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Arithmetic Operations for Generalized 4th Multiple Polygonal Fuzzy Numbers

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Abstract: *In this paper, we generalized an arithmetic operation of 4th multiple polygonal fuzzy numbers with its membership function. We proposed a generalized technique for basic fundamental arithmetic operations of 4th multiple polygonal fuzzy numbers by using arithmetic interval of alpha- cut.*
***Key Word**: 4^{th} multiple polygonal fuzzy numbers, Arithmetic interval, α-cut, Membership function.*

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I. Introduction

In 1965, L. A. Zadeh[4] was the first person whose developed the concepts of fuzzy set with membership function in this work, fuzzy sets gives out natural way of dealing with control system and decision making system in our real life. The membership function of the fuzzy set uniquely described the set. Many researchers and authors had been done work on the basic fundamental arithmetic operations by using arithmetic interval of α- cut for fuzzy numbers such as Trapezoidal fuzzy number[5], Octagonal fuzzy number[8], Dodecagonal fuzzy number[6], Hexadecagonal fuzzy number[1], and Icosagonal fuzzy number[9] , Icosatetragonal fuzzy number[3] and Icosikaioctagonal fuzzy number[10]. These fuzzy numbers were introduced to clear the vagueness. D. Kumar and J. Singh[11] proposed a measure of central tendency approach to obtain optimal solution for pentagonal intuitionistic fuzzy and compare other traditional methods. V. Raju and P. M. Prauatha Vathana[7] developed a method for solving fuzzy critical path in which activity duration times represented in the form of the Icosagonal fuzzy number. In the fuzzy project network, this fuzzy network problem converted into the crisp network problem using the ranking function and obtained critical path form the initial point to terminal point. B. Amutha and G. Uthra[2] proposed a method to solve Intuitionistic fuzzy assignment problem in which cost values are in form of Symmetric octagonal fuzzy number. This fuzzy problem converted into crisp assignment problem by using ranking function and obtained an optimal solution by Hungarian method. In this paper, we extended this work as generalized form for 4th multiple polygonal fuzzy numbers and its membership function. The basic fundamental arithmetic operations are introduced by using arithmetic interval of α- cut for this type of fuzzy numbers.

II. Preliminaries

2.1 Fuzzy Set: Let X be real number set then fuzzy set P of X with membership function $\mu_P(x) : X \to [0, 1]$ in P define as $P = \{(x, \mu_P(x)) / x \in X\}$,

2.2 Fuzzy Number: The fuzzy set P is called fuzzy number if its membership function $\mu_P(x)$ is satisfied following conditions:

- The set P is normal if there exists $x_0 \in X$ such that $\mu_P(x_0) = 1$.
- $\mu_P(x)$ is piecewise continuous.
- P is convex
- $\mu_P\{(\lambda x_1 + (1-\lambda)x_2\} \geq min\{\mu_P(x_1), \mu_P(x_2)\}, x_1, x_2 \in X$ & $\lambda \in [0,1]$.
- The support of P is bounded in X where $S(P) = \{x \in X / \mu_P(x) > 0\}$.

2.3 Alpha – Cut: The α-cut of fuzzy set P

$$[P]_\alpha = \{x \in X / \mu_P(x) \geq \alpha\}.$$

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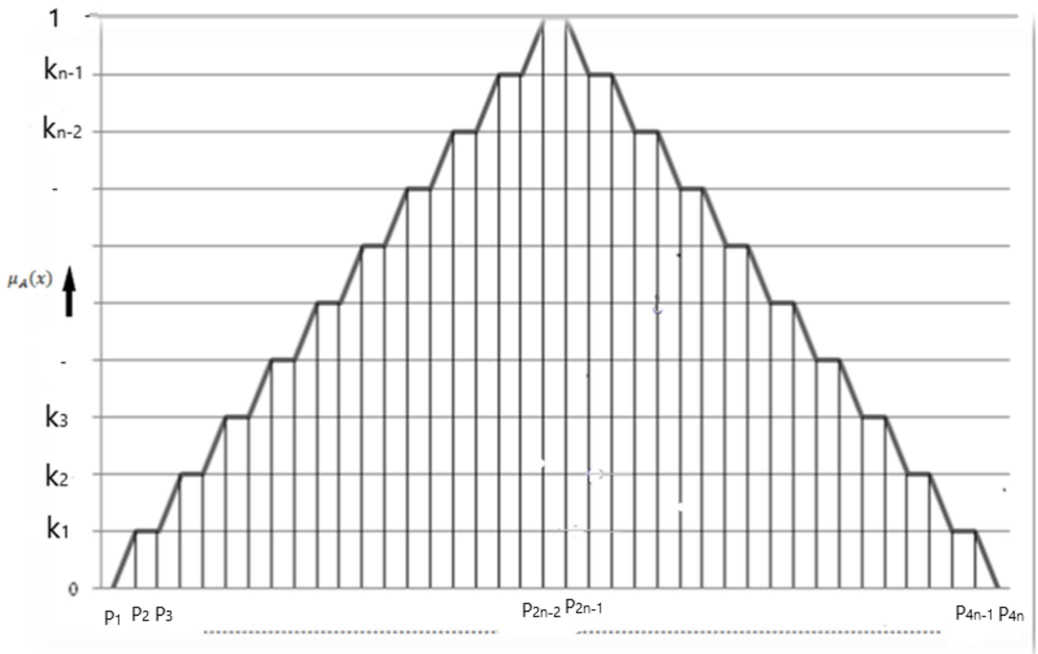
III. Generalized 4th multiple polygonal fuzzy number

3.1 Membership function:

$$\mu_P(x) = \begin{cases} 0 & for \quad 0 < p_1 \\ k_1(\frac{x-p_1}{p_2-p_1}) & for \quad p_1 \le x \le p_2 \\ k_1 & for \quad p_2 \le x \le p_3 \\ k_1+(k_2-k_1)(\frac{x-p_3}{p_4-p_3}) & for \quad p_3 \le x \le p_4 \\ k_2 & for \quad p_4 \le x \le p_5 \\ .. & \\ .. & \\ k_{n-2} & for \quad p_{2n-4} \le x \le p_{2n-3} \\ k_{n-2}+(k_{n-1}-k_{n-2})(\frac{x-p_{2n-3}}{p_{2n-2}-p_{2n-3}}) & for \quad p_{2n-3} \le x \le p_{2n-2} \\ k_{n-1} & for \quad p_{2n-2} \le x \le p_{2n-1} \\ k_{n-1}+(1-k_{n-1})(\frac{x-p_{2n-1}}{p_{2n}-p_{2n-1}}) & for \quad p_{2n-1} \le x \le p_{2n} \\ 1 & for \quad p_{2n} \le x \le p_{2n+1} \\ k_{n-1}+(1-k_{n-1})(\frac{p_{2n+2}-x}{p_{2n+2}-p_{2n+1}}) & for \quad p_{2n+1} \le x \le p_{2n+2} \\ k_{n-1} & for \quad p_{2n+2} \le x \le p_{2n+3} \\ k_{n-2}+(k_{n-1}-k_{n-2})(\frac{p_{2n+4}-x}{p_{2n+4}-p_{2n+3}}) & for \quad p_{2n+3} \le x \le p_{2n+4} \\ k_{n-2} & for \quad p_{2n+4} \le x \le p_{2n+5} \\ .. & \\ .. & \\ k_2 & for \quad p_{4n-4} \le x \le p_{4n-3} \\ k_1+(k_2-k_1)(\frac{p_{4n-2}-x}{p_{4n-2}-p_{4n-3}}) & for \quad p_{4n-3} \le x \le p_{4n-2} \\ k_1 & for \quad p_{4n-2} \le x \le p_{4n-1} \\ k_1(\frac{p_{4n}-x}{p_{4n}-p_{4n-1}}) & for \quad p_{4n-1} \le x \le p_{4n} \\ 0 & for \quad a_{4n} \le x \end{cases}$$

Where $0 \le k_1 \le k_2 \le \ldots\ldots.. \le k_{n-2} \le k_{n-1} \le 1$

3.2 The graphically representation:



3.3 Arithmetic operations:

If P = (p_1, p_2, p_3……., p_{4n}) and Q = (q_1, q_2, q_3,……., q_{4n},) then

- **Addition**: P+Q = (p_1+q_1, p_2+q_2,……………, $p_{4n}+q_{4n}$)
- **Subtraction**: P-Q = (p_1-q_1, p_2-q_2,……………., $p_{4n}-q_{4n}$)
- **Multiplication**: P*Q = (p_1q_1, p_2q_2,…………. ……, $p_{4n}q_{4n}$)

3.4 Alpha cut:

For $\alpha \in [0, 1]$, then α- cut of 4th multiple polygonal fuzzy numbers P = (p_1, p_2, p_3……., p_{4n}) $(n \in N)$ is defined as

$$[P]_\alpha = \begin{cases} [p_1 + \frac{\alpha}{k_1}(p_2 - p_1), \quad p_{4n} - \frac{\alpha}{k_1}(p_{4n} - p_{4n-1})] & for\,\alpha \in [0, k_1] \\ [p_3 + (\frac{\alpha - k_1}{k_2 - k_1})(p_4 - p_3), \quad p_{4n-2} - (\frac{\alpha - k_1}{k_2 - k_1})(p_{4n-2} - p_{4n-3})] & for\,\alpha \in [k_1, k_2] \\ .. & \\ .. & \\ [p_{2n-3} + (\frac{\alpha - k_{n-2}}{k_{n-1} - k_{n-2}})(p_{2n-2} - p_{2n-3}), \quad p_{2n+4} - (\frac{\alpha - k_{n-2}}{k_{n-1} - k_{n-2}})(p_{2n+4} - p_{2n+3})] & for\,\alpha \in [k_{n-2}, k_{n-1}] \\ [p_{2n-1} + (\frac{\alpha - k_{n-1}}{1 - k_{n-1}})(p_{2n} - p_{2n-1}), \quad p_{2n+2} - (\frac{\alpha - k_{n-1}}{1 - k_{n-1}})(p_{2n+2} - p_{2n+1})] & for\,\alpha \in [k_{n-1}, 1] \end{cases}$$

$For\ all\ \alpha \in [0,1]\ \ and\ here\ [k_1, k_2, k_{3,} \dots\dots\dots.., k_{n-1}, k_n] = [\frac{1}{n}, \frac{2}{n}, \frac{3}{n}, \dots\dots.., \frac{n-1}{n}, 1],\ n \in N$ is given by

$$[P]_\alpha = \begin{cases} [p_1 + n\alpha(p_2 - p_1), \quad p_{4n} - n\alpha(p_{4n} - p_{4n-1})] & for\,\alpha \in [0, \frac{1}{n}] \\ [p_3 + (n\alpha - 1)(p_4 - p_3), \quad p_{4n-2} - (n\alpha - 1)(p_{4n-2} - p_{4n-3})] & for\,\alpha \in [\frac{1}{n}, \frac{2}{n}] \\ .. \\ .. \\ [p_{2n-3} + (n\alpha - n + 2)(p_{2n-2} - p_{2n-3}), \quad p_{2n+4} - (n\alpha - n + 2)(p_{2n+4} - p_{2n+3})] & for\,\alpha \in [\frac{n-2}{n}, \frac{n-1}{n}] \\ [p_{2n-1} + (n\alpha - n + 1)(p_{2n} - p_{2n-1}), \quad p_{2n+2} - (n\alpha - n + 1)(p_{2n+2} - p_{2n+1})] & for\,\alpha \in [\frac{n-1}{n}, 1] \end{cases}$$

3.5 The α- cut for arithmetic operations of 4th multiple polynomial fuzzy numbers:

If P = (p_1, p_2, p_3……., p_{4n}) and Q = (q_1, q_2, q_3,……., q_{4n},) are two 4th multiple polynomial fuzzy numbers. Then the arithmetic operations for the α cut of P_α and Q_α of P and Q using interval arithmetic as define below-

- **Addition:**

$$[P]_\alpha + [Q]_\alpha = \begin{cases} [p_1 + n\alpha(p_2 - p_1), \quad p_{4n} - n\alpha(p_{4n} - p_{4n-1})] + \\ [q_1 + n\alpha(q_2 - q_1), \quad q_{4n} - n\alpha(q_{4n} - q_{4n-1})], for\ \alpha \in [0, \frac{1}{n}] \\ [p_3 + (n\alpha - 1)(p_4 - p_3), \quad p_{4n-2} - (n\alpha - 1)(p_{4n-2} - p_{4n-3})] + \\ [q_3 + (n\alpha - 1)(q_4 - q_3), \quad q_{4n-2} - (n\alpha - 1)(q_{4n-2} - q_{4n-3})], for\ \alpha \in [\frac{1}{n}, \frac{2}{n}] \\ .. \\ .. \\ .. \\ [p_{2n-3} + (n\alpha - n + 2)(p_{2n-2} - p_{2n-3}), \quad p_{2n+4} - (n\alpha - n + 2)(p_{2n+4} - p_{2n+3})] + \\ \quad [q_{2n-3} + (n\alpha - n + 2)(q_{2n-2} - q_{2n-3}), \quad q_{2n+4} - (n\alpha - n + 2)(q_{2n+4} - q_{2n+3})] \quad for\ \alpha \in [\frac{n-2}{n}, \frac{n-1}{n}] \\ [p_{2n-1} + (n\alpha - n + 1)(p_{2n} - p_{2n-1}), \quad p_{2n+2} - (n\alpha - n + 1)(p_{2n+2} - p_{2n+1})] + \\ \quad [q_{2n-1} + (n\alpha - n + 1)(q_{2n} - q_{2n-1}), \quad q_{2n+2} - (n\alpha - n + 1)(q_{2n+2} - q_{2n+1})] \quad for\ \alpha \in [\frac{n-1}{n}, 1] \end{cases}$$

- **Subtraction:**

$$[P]_\alpha - [Q]_\alpha = \begin{cases} [p_1 + n\alpha(p_2 - p_1), \quad p_{4n} - n\alpha(p_{4n} - p_{4n-1})] - \\ \quad [q_1 + n\alpha(q_2 - q_1), \quad q_{4n} - n\alpha(q_{4n} - q_{4n-1})] \quad for\ \alpha \in [0, \frac{1}{n}] \\ [p_3 + (n\alpha - 1)(p_4 - p_3), \quad p_{4n-2} - (n\alpha - 1)(p_{4n-2} - p_{4n-3})] - \\ \quad [q_3 + (n\alpha - 1)(q_4 - q_3), \quad q_{4n-2} - (n\alpha - 1)(q_{4n-2} - q_{4n-3})] \quad for\ \alpha \in [\frac{1}{n}, \frac{2}{n}] \\ .. \\ .. \\ .. \\ [p_{2n-3} + (n\alpha - n + 2)(p_{2n-2} - p_{2n-3}), \quad p_{2n+4} - (n\alpha - n + 2)(p_{2n+4} - p_{2n+3})] - \\ \quad [q_{2n-3} + (n\alpha - n + 2)(q_{2n-2} - q_{2n-3}), \quad q_{2n+4} - (n\alpha - n + 2)(q_{2n+4} - q_{2n+3})] \quad for\ \alpha \in [\frac{n-2}{n}, \frac{n-1}{n}] \\ [p_{2n-1} + (n\alpha - n + 1)(p_{2n} - p_{2n-1}), \quad p_{2n+2} - (n\alpha - n + 1)(p_{2n+2} - p_{2n+1})] - \\ \quad [q_{2n-1} + (n\alpha - n + 1)(q_{2n} - q_{2n-1}), \quad q_{2n+2} - (n\alpha - n + 1)(q_{2n+2} - q_{2n+1})] \quad for\ \alpha \in [\frac{n-1}{n}, 1] \end{cases}$$

- **Multiplication:**

$$[P]_\alpha * [Q]_\alpha = \begin{cases} [p_1 + n\alpha(p_2 - p_1),\ p_{4n} - n\alpha(p_{4n} - p_{4n-1})]* \\ \qquad [q_1 + n\alpha(q_2 - q_1),\ q_{4n} - n\alpha(q_{4n} - q_{4n-1})] & for\ \alpha \in [0, \frac{1}{n}] \\ [p_3 + (n\alpha - 1)(p_4 - p_3),\ p_{4n-2} - (n\alpha - 1)(p_{4n-2} - p_{4n-3})]* \\ \qquad [q_3 + (n\alpha - 1)(q_4 - q_3),\ q_{4n-2} - (n\alpha - 1)(q_{4n-2} - q_{4n-3})] & for\ \alpha \in [\frac{1}{n}, \frac{2}{n}] \\ .. \\ .. \\ .. \\ [p_{2n-3} + (n\alpha - n + 2)(p_{2n-2} - p_{2n-3}),\ p_{2n+4} - (n\alpha - n + 2)(p_{2n+4} - p_{2n+3})]* \\ \qquad [q_{2n-3} + (n\alpha - n + 2)(q_{2n-2} - q_{2n-3}),\ q_{2n+4} - (n\alpha - n + 2)(q_{2n+4} - q_{2n+3})] & for\ \alpha \in [\frac{n-2}{n}, \frac{n-1}{n}] \\ [p_{2n-1} + (n\alpha - n + 1)(p_{2n} - p_{2n-1}),\ p_{2n+2} - (n\alpha - n + 1)(p_{2n+2} - p_{2n+1})]* \\ \qquad [q_{2n-1} + (n\alpha - n + 1)(q_{2n} - q_{2n-1}),\ q_{2n+2} - (n\alpha - n + 1)(q_{2n+2} - q_{2n+1})] & for\ \alpha \in [\frac{n-1}{n}, 1] \end{cases}$$

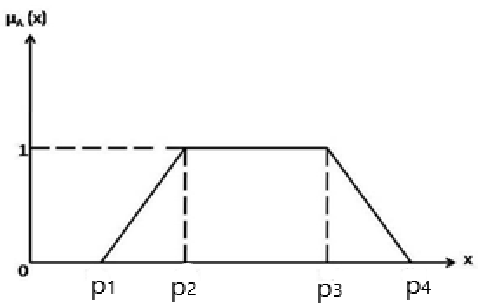
IV. Case-I for n=1 then m=4 (Trapezoidal Fuzzy Number):

$$P_4 = (p_1, p_2, p_3, p_4).$$

4.1 Membership Function

$$\mu_{P_4}(x) \begin{cases} 0 & if\ x \le p_1 \\ \frac{x - p_1}{p_2 - p_1} & if\, p_1 \le x \le p_2 \\ 1 & if\ p_2 \le x \le p_3 \\ \frac{p_4 - x}{p_4 - p_3} & if\, p_3 \le x \le p_4 \\ 0 & if\ x \ge p_4 \end{cases}$$

4.2 The graphically representation:



4.3 Arithmetic operations If $P_4 = (p_1, p_2, p_3, p_4)$ and $Q_4 = (q_1, q_2, q_3, q_4)$, then

- **Addition** $P_4+Q_4 = (p_1+q_1, p_2+q_2, p_3+q_3, p_4+q_4)$
- **Subtraction** $P_4-Q_4 = (p_1-q_1, p_2-q_2, p_3-q_3, p_4-q_4)$
- **Multiplication** $P_4*Q_4 = (p_1q_1, p_2q_2, p_3q_3, p_4q_4)$

4.4 Alpha cut: $For\ \alpha \in [0,1]$

$$[P_4]_\alpha = [p_1 + \alpha(p_2 - p_1),\ p_4 + \alpha(p_4 - p_3)]\ .$$

4.5 The α- cut for arithmetic operations:

For all $\alpha \in [0,1]$, If $P_4 = (p_1, p_2, p_3, p_4)$ and $Q_4 = (q_1, q_2, q_3, q_4)$, then

- **Addition** $[P_4]_\alpha + [Q_4]_\alpha = [p_1 + \alpha(p_2 - p_1),\ p_4 + \alpha(p_4 - p_3)] + [q_1 + \alpha(q_2 - q_1),\ q_4 + \alpha(q4-q3)$
- **Subtraction** $[P_4]_\alpha - [Q_4]_\alpha = [p_1 + \alpha(p_2 - p_1),\ p_4 + \alpha(p_4 - p_3)] - [q_1 + \alpha(q_2 - q_1),\ q_4 + \alpha(q4-q3)$
- **Multiplication** $[P_4]_\alpha * [Q_4]_\alpha = [p_1 + \alpha(p_2 - p_1),\ p_4 + \alpha(p_4 - p_3)] * [q_1 + \alpha(q_2 - q_1),\ q_4 + \alpha(q4-q3)$

V. Case-II for n=2, then m=8 (Octagonal fuzzy number):

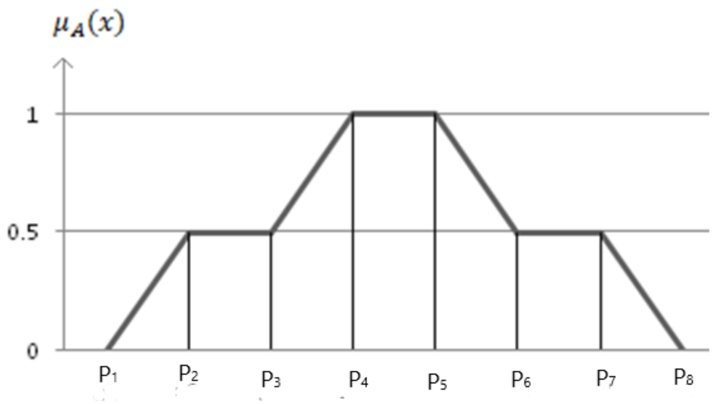
$$P_8 = (p_1, p_2, p_3, p_4, p_5, p_6, p_7, p_8).$$

5.1 Membership function:

$$\mu_{P_8}(x) = \begin{cases} 0 & for \quad 0 < p_1 \\ k_1(\frac{x - p_1}{p_2 - p_1}) & for \quad p_1 \le x \le p_2 \\ k_1 & for \quad p_2 \le x \le p_3 \\ k_1 + (1 - k_1)(\frac{x - p_3}{p_4 - p_3}) & for \quad p_3 \le x \le p_4 \\ 1 & for \quad p_4 \le x \le p_5 \\ k_1 + (1 - k_1)(\frac{p_6 - x}{p_6 - p_5}) & for \quad p_5 \le x \le p_6 \\ k_1 & for \quad p_6 \le x \le p_7 \\ k_1(\frac{p_8 - x}{p_8 - p_7}) & for \quad p_7 \le x \le p_8 \\ 0 & for \quad p_8 \le x \end{cases}$$

Where $0 \le k_1 \le 1$

5.2 The graphically representation:



5.3 Arithmetic Operations: If $P_8 = (p_1, p_2, p_3, p_4, p_5, p_6, p_7, p_8)$ and $Q_8 = (q_1, q_2, q_3, q_4, q_5, q_6, q_7, q_8)$, then

- **Addition** $P_8+Q_8 = (p_1+q_1, p_2+q_2, p_3+q_3, p_4+q_4, p_5+q_5, p_6+q_6, p_7+q_7, p_8+q_8)$
- **Subtraction** $P_8-Q_8 = (p_1-q_1, p_2-q_2, p_3-q_3, p_4-q_4, p_5-q_5, p_6-q_6, p_7-q_7, p_8-q_8)$
- **Multiplication** $P_8*Q_8 = (p_1q_1, p_2q_2, p_3q_3, p_4q_4, p_5q_5, p_6q_6, p_7q_7, p_8q_8)$

5.4 Alpha cut For all $\alpha \in [0,1]$ and $0\leq k_1\leq 1$ and $k_1= 0.5$

$$[P_8]_\alpha = \begin{cases} [p_1 + \frac{\alpha}{k_1}(p_2 - p_1), \quad p_8 - \frac{\alpha}{k_1}(p_8 - p_7)] & \text{for } \alpha \in [0, k_1] \\ [p_3 + (\frac{\alpha - k_1}{1-k_1})(p_4 - p_3), \quad p_6 - (\frac{\alpha - k_1}{1-k_1})(p_6 - p_5)] & \text{for } \alpha \in [k_1, 1] \end{cases}$$

5.5 The α- cut for arithmetic operations: For all $\alpha \in [0,1]$ and $0\leq k_1\leq 1$

If $P_8 = (p_1, p_2, p_3, p_4, p_5, p_6, p_7, p_8)$ and $Q_8 = (q_1, q_2, q_3, q_4, q_5, q_6, q_7, q_8)$, then

- **Addition:**

$$[P_8]_\alpha + [Q_8]_\alpha = \begin{cases} [p_1 + \frac{\alpha}{k_1}(p_2 - p_1), \; p_8 - \frac{\alpha}{k_1}(p_8 - p_7)] \\ \qquad + [q_1 + \frac{\alpha}{k_1}(q_2 - q_1), \; q_8 - \frac{\alpha}{k_1}(q_8 - q_7)] & \text{for } \alpha \in [0, k_1] \\ [p_3 + (\frac{\alpha - k_1}{1-k_1})(p_4 - p_3), \; p_6 - (\frac{\alpha - k_1}{1-k_1})(p_6 - p_5)] \\ \qquad + [q_3 + (\frac{\alpha - k_1}{1-k_1})(q_4 - q_3), \; q_6 - (\frac{\alpha - k_1}{1-k_1})(q_6 - q_5)] & \text{for } \alpha \in [k_1, 1] \end{cases}$$

- **Subtraction:**

$$[P_8]_\alpha - [Q_8]_\alpha = \begin{cases} [p_1 + \frac{\alpha}{k_1}(p_2 - p_1), \; p_8 - \frac{\alpha}{k_1}(p_8 - p_7)] \\ \qquad - [q_1 + \frac{\alpha}{k_1}(q_2 - q_1), \; q_8 - \frac{\alpha}{k_1}(q_8 - q_7)] & \text{for } \alpha \in [0, k_1] \\ [p_3 + (\frac{\alpha - k_1}{1-k_1})(p_4 - p_3), \; p_6 - (\frac{\alpha - k_1}{1-k_1})(p_6 - p_5)] \\ \qquad - [q_3 + (\frac{\alpha - k_1}{1-k_1})(q_4 - q_3), \; q_6 - (\frac{\alpha - k_1}{1-k_1})(q_6 - q_5)] & \text{for } \alpha \in [k_1, 1] \end{cases}$$

- **Multiplication**:

$$[P_8]_\alpha * [Q_8]_\alpha = \begin{cases} [p_1 + \frac{\alpha}{k_1}(p_2 - p_1), \; p_8 - \frac{\alpha}{k_1}(p_8 - p_7)] \\ \qquad * [q_1 + \frac{\alpha}{k_1}(q_2 - q_1), \; q_8 - \frac{\alpha}{k_1}(q_8 - q_7)] & \text{for } \alpha \in [0, k_1] \\ [p_3 + (\frac{\alpha - k_1}{1-k_1})(p_4 - p_3), \; p_6 - (\frac{\alpha - k_1}{1-k_1})(p_6 - p_5)] \\ \qquad * [q_3 + (\frac{\alpha - k_1}{1-k_1})(q_4 - q_3), \; q_6 - (\frac{\alpha - k_1}{1-k_1})(q_6 - q_5)] & \text{for } \alpha \in [k_1, 1] \end{cases}$$

We introduced 4th multiple polygonal fuzzy number in Table no 1 as below-

Table no1 (4th multiple polygonal fuzzy numbers)

S. No.	Type of fuzzy number m= 4n, n ∈ N		Name of polygonal fuzzy numbers
1	n= 1	m=4	Trapezoidal fuzzy number[5]
2	n= 2	m= 8	Octagonal fuzzy number[8]
3	n= 3	m = 12	Dodecagonal fuzzy number[6]
4	n= 4	m = 16	Hexadecagonal fuzzy number[1]
5	n= 5	m = 20	Icosagonal fuzzy number[9]
6	n= 6	m = 24	Icosikaitetragonal fuzzy number[3]
7	n= 7	m = 28	Icosikaioctagonal fuzzy number[10]
8	n = 8	m = 32	Triacontakaidigonal fuzzy number
- - -	- - - - - -	------ -- --- --- ---	- -
	For $n \in N$	m = 4n	4th multiple polygonal fuzzy number (purposed)

VI. Conclusion

The aim of this paper is to present generalized in 4th multiple polygon fuzzy numbers with arithmetic operation for the help of alpha cut technique. We also used graphical representation for proposed fuzzy number. This proposed technique is used for solving different type of fuzzy optimization problems in which 4th multiple polygonal fuzzy numbers are used. The complexity in solving this type of problems has reduced to easy computation.

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