2-a_1}, & if\ x \in [a_1, a_2] \\ \frac{a_4-x}{a_4-a_3}, & if\ x \in [a_3, a_4] \\ 0, & otherwise \end{cases}$$

$$\mu_{\tilde{b}}(x) = \begin{cases} \frac{x-b_1}{b_2-b_1}, b_1 \leq x \leq b_2 \\ \frac{b_4-x}{b_4-b_3}, b_3 \leq x \leq b_4 \\ 0\ \ , otherwise \end{cases}$$

Then $\alpha_{\tilde{a}} = [(a_2-a_1)\alpha + a_1, a_4 - (a_4-a_3)\alpha]$ and $\alpha_{\tilde{b}} = [(b_2-b_1)\alpha + b_1, b_4 - (b_4-b_3)\alpha]$ are the α-cuts of fuzzy numbers $\tilde{a}$ and $\tilde{b}$ respectively.

Now for calculate addition, subtraction, multiplication and division of fuzzy numbers $\tilde{a}$ and $\tilde{b}$ using interval arithmetic.

Addition

$$\alpha_{\tilde{a}} + \alpha_{\tilde{b}} = \left[(a_2 - a_1)\alpha + a_1, a_4 - (a_4 - a_3)\alpha\right] + \left[(b_2 - b_1)\alpha + b_1, b_4 - (b_4 - b_3)\alpha\right]$$
$$= \left[(a_2 + b_2 - a_1 - b_1)\alpha + a_1 + b_1, a_4 + b_4 + (a_3 + b_3 - a_4 - b_4)\alpha\right]$$

Subtraction

$$\alpha_{\tilde{a}} - \alpha_{\tilde{b}} = \left[(a_2 - a_1)\alpha + a_1, a_4 - (a_4 - a_3)\alpha\right] - \left[(b_2 - b_1)\alpha + b_1, b_4 - (b_4 - b_3)\alpha\right]$$
$$= \left[(a_2 + b_4 - a_1 - b_3)\alpha + a_1 + b_4, a_4 + b_1 + (a_3 + b_1 - a_4 - b_2)\alpha\right]$$

Multiplication

$$\alpha_{\tilde{a}} \times \alpha_{\tilde{b}} = \left[(a_2 - a_1)\alpha + a_1, a_4 - (a_4 - a_3)\alpha\right] \times \left[(b_2 - b_1)\alpha + b_1, b_4 - (b_4 - b_3)\alpha\right]$$
$$= \left[(a_2 - a_1)\alpha + a_1 \times (b_2 - b_1)\alpha + b_1, a_4 - (a_4 - a_3)\alpha \times b_4 - (b_4 - b_3)\alpha\right]$$

Division

$$\frac{\alpha_{\tilde{a}}}{\alpha_{\tilde{b}}} = \left[\frac{(a_2 - a_1)\alpha + a_1}{b_4 - (b_4 - b_3)\alpha}, \frac{a_4 - (a_4 - a_3)\alpha}{(b_2 - b_1)\alpha + b_1}\right]$$

PROPOSED ALGORITHM

The arithmetic operations of fuzzy numbers using -cut operations discussed in the earlier sections are used below to solve the fuzzy linear programming problem. The steps for the computation of an optimum solution are as follows:

Step 1 Find the value of α $\alpha_{\tilde{a}}$ and $\alpha_{\tilde{b}}$.

Step 2 Add the -cuts of $\tilde{a}$ and $\tilde{b}$ using interval arithmetic.

Step 3 The values obtained in step 1 and 2 is converted into a crisp linear programming problem and formulated as,

$$\text{Max } Z = \sum_{j=1}^{n} c_j x_j$$
$$\text{subject to} \sum_{j=1}^{n} a_{ij} x_j \le or \ge or = b_i$$
$$i = 1,2,\ldots\ldots m$$
$$\text{where } x_j \ge 0$$

The function to be maximized is called an objective function. This is denoted by $Z.\ c = (c_1, c_2 \ldots\ldots c_n)$ is called a cost vector. The matrix $[a_{ij}]$ is called an activity matrix and the vector $b_i = b_1, b_2, \ldots\ldots b_m$ is called right hand side vector. Step 4 Now solve reduced linear programming problem by two phase simplex method.

TWO PHASE SIMPLEX METHOD

The two phase simplex method is used to solve a given linear programming problem in which some artificial variables are involved. The solution is obtained in two phases as follows:

Phase I

In this phase, the simplex method is applied to a specially constructed auxiliary linear programming problem leading to a final simplex table containing a basic feasible solution to the original problem.

- Assign a cost -1 to each artificial variable and a cost 0 to all other variables (in place of their original cost) in the objective function.
- Construct the auxiliary linear programming problem in which the new objective function Z^* is to be maximized subject to the given set of constraints.
- Solve the auxiliary problem by simplex method until either of the following three possibilities do arise.
- Max $Z^* < 0$ and at least one artificial vector appear in the optimum basis at a positive level. In this case given problem does not possess any feasible solution.
- Max $Z^* = 0$ and at least one artificial vector appears in the optimum basis at zero level or no artificial vector appears in the optimum basis. In this case proceed to phase II.

Phase II

Now, put the real costs into the variable in the goal function, and put a zero cost into every artificial variable that is in the basis at the zero level. Now, the simplex method is used to try to maximise this new goal function, but only if the given constraints are met. That is, the simplex method is used on the modified simplex table that was found at the end of phase-I until an optimum basic feasible solution (if there is one) has been found. All of the artificial variables that aren't basic at the end of Phase I are taken away.

CONCLUSION

Fuzzy linear programming problem using interval arithmetic when compared to the earlier approaches. This also can be applied in triangular, hexagonal, octagonal fuzzy numbers and also can be extended to multi objective linear programming and fully fuzzy linear programming problems. Interval arithmetic linear programming problem with trapezoidal fuzzy number is solved by using α-cut operation without converting them into a classical linear programming problem.Fuzzy logic is a computational worldview that gives a numerical apparatus to managing the vulnerability and the imprecision which is ordinary of human thinking. The great trait of fuzzy logic is its capacity of communicating information in an etymological manner, permitting a framework to be depicted by a straightforward, human-accommodating principle. The fuzzy set system has been used in a few unique approaches to demonstrate the symptomatic cycle. This part manages the extension of Sanchez's methodology for medical diagnosis utilizing the portrayal of a stretch esteemed fuzzy lattice as a time period fuzzy grids. The vast majority of our genuine issues in medical sciences, designing, the executives, climate and sociologies regularly include data which are not really fresh, exact and deterministic in character because of different vulnerabilities related with these issues. Such vulnerabilities are typically being taken care of with the assistance of the themes like likelihood, fuzzy sets, intuitionistic fuzzy sets, span arithmetic and harsh sets and so on Span esteemed intuitionistic fuzzy sets acquired consideration from specialists for their applications in different fields. The fuzzy set structure has been used in a few distinct approaches to demonstrate the symptomatic interaction.

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