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Introduction to Plithogenic Sociogram with preference representations by Plithogenic Number

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A B S T R A C T

The theory of Plithogeny is gaining momentum in recent times as it generalizes the concepts of fuzzy, intuitionistic, neutrosophy and other extended representations of fuzzy sets. The relativity of the comprehensive and accommodative nature of plithogenic sets in dealing with attributes shall be applied to handle the decision–making problems in the field of sociology. This paper introduces the concepts of Plithogenic Sociogram (PS) and Plithogenic Number (PN) where the former is the integration of plithogeny to the sociometric technique of sociogram and the latter is the generalization of fuzzy, intuitionistic and neutrosophic numbers that shall be used in representations of preferences in group dynamics. This research work outlines the conceptual development of these two newly proposed concepts and discusses the merits of the existing theory of similar kind with suitable substantiation. The plithogenic sociogram model encompassing the attributive preferences with plithogenic number representation is also developed to explicate how it can be materialized in the real social field. A conjectural illustration is put forth to analyze the efficiency and the feasibility of the proposed plithogenic sociogram model and its function in decision-making. This paper also throws light on generalized plithogenic number, dominant attribute constrained plithogenic number and combined dominant attribute constrained plithogenic number together with its operations and suitable illustrations.

1. Introduction

The social relationship is the resultant of the social interaction between persons and the longevity of their relationship depends on the alikeness in thoughts, behaviour and sometimes the influence of one’s attribute over another. The formation of social groups for carrying out group activities is

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sometimes deliberate but quite natural in any social setting ranging from small schools, organizations to mammoth industries. Should we concern about the strength of the interrelationship between the members of the group? Will making the bond strong between the members benefit the group? The answer is certainly yes, because the extent of functioning as a group with common objectives and the success in goal attainment depends on the coordination and cooperativeness of the members of the group. Hence, the study of interpersonal relationships in a group, preferably a social group has greater significance in group dynamics. Sociogram developed by Jacob Levy Moreno [1] is one of the sociometric techniques that is widely used in the quantitative study on interpersonal relationship. This technique is used to determine the structure of interrelationship in a group setting by determining the order of preferences of the members of the group to work with through a questionnaire. The preferential positions of the members determine the most influential and isolated people of the group and as the result, the decision-makers or the group coordinators can work on enhancing interpersonal relationship and make other alternatives for improving the group efficiency.

Conventional sociogram characterized by crisp preferential ordering, matrix and graphical representations finds several applications in a various social setting. The uncertainty in the order of preferences led to the development of fuzzy sociogram with fuzzy matrix and fuzzy graphical representations and it has made the researchers explore its applicability in determining the interrelationship between the members [2,3]. The decision-making environment is characterized not only by uncertainty but also indeterminacy, to handle such circumstances, Smarandache [4,5]introduced neutrosophic sets which consist of truth values, indeterminacy values and falsity values. Neutrosophic sets are used in decision-making on green supply chain management [6], decision support systems and in many other. Gustavo et al [7] extended fuzzy sociogram to neutrosophic sociogram to incorporate the notion of the existence of indeterminacy in relationships. The preferential ordering is certainly influenced by the indeterminacy that occurs when the members are not sure of certain attributes of others and also they may not sure of their compatibility or suitability to perform a particular task. A hypothetical example was used to illustrate the applicability of the neutrosophic sociogram model to group analysis. On profound analysis over the transition from conventional or the classical sociogram to neutrosophic sociogram, the order of preferences or the preferential ordering is influenced by certainty in the case of classical, uncertainty in the case of fuzzy and indeterminacy in the case of neutrosophic. This fact has led the authors to investigate the factors that influence preferential ordering as it is the deciding factor of the nature of the sociogram. This is the origin of the Plithogenic sociogram which encompasses the attributive preferential ordering, i.e order of preference based on the attributives of the members. Before making the order of preferences, in the sociograms of earlier kinds, the activities (such as quiz program, team-based tasks) that require group work are stated first and the members express their preference for working with others, but in the realm, the choice of choosing or giving preference to the members to get involved in activity also depends on the attributes possessed by the members that are essential to make partnership to take part in any particular activity and many times these attributes may be an essential requisite to take part in the activity or the activities may itself demand the same. In such circumstances, the preferential ordering will be characterized not just by stating the members preferred alone but it also carries the additional information on why the members are being preferred and naturally it brings the attributes of the members and the extent to which the members possess in the perception of the choice-maker, i.e the person who makes the preference. The making of choice in preferring a person depending on the attributes has led to the development of Plithogenic sociogram and on exploring will certainly yield better results.

Plithogeny is the recently evolved philosophy that deals with the evolution of entities and their attributes. Smarandache [8] introduced Plithogenic sets that are widely applied in decision making on sustainability [9], medical decision system model [10] and supply chain management [11]. Plithogenic sets are used in decision making as it is highly embedded with wide-ranging generalization approaches in accommodating crisp, fuzzy, intuitionistic, neutrosophic sets and the other kinds of extended sets. The preferential ordering assumes either crisp, fuzzy or neutrosophic values, but if the preferential ordering presumes linguistic representation then the linguistic variable requires to be quantified using either fuzzy, intuitionistic or neutrosophic numbers. To make such kind of representations more comprehensive, the notion of plithogenic number shall be used. This research work intends to investigate and unveil the Plithogenic sociogram with plithogenic number representing the preferential ordering.

The paper is structured into the following sections, section 2 introduces plithogenic number and discusses their nature; section 3 describes plithogenic sociogram and its utility in decision making and the last section concludes the work.

2. Plithogenic Number

Zadeh [12] introduced Fuzzy numbers and their arithmetic operations to characterize uncertainty. A fuzzy number is a fuzzy set if it is a normal fuzzy set with bounded support and alpha cut being a closed interval for every alpha belonging to [0,1]. The fuzzy numbers are the special kind of fuzzy sets used to quantify linguistic variables and it is applied to represent quantities that are uncertain in nature, for instance, the costs parameters, demand are represented as fuzzy numbers. Luciano et al [13,14] discussed fuzzy numbers, fuzzy arithmetic. Mike et al [15] presented the different kinds of fuzzy numbers and their properties. Saed et al [16] described special kinds of fuzzy numbers. Przemyslaw et al [17] illustrated the applications of fuzzy numbers. Thus, fuzzy numbers are the simple form of representing uncertainty and are extended to intuitionistic fuzzy numbers which are the next higher or extended form that are extensively applied in decision-making models. Atanassov [18] introduced the concept of intuitionistic sets. Intuitionistic fuzzy numbers are characterized by membership and non-membership values. Mahapatra et al [19] briefed the applications of an intuitionistic fuzzy number. Mijanu et al [20] presented the various kinds of intuitionistic fuzzy numbers. Researchers have discussed the different ordering techniques of IFN [21-23]. Smarandache extended Intuitionistic sets to neutrosophic sets and discussed the arithmetic operations of neutrosophic numbers. Neutrosophic numbers are the extended or the higher forms of representing uncertainty. Sapna et al [24] described single-valued neutrosophic number, Sun et al [25] elaborated interval-valued neutrosophic number, Faruk [26] explored Gaussian neutrosophic number, Avishek et al [27] discussed the applications of Cylindrical neutrosophic single-valued number in networking, decision making. Researchers like Rajesh et al [28], Nancy et al [29] stated the applications of neutrosophic number in various fields of decision making [30]. Neutrosophic numbers are the extended forms of intuitionistic and fuzzy numbers and neutrosophic numbers can be stated as higher forms or super forms of fuzzy numbers. The defuzzification techniques of the extended higher/super forms of fuzzy numbers to its next sub forms of fuzzy numbers are also discussed by Dragan et al [31], Radhika et al [32], Ali Mert [33], Luca et al [34], and many others. The above discussed forms of fuzzy numbers ranging from simple to higher versions shall be generalized into plithogenic number.

Classical Plithogenic set is characterized by (P, a, V, d, c), where P is a set, a is the attribute, V is the set of attribute values, d is the degree of appurtenance stating the extent of elements belonging to P satisfying the attribute values and c is the contradiction degree. In this work, the plithogenic set is newly characterized as (P, A, V A, d, c), where A is a system of attributes and V A is the set of all possible attribute values corresponding to each attribute a in A. The classical characterization is with respect to a single attribute and this newly proposed pertains to the system of attributes. To define plithogenic number, the attributes should also be considered and the plithogenic number can also be differentiated into Plithogenic fuzzy number, plithogenic intuitionistic fuzzy number, plithogenic neutrosophic number based on the degree of appurtenance

Let U be a universe of discourse, and a non-empty set M included in U.

Let x be a generic element from M.

Let's consider the attributes A_1, A_2,..,.A_n, for $n \geq 1$.

The attribute A_1 has the attribute values A_{11}, A_{12}, ..., A_{1m1}, where $m_1 \geq 1$.

The attribute A_2 has the attribute values A_{21}, A_{22}, ..., A_{2m2}, where $m_2 \geq 1$.

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The attribute An has the attribute values A_{n1}, A_{n2}, ...,A_{nm} where m, $n \geq 1$.

The plithogenic fuzzy number will be of the form

M = {x($A_{11}(t_{11})$, $A_{12}(t_{12})$, ..., $A_{1m1}(t_{1m1})$; $A_{21}(t_{21})$, $A_{22}(t_{22})$, ..., $A_{2m2}(t_{2m2})$; ... $A_{n1}(t_{n1})$, $A_{n2}(t_{n2})$, $A_{nm}(t_{nm})$; with x in U} ,

where

t_{11} is the degree of appurtenance of element x to the set M with respect to the attribute value A_{11};

t_{12} is the degree of appurtenance of element x to the set M with respect to the attribute value A_{12}; etc.

The plithogenic intuitionistic fuzzy number will be of the form

M = {x($A_{11}(t_{11}, f_{11})$, $A_{12}(t_{12}, f_{12})$, ..., $A_1m_1(t_1m_1, f_1m_1)$; $A_{21}(t_{21}, f_{21})$, $A_{22}(t_{22}, f_{22})$, ..., $A_{2m2}(t_{2m2}, f_{2m2})$; ... $A_{n1}(t_{n1}, f_{n1})$, $A_{n2}(t_{n2}, f_{n2})$, A_{nm} (t_{nm}, f_{nm}); with x in U} ,

Where

t_{11} is the degree of appurtenance of element x to the set M with respect to the attribute value $A_{11}$and f_{11} is the degree of non-appurtenance of element x to the set M with respect to the attribute value A_{11};

t_{12} is the degree of appurtenance of element x to the set M with respect to the attribute value $A_{12}$and f_{12} is the degree of non-appurtenance of element x to the set M with respect to the attribute value A_{12}; etc.

The neutrosophic plithogenic set:

$M = \{x(A_{11}(t_{11}, i_{11}, f_{11}), A_{12}(t_{12}, i_{12}, f_{12}), ..., A_{1m1}(t_{1m1}, i_{1m1}, f_{1m1});\quad A_{21}(t_{21}, i_{21}, f_{21}), A_{22}(t_{22}, i_{22}, f_{22}), ..., A_{2m2}(t_{2m2}, i_{2m2}, f_{2m2});\quad ...\quad A_{n1}(t_{n1}, i_{n1}, f_{n1}), A_{n2}(t_{n2}, i_{n2}, f_{n2}), A_{nm}(t_{nm}, i_{nm}, f_{nm})$; with x in U} ,

where

t_{11} is the degree of appurtenance of element x to the set M with respect to the attribute value A_{11},i_{11} is the degree of indeterminacy of element x to the set M with respect to the attribute value $A_{11}$and f_{11} is the degree of non-appurtenance of element x to the set M with respect to the attribute value A_{11};

t_{12} is the degree of appurtenance of element x to the set M with respect to the attribute value A_{12},i_{12} is the degree of indeterminacy of element x to the set M with respect to the attribute value $A_{12}$and f_{12} is the degree of non-appurtenance of element x to the set M with respect to the attribute value A_{12}; etc.

Example

Let U = { a, b, c, d, e, f}, M = { b, c,e}, A = { a_1,a_2,a_3}, V_{a1} = { A_{11},A_{12},A_{13}}, Va_2 = { A_{21},A_{22}} Va_3 = {A_{31},A_{32},A_{33},A_{34}}.

Contradiction Degree		0	1/3	2/3	0	½	0	¼	2/4	3/4
Attribute Values		A_{11}	A_{12}	A_{13}	A_{21}	A_{22}	A_{31}	A_{32}	A_{33}	A_{34}
Fuzzy Degree of Appurtenance	b	0.2	0.5	0.6	0.7	0.6	0.5	0.4	0.8	0.9
	c	0.3	0.5	0.6	0.5	0.8	0.9	0.7	0.5	0.6
	e	0.5	0.6	0.4	0.7	0.5	0.6	0.8	0.4	0.5
Intuitionistic Degree of Appurtenance	b	(0.7,0.2)	(0.8,0.1)	(0.4,0.6)	(0.7,0.3)	(0.6,0.2)	(0.7,0.1)	(0.8,0.2)	(0.6,0.3)	(0.5,0.3)
	c	(0.8,0.1)	(0.7,0.3)	(0.5,03)	(0.6,0.2)	(0.7,0.3)	(0.6,0.3)	(0.7,0.2)	(0.8,0.1)	(0.6,0.2)
	e	(0.5,0.3)	(0.8,.01)	(0.7,0.2)	(0.8,0.2)	(0.8,0.1)	(0.6,0.2)	(0.7,0.2)	(0.5,0.3)	(0.6,0.3)
Neutrosophic Degree of Appurtenance	b	(0.7,0.2,0.3)	(0.8,0.1,0.3)	(0.6,0.4,0.5)	(0.7,0.2,0.3)	(0.6,0.2,0.3)	(0.5,0.2,0.4)	(0.5,0.1,0.3)	(0.7,0.2,0.3)	(0.7,0.2, 0.2)
	c	(0.5,0.1,0.3)	(0.7,0.2,0.3	(0.5,0.1,0.3)	(0.5,0.2,0.4)	(0.7,0.2,0.3)	(0.6,0.4,0.2)	(0.4,0.1,0.3)	(0.7,0.2,0.2)	(0.8,0.1, 0.3)
	e	0.8,0.1,0.3)	(0.5,0.1,0.3)	(0.6,0.4,0.5)	(0.7,0.2,0.3)	(0.5,0.1,0.3)	(0.7,0.2,0.3)	(0.6,0.4,0.5)	(0.5,0.1,0.3)	(0.7,0.2, 0.2)

The plithogenic number with fuzzy degree of appurtenance to all the attribute values will be of the form P={b(A11(0.2), A_{12}(0.5), A_{13}(0.6), A_{21}(0.7), A_{22}(0.6), A_{31}(0.5), A_{32}(0.4), A_{33}(0.8), A_{34}(0.9)), c(A11(0.3), A_{12}(0.5), A_{13}(0.6), A_{21}(0.5), A_{22}(0.8), A_{31}(0.9), A_{32}(0.7), A_{33}(0.5), A_{34}(0.6))}This plithogenic number may be termed as generalized plithogenic fuzzy number as it encompasses all the attribute values. From the values of intuitionistic and neutrosophic degrees of appurtenance to all the attribute values the generalized plithogenic intuitionistic and generalized plithogenic neutrosophic numbers can be defined.

2.1 Dominant Attribute Constrained Plithogenic Number

This section also proposes the concept of dominant attribute constrained Plithogenic number and it shall be defined by considering only the dominant attribute values.

Let U = { a, b, c, d, e, f}, M = { b, c,e}, A = { a_1,a_2,a_3}, V_{a1} = { $\mathbf{A_{11}}$,A_{12},A_{13}}, Va_2 = {$\mathbf{A_{21}}$,A_{22}}

Va_3 = {$\mathbf{A_{31}}$,A_{32},A_{33},A_{34}}.

In this example, the attribute values A_{11}, A_{21}, A_{31} are considered to be dominant and the plithogenic number considering the values of degree of appurtenance corresponding only to the dominant attribute values are called as **Dominant Attribute Constrained Plithogenic Number.**

Let P1 = {b (A_{11}(0.5), A_{21}(0.7),A_{31}(0.8)) , c (A_{11}(0.4), A_{21}(0.5),A_{31}(0.6)), b (A_{11}(0.4), A_{21}(0.6),A_{31}(0.7))} and P2 = {b (A_{11}(0.6), A_{21}(0.5),A_{31}(0.3)) , c (A_{11}(0.5), A_{21}(0.2),A_{31}(0.5)), b (A_{11}(0.5), A_{21}(0.6),A_{31}(0.8))}where P1 and P2 are the Dominant Attribute Constrained plithogenic fuzzy numbers with fuzzy degree of appurtenance with respect to the dominant attribute values.

The union of two Dominant Attribute Constrained plithogenic fuzzy numbers is $P1U_FP2$ is defined as max {a1($A_\alpha(t_\alpha)$, $A_\beta(t_\beta)$, ..., $A_\lambda(t_\lambda)$), a2 ($A_\alpha(t_\alpha)$, A_β (t_β), ..., A_λ (t_λ)),……am($A_\alpha(t_\alpha)$, A_β (t_β), ..., A_λ (t_λ))}

Where A_α , A_β, …. A_λ are the dominant attribute values and t_α , t_β, …. t_λ are the respective fuzzy degree of appurtenance with respective to each elements of M.

$P1U_FP2$={b (A_{11}(0.6), A_{21}(0.7),A_{31}(0.8)) , c (A_{11}(0.5), A_{21}(0.5),A_{31}(0.6)), b (A_{11}(0.5), A_{21}(0.6),A_{31}(0.8))}

The intersection of two Dominant Attribute Constrained plithogenic fuzzy numbers is P1 $\cap_F$P2 is defined as min {a1($A_\alpha(t_\alpha)$, A_β (t_β), ..., A_λ (t_λ)), a2 ($A_\alpha(t_\alpha)$, A_β (t_β), ..., A_λ (t_λ)),……am($A_\alpha(t_\alpha)$, A_β (t_β), ..., A_λ (t_λ))}

P1 $\cap_F$P2= {b (A_{11}(0.5), A_{21}(0.5),A_{31}(0.3)) , c (A_{11}(0.4), A_{21}(0.2),A_{31}(0.5)), b (A_{11}(0.4), A_{21}(0.6),A_{31}(0.7))}

Let P1 = {b (A_{11}(0.7,0.2), A_{21}(0.8,0.1), A_{31}(0.7,0.1)) , c (A_{11}(0.7,0.3), A_{21}(0.4,0.6), A_{31}(0.5,03)), e (A_{11}(0.6,0.2), A_{21}(0.5,0.3), A_{31}(0.7,0.2)} and

P2 = { b (A_{11}(0.6,0.3), A_{21} (0.5,0.3), A_{31}(0.6,0.3)) , c (A_{11}(0.7,0.1), A_{21}(0.5,03), A_{31}(0.7,0.3)), e (A_{11}(0.5,0.3), A_{21}(0.6,0.3), A_{31} (0.8,0.2))} where P1 and P2 are the Dominant Attribute Constrained plithogenic intuitionistic fuzzy numbers with intuitionistic fuzzy degree of appurtenance with respect to the dominant attribute values.

The union of two Dominant Attribute Constrained plithogenic intuitionistic fuzzy numbers is $P1U_{IF}P2$ is defined as (max {a1($A_\alpha(t_\alpha)$, A_β (t_β), ..., A_λ (t_λ)), a2 ($A_\alpha(t_\alpha)$, A_β (t_β), ..., A_λ

$(t_\lambda)), \ldots\ldots am(A_\alpha(t_\alpha), A_\beta(t_\beta), ..., A_\lambda(t_\lambda))$, min $\{a1(A_\alpha(f_\alpha), A_\beta(f_\beta), ..., A_\lambda(f_\lambda)), a2(A_\alpha(f_\alpha), A_\beta(f_\beta), ..., A_\lambda(f_\lambda)), \ldots\ldots am(A_\alpha(f_\alpha), A_\beta(f_\beta), ..., A_\lambda(f_\lambda))\}$

$P1U_{IF}P2$ ={b (A_{11}(0.7,0.2), A_{21}(0.8,0.1), A_{31}(0.7,0.1)) , c (A_{11}(0.7,0.1), A_{21}(0.5,0.3), A_{31}(0.7,03)), e (A_{11}(0.6,0.2), A_{21}(0.6,0.3), A_{31}(0.8,0.2)}

The intersection of two Dominant Attribute Constrained plithogenic intuitionistic fuzzy numbers is $P1\cap_{IF}P2$ is defined as (min$\{a1(A_\alpha(t_\alpha), A_\beta(t_\beta), ..., A_\lambda(t_\lambda)), a2(A_\alpha(t_\alpha), A_\beta(t_\beta), ..., A_\lambda(t_\lambda)), \ldots\ldots am(A_\alpha(t_\alpha), A_\beta(t_\beta), ..., A_\lambda(t_\lambda))$, max $\{a1(A_\alpha(f_\alpha), A_\beta(f_\beta), ..., A_\lambda(f_\lambda)), a2(A_\alpha(f_\alpha), A_\beta(f_\beta), ..., A_\lambda(f_\lambda)), \ldots\ldots am(A_\alpha(f_\alpha), A_\beta(f_\beta), ..., A_\lambda(f_\lambda))\}$

$P1\cap_{IF}P2$ = {b (A_{11}(0.6,0.3), A_{21}(0.5,0.3),A_{31}(0.6,0.3)) , c (A_{11}(0.7,0.3), A_{21} (0.4,0.6),A_{31}(0.5,03)), e (A_{11}(0.5,0.3), A_{21}(0.5,0.3), A_{31}(0.7,0.2)}

Let P1 = {b (A_{11}(0.7,0.2,0.3), A_{21}(0.8,0.1,0.3) , A_{31}(0.6,0.4,0.5)), c (A_{11}(0.6,0.4,0.2), A_{21}(0.5,0.1,0.3), A_{31} (0.7,0.2,0.2)), e (A_{11}(0.6,0.2,0.1), A_{21}(0.5,0.1,0.3), A_{31} (0.7,0.2,0.3)} and

P2 = { b (A_{11}(0.6,0.2,0.3) , A_{21} (0.5,0.2,0.4), A_{31}(0.6,0.4,0.2)),c (A_{11}(0.7,0.2,0.3), A_{21}(0.5,0.2,0.4), A_{31}(0.7,0.2,0.3)), e (A_{11}(0.6,0.4,0.2), A_{21}(0.7,0.2,0.3), A_{31}(0.8,0.1,0.3))} where P1 and P2 are the Dominant Attribute Constrained plithogenic neutrosophic numbers with neutrosophic degree of appurtenance with respect to the dominant attribute values.

The union of two Dominant Attribute Constrained plithogenic neutrosophic numbers is $P1U_NP2$ is defined as (max $\{a1(A_\alpha(t_\alpha), A_\beta(t_\beta), ..., A_\lambda(t_\lambda)), a2(A_\alpha(t_\alpha), A_\beta(t_\beta), ..., A_\lambda(t_\lambda)), \ldots\ldots am(A_\alpha(t_\alpha), A_\beta(t_\beta), ..., A_\lambda(t_\lambda))$, max $\{a1(A_\alpha(I_\alpha), A_\beta(I_\beta), ..., A_\lambda(I_\lambda)), a2(A_\alpha(I_\alpha), A_\beta(I_\beta), ..., A_\lambda(I_\lambda)), \ldots\ldots am(A_\alpha(I_\alpha), A_\beta(I_\beta), ..., A_\lambda(I_\lambda))$,min $\{a1(A_\alpha(f_\alpha), A_\beta(f_\beta), ..., A_\lambda(f_\lambda)), a2(A_\alpha(f_\alpha), A_\beta(f_\beta), ..., A_\lambda(f_\lambda)), \ldots\ldots am(A_\alpha(f_\alpha), A_\beta(f_\beta), ..., A_\lambda(f_\lambda))\})$

$P1U_NP2$ = = { b (A_{11}(0.7,0.2,0.3) , A_{21} (0.8,0.2,0.3), A_{31}(0.6,0.4,0.2)),c (A_{11}(0.7,0.4,0.2), A_{21}(0.5,0.2,0.3), A_{31}(0.7,0.2,0.2)), e (A_{11}(0.6,0.4,0.1), A_{21}(0.7,0.2,0.3), A_{31}(0.8,0.2,0.3))}

The intersection of two Dominant Attribute Constrained plithogenic neutrosophic numbers is $P1\cap_N P2$ is defined as (min $\{a1(A_\alpha(t_\alpha), A_\beta(t_\beta), ..., A_\lambda(t_\lambda)), a2(A_\alpha(t_\alpha), A_\beta(t_\beta), ..., A_\lambda(t_\lambda)), \ldots\ldots am(A_\alpha(t_\alpha), A_\beta(t_\beta), ..., A_\lambda(t_\lambda))$, max $\{a1(A_\alpha(I_\alpha), A_\beta(I_\beta), ..., A_\lambda(I_\lambda)), a2(A_\alpha(I_\alpha), A_\beta(I_\beta), ..., A_\lambda(I_\lambda)), \ldots\ldots am(A_\alpha(I_\alpha), A_\beta(I_\beta), ..., A_\lambda(I_\lambda))$,max $\{a1(A_\alpha(f_\alpha), A_\beta(f_\beta), ..., A_\lambda(f_\lambda)), a2(A_\alpha(f_\alpha), A_\beta(f_\beta), ..., A_\lambda(f_\lambda)), \ldots\ldots am(A_\alpha(f_\alpha), A_\beta(f_\beta), ..., A_\lambda(f_\lambda))\})$

$P1\cap_N P2$ = {b (A_{11}(0.6,0.2,0.3), A_{21}(0.5,0.1,0.4) , A_{31}(0.6,0.4,0.5)), c (A_{11}(0.6,0.4,0.3), A_{21}(0.5,0.2,0.4), A_{31}(0.7,0.2,0.3)), e (A_{11}(0.6,0.4,0.2), A_{21}(0.5,0.2,0.3), A_{31}(0.7,0.2,0.3)}

2.2 Combined Dominant Attribute Constrained Plithogenic Number

In **Combined Dominant Attribute Constrained Plithogenic Number**, the attribute values possess combined degree of appurtenance of the attribute values. For instance

P1 = {b (A_{11}(0.7,0.2), A_{21}(0.8,0.1),A_{31} (0.7,0.1)) , c (A_{11}(0.5), A_{21} (0.5),A_{31} (0.3),e (A_{11}(0.6,0.4,0.2), A_{21}(0.5,0.2,0.3), A_{31}(0.7,0.2,0.3)} In this plithogenic representation, the element b has intuitionistic degree of appurtenance with respect to the attribute values, the element c has fuzzy degree of

appurtenance with respect to the attribute values and the element e has neutrosophic degree of appurtenance with respect to the attribute values.
On other hand the combined plithogenic number can also be represented as
P1 = {b (A_{11}(0.7,0.2), A_{21} (0.8), A_{31}(0.7,0.1,0.1)) , c (A_{11} (0.5), A_{21}(0.7,0.2) , A_{31} (0.3)),e (A_{11}(0.6,0.4,0.2), A_{21}(0.5,0.2), A_{31} (0.7)} in which the element b has the combination of intuitionistic, fuzzy and neutrosophic degree of appurtenance with respect to the dominant attribute values and the other elements c and e also have a combination of degree of appurtenance.

The union and intersection of combined Plithogenic numbers shall be computed after converting the combined degrees of appurtenance into a same degree of appurtenance using 2.1,2.2 or 2.3

2.1 Method I (Imprecision membership):Any neutrosophic fuzzy set $N_A = (T_A,\ I_A, F_A)$ including neutrosophic fuzzy values are transformed into intuitionistic fuzzy values or vague values as η(A) = $(T_A,\ f_A)$ where f_A is estimated the formula stated below which is called as Impression membership method. [35]

$$f_A = \begin{cases} F_A + \frac{[1-F_A-I_A][1-F_A]}{[F_A+I_A]} & if\ F_A = 0 \\ F_A + \frac{[1-F_A-I_A][F_A]}{[F_A+I_A]} & if\ \ 0 < F_A \leq 0.5 \\ F_A + [1-F_A-I_A]\left[0.5 + \frac{F_A-0.5}{F_A+I_A}\right] & if\ 0.5 < F_A \leq 1 \end{cases}$$

2.2 Method II (Defuzzification):After Method I (Median membership), intuitionistic (vague)

fuzzy values of the form η(A)= (T_A, f_A) are transformed into fuzzy set including fuzzy values

as<Δ(A)> = $<\frac{T_A}{[T_A+f_A]}>$. [35]

2.3 The score function of the intuitionistic set of the form(μ_A, ϑ_A) is μ_A-ϑ_A. [35]

Let P1 = {b (A_{11}(0.7,0.2), A_{21} (0.8), A_{31}(0.7,0.1,0.1)) , c (A_{11} (0.5), A_{21}(0.7,0.2) , A_{31} (0.3)),e (A_{11}(0.6,0.4,0.2), A_{21}(0.5,0.2), A_{31} (0.7)} and P2 = {b (A_{11}(0.7), A_{21}(0.5,0.2), A_{31} (0.6)), c (A_{11}(0.5,0.2), A_{21} (0.8), A_{31} (0.2)),e (A_{11}(0.6,0.4), A_{21}(0.5,0.2,0.1), A_{31} (0.5)} be two combined plithogenic number with different degrees of appurtenance and it can be converted to plithogenic number with same degree of appurtenance using the above methods I and II. The modified plithogenic numbers are

P_1'= {b (A_{11}(0.5), A_{21} (0.8), A_{31} (0.58)), c (A_{11}(0.5), A_{21} (0.5), A_{31} (0.3)),e (A_{11}(0.64), A_{21} (0.3), A_{31} (0.7))} and P_2' = {b (A_{11}(0.7), A_{21} (0.3), A_{31} (0.6)), c (A_{11}(0.3), A_{21} (0.8) , A_{31} (0.2)),e (A_{11} (0.2), A_{21} (0.6), A_{31} (0.5)}

$P_1' \cup P_2'$ = {b (A_{11} (0.7), A_{21} (0.8), A_{31} (0.6)), c (A_{11} (0.5), A_{21} (0.8) , A_{31} (0.3)),e (A_{11} (0.64), A_{21} (0.6), A_{31} (0.7)}

$P_1' \cap P_2'$= {b (A_{11} (0.5), A_{21} (0.3), A_{31} (0.58)), c (A_{11} (0.3), A_{21} (0.5) , A_{31} (0.2)),e (A_{11} (0.2), A_{21} (0.6), A_{31} (0.5)}

3. Plithogenic Sociogram

In this section, the concept of Plithogenic sociogram is discussed with a simple illustration based on the conceptualization of Neutrosophic sociogram developed by Smarandache. A group of members are given a questionnaire to give their choices of preference in partaking as a team with other members based on certain attributives.

Let S = {s_1,s_2,s_3,s_4,s_5} be the members interviewed with the following questions. The members are asked to give their preferential choices of teaming with respect to the attributes.

Write your friends with whom you want to work as a team with respect to their

Q_1: Degree of compatibility
Q_2: Optimistic approaches
Q_3: Disciplinary Knowledge
These questions are focusing on the attributive preferential choice making.

The attributes are the degree of compatibility, optimistic approach and disciplinary knowledge. The attribute values of the attributes are as follows

Degree of compatibility = {low (Q_{11}), moderate (Q_{12}), **high (Q_{13})**}

Optimistic Approach = {**Dispositional (Q_{21})**, Unrealistic (Q_{22}), comparative (Q_{23})}

Disciplinary Knowledge = {**Excellent (Q_{31})**, good (Q_{32}), average (Q_{33})}

The preferential choice making of the members with respect to the dominant attributive values say high (Q_{13}), Dispositional (Q_{21}), Excellent (Q_{31}) are presented in the form of Dominant attribute constrained plithogenic number in Table 3.1

Table 3.1 Attributive Preferential Choice-making of the Members

Members	Attributive Preferential Choice-making
s_1	{$s_2(Q_{13}(0.5),Q_{21}(0.6),Q_{31}(0.8)),s_4(Q_{13}(0.6),Q_{21}(0.7),Q_{31}(0.8))$}
s_2	{$s_1(Q_{13}(0.4),Q_{21}(0.7),Q_{31}(0.6)),s_3(Q_{13}(0.5),Q_{21}(0.6),Q_{31}(0.9))$, $S_5(Q_{13}(0.3),Q_{21}(0.4),Q_{31}(0.6))$}
s_3	{$s_2(Q_{13}(0.5),Q_{21}(0.6),Q_{31}(0.7)),s_4(Q_{13}(0.4),Q_{21}(0.2),Q_{31}(0.5))$}
s_4	{$s_1(Q_{13}(0.7),Q_{21}(0.8),Q_{31}(0.6)),s_3(Q_{13}(0.7),Q_{21}(0.5),Q_{31}(0.3))$}
s_5	{$s_2(Q_{13}(0.5),Q_{21}(0.6),Q_{31}(0.7)),s_4(Q_{13}(0.5),Q_{21}(0.6),Q_{31}(0.6))$}

S_1 prefers $S_2$with the Plithogenic fuzzy degree of appurtenance of 0.5 to high degree of compatibility, 0.6 to dispositional optimistic approach and 0.8 to excellent disciplinary knowledge and similarly the preference to S_4 can also be comprehended with the help of fuzzy degree of appurtenance. The approach of Plithogenic sociogram is based on the methodology of neutrosophic sociogram.

The evaluation matrix $M_k = (m_{gh})$, where m_{gh} assumes the degree of appurtenance (in this case, it is fuzzy) of the member s_g selecting s_h with respect to the dominant attribute values and when g=h m_{gh} =

0. In neutrosophic sociogram the elements of the evaluation matrix assumes either 0 or 1 based on the number of times a member selects another.

The evaluation matrix M_1 for the dominant attribute value Q_{13} is

	s_1	s_2	s_3	s_4	s_5
s_1	0	0.5	0	0.6	0
s_2	0.4	0	0.5	0	0.3
s_3	0	0.5	0	0.4	0
s_4	0.7	0	0.7	0	0
s_5	0	0.5	0	0.5	0

The evaluation matrix M_2 for the dominant attribute value Q_{21} is

	s_1	s_2	s_3	s_4	s_5
s_1	0	0.6	0	0.7	0
s_2	0.7	0	0.6	0	0.4
s_3	0	0.6	0	0.2	0
s_4	0.8	0	0.5	0	0
s_5	0	0.6	0	0.6	0

The evaluation matrix M_3 for the dominant attribute value Q_{31} is

	s_1	s_2	s_3	s_4	s_5
s_1	0	0.8	0	0.8	0
s_2	0.6	0	0.9	0	0.6
s_3	0	0.7	0	0.5	0
s_4	0.6	0	0.3	0	0
s_5	0	0.7	0	0.6	0

In neutrosophic sociogram each question was given weightage but here in Plithogenic sociogram the dominant attributes are given weightage. By considering the weights of the dominant attributes values, the final weighted evaluation matrix is determined by assigning the weights as 0.5, 0.25 and 0.25 to the dominant attribute values high (Q_{13}), Dispositional (Q_{21}) and Excellent (Q_{31}) respectively.

	s_1	s_2	s_3	s_4	s_5
s_1	0	0.6	0	0.675	0

s_2	0.525	0	0.625	0	0.4
s_3	0	0.575	0	0.375	0
s_4	0.7	0	0.55	0	0
s_5	0	0.575	0	0.55	0

The fuzzy amicable degree t_{gh} is calculated by using the formula

$\frac{2}{t_{gh}} = \frac{1}{f_{gh}} + \frac{1}{f_{hg}}$, where f_{gh} represents the compatibility existing between the members g and h which means the member g prefers h and it is vice-versa for f_{hg}

The final scores of the members s_g(i = 1,2,..5) of the group, F (s_g) is determined by $\frac{\sum_h t_{gh}}{\sum_g \sum_h t_{gh}}$

	s_1	s_2	s_3	s_4	s_5
s_1	0	0.56	0	0.69	0
s_2	0.56	0	0.6	0	0.47
s_3	0	0.6	0	0.45	0
s_4	0.69	0	0.45	0	0
s_5	0	0.47	0	0	0

Table 3.2 Preferential scores of the members

s_1	0.225632
s_2	**0.294224**
s_3	0.189531
s_4	0.205776
s_5	0.084838

Based on the scores as in Table 3.2, it is very vivid that the member s_2 has the maximum score and it represents the significance of the member s_2 in the group and his influencing attributes have made s_2 more preferable, on other hand, the member s_5 has the least score and it shows that the member is not much preferred as the attributes of s_5 may not seems to be influential. This preferential ranking is based on considering plithogenic fuzzy degree of appurtenance. Plithogenic intuitionistic fuzzy, Plithogenic neutrosophic degrees of appurtenance and the concept of combined plithogenic shall also be used to represent the attributive preferential choice making.

3.1 Plithogenic Sociogram in Decision-making

The approach of Plithogenic sociogram shall also be used in decision-making on the alternatives that satisfy the criteria. Let A be the set of alternative methods of food processing say

$A= \{A_1,A_2,A_3,A_4,A_5\}$ and C be the set of criteria or the attributives with attributive values.
$C = \{C_1,C_2,C_3\}$
C = { cost efficiency, energy efficiency, quality conservation}
The attribute values are
Cost efficiency ={**highly economic** (C_{11}), moderately economic (C_{12}), lowly economic (C_{13})}
Energy efficiency = { **above 90%** (C_{21}), above 70% (C_{22}), above 50% (C_{23})}
Quality conservation = {**very good** (C_{31}), good (C_{32}), average (C_{33})}
The comparative attributive preferential choice making over compatibility of the alternatives from expert's point of view with respect to the dominant attribute values highly economic (C_{11}), above 90% (C_{21}) and very good (C_{31}) is presented in the Table 3.3

Table 3.3 Alternatives and its compatibility comparison

Alternatives	Comparative Attributive Preferential Choice-making over compatibility	
	Expert-I	Expert-II
A_1	$\{A_3(C_{11}(0.4),C_{21}(0.6),C_{31}(0.8),$ $A_4(C_{11}(0.6),C_{21}(0.6),C_{31}(0.7))\}$	$\{A_2(C_{11}(0.6),C_{21}(0.6),C_{31}(0.8)),A_4(C_{11}(0.7),C_{21}(0.8),C_{31}(0.7))\}$
A_2	$\{A_1(C_{11}(0.5),C_{21}(0.8),C_{31}(0.7)),$ $A_3(C_{11}(0.7),C_{21}(0.5),C_{31}(0.8)),A_4(C_{11}(0.8),C_{21}(0.6),C_{31}(0.7))\}$	$\{A_1(C_{11}(0.6),C_{21}(0.6),C_{31}(0.7)),$ $A_3(C_{11}(0.8),C_{21}(0.6),C_{31}(0.8)),A_5(C_{11}(0.9),C_{21}(0.6),C_{31}(0.7))\}$
A_3	$\{A_4(C_{11}(0.5),C_{21}(0.7),C_{31}(0.9)),$ $A_5(C_{11}(0.6),C_{21}(0.7),C_{31}(0.8))\}$	$\{A_1(C_{11}(0.6),C_{21}(0.7),C_{31}(0.8)),$ $A_2(C_{11}(0.7),C_{21}(0.5),C_{31}(0.8)\}$
A_4	$\{A_2(C_{11}(0.6),C_{21}(0.8),C_{31}(0.8)),$ $A_3(C_{11}(0.6),C_{21}(0.5),C_{31}(0.7))\}$	$\{A_1(C_{11}(0.6),C_{21}(0.7),C_{31}(0.7)),$ $A_3(C_{11}(0.5),C_{21}(0.6),C_{31}(0.8))\}$
A_5	$\{A_3(C_{11}(0.7),C_{21}(0.6),C_{31}(0.7)),$ $A_4(C_{11}(0.5),C_{21}(0.6),C_{31}(0.6))\}$	$\{A_2(C_{11}(0.8),C_{21}(0.6),C_{31}(0.5)),$ $A_4(C_{11}(0.5),C_{21}(0.7),C_{31}(0.8))\}$

With respect to the dominant attribute values, the alternative A_1 is compatible in comparison with the alternatives A_3 and A_4according to the viewpoint of Expert I and compatible in comparison with the alternatives A_2 and A_4 according to the viewpoint of Expert II

The weights of the dominant attributes values are considered and the final weighted evaluation matrix is determined by assigning the weights as 0.5, 0.25 and 0.25 to the dominant attribute values highly economic (C_{11}), above 90% (C_{21}) and very good (C_{31}) respectively.

	A_1	A_2	A_3	A_4	A_5
A_1	0	0.325	0.275	0.675	0
A_2	0.625	0	0.7125	0.3625	0.3875
A_3	0.3375	0.3375	0	0.325	0.3
A_4	0.325	0.35	0.6	0	0

A_5	0	0.3375	0.3375	0.5875	0

The amicable degree is presented as in the below

	A_1	A_2	A_3	A_4	A_5
A_1	0	0.428	0.3031	0.439	0
A_2	0.428	0	0.458	0.356	0.361
A_3	0.3031	0.458	0	0.422	0.3176
A_4	0.439	0.356	0.422	0	0
A_5	0	0.361	0.3176	0	0

The score values of the alternatives are presented in Table 3.4

Table 3.4 Score values of Alternatives

A_1	0.189662
A_2	0.259831
A_3	0.243249
A_4	0.197264
A_5	0.109994

The alternative A_2 is the most preferred method of food processing based on the satisfaction of the dominant attribute values and in comparison with other alternatives. This plithogenic sociogram is used to determine the most influential member in the group based on the attributives and the most preferred alternative in decision-making.

Conclusion

This paper introduces the concept of generalized plithogenic number, dominant attribute constrained plithogenic number, combined dominant attribute constrained plithogenic number and its utility in plithogenic sociogram. On comparing the proposed Plithogenic Sociogram with neutrosophic sociogram the former approach is more comprehensive in nature. In neutrosophic sociogram, the questions were deterministic and indeterminate in nature, in the sense, the members are asked to make the selection of their choice with whom they are very sure to take part in a quiz or study and also they are not sure of teaming up for the group activities. The calculation was done separately by considering members of deterministic teaming and later together with the deterministic and indeterminate teaming. Finally, based on the neutrosophic amicable degree, the opportunity of enhancing the relationship between the members, leadership index and potential leadership index was discussed. But in the neutrosophic sociogram, the reasons for preferring and hesitance were not much explored which are very significant to enhance the relationship in future. The calculation of the numerical ranges representing the extent of the relationship shall become more meaningful if the attributes are considered. This is the origin of the Plithogenic sociogram in which the choice of the members are based on the attributes and the degree of appurtenance states the nature of their preference. The qualitative nature of the members plays a vital role in decision making on the choice of the members preferred. The score values of the members indicate their preference and significance in the group. The members with the least score can be subjected to counselling and made exposed to other kinds of training programs to enhance their attributes of group dynamics. Thus in the Plithogenic sociogram with dominant attribute constrained plithogenic number representing the degree of appurtenance, the attributive preferential choice-making appears to be more realistic and pragmatic in nature. This works on the principle of identifying the attribute deficiency of the members and finds the possibilities of enhancing it to improve the efficiency of teamwork. On enriching the attributes of the members then all the members of the group shall team up with each other without any constraints. The proposed concept shall be extended and employed in decision-making and the illustrations of plithogenic sociogram and plithogenic sociogram in decision making shall be discussed under intuitionistic or neutrosophic degrees of appurtenance.

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