Single-valued Plithogenic graph for handling multi-valued attribute data and its context

Prem Kumar Singh[1,*]

[1]Department of Computer Science and Engineering,

Gandhi Institute of Technology and Management-Visakhapatnam, Andhra Pradesh 530045, India

ORCID: 0000-0003-1465-6572

* Correspondence: premsingh.csjm@gmail.com , premsingh.csjm@yahoo.com

Abstract

Recently, several researchers paid attention towards dealin with uncertainty in data with neutrosophic attributes. In this process, a problem is addressed while dealing with contradiction and its impact on decision making. It is considered as one of the major issues for data science researchers working in three-way fuzzy concept lattice. To deal with this issue, current paper tried to introduce the algebra of single-valued Plithogenic graph and its visualization based on infium and supremum. The proposed method also demonstated with an illustrative example for better understanding.

Keywords: Knowledge representation; Multi-valued data, Neutrosophic set, Plithogenic graph; Plithogenic set.

1. Introduction

Recently, attention has been paid towards precise measurement of uncertainty and its fluctuation [1-2]. Singh [3-4] try to measure the uncertainty in the multi-valued attribute using turiyam set which need mathematics establishment. However, the mathematics of neutrosophic set introduced by Smarandache [5] played a vital role to deal with uncertainty based on its true, false and indeterminant regions, independently. Due to which, the algebra of neutrosophic set is utilized recently by some of the researchers for knowledge processing tasks [6-7]. The problem arises when the data set contains multi-valued fuzzy attributes [7] an associated contradiction for them [8-9]. It used to be observed mostly in sports data sets like Cricket where win, draw or loss of a match fluctuate several time [10].

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It creates many contradiction among the experts [3-4]. It is observed in other sports like Olympics also where to win, draw or loss of gold, silver or bronze medal depends on the consistency and fitness of given player. It creates contradiction among two experts for decision making process. The precise representation of multi-valued attributes data set is a major tasks for the research communtites of current era. Hence, the current paper focused on tackling this issues try to introduce a mathematical way for dealing with multi-valued attribute data sets for knowledge processing tasks.

Recently, some of the authors paid attention towards dealing with multi-valued attribute data sets [11-13] based on Plithogenic set introduced by Smarandache [7-8]. It is considered as one of the prominent set to represent the multi-valued attributes with its contradiction [14-15]. The problem arises while finding some of the useful pattern from the data with Plithogenic attributes and its graphical visualization [16-17] motivated from some recent studies [18-20]. The reason is numerical representation of data with multi-valued attribute is mathematically expensive tasks. To tackle this issue, a method is proposed in this paper to visualize the single-valued Plithogenic data set using min and max operator with an illustrative example. It will help in drawing the single-valued Plithogenic lattice also. The motivation is to provide a way for compact representation of data with single-valued Plithogenic attribute. The objective is to find some of the useful pattern from the given data set for knowledge processing tasks while considering the contradiction part.

Other parts of the paper is organized as follows : Section 2 provides preliminaries about single-valued Plithogenic set and its algebra. Section 3 contains the proposed method for handling data with single-valued Plithogenic attributes with its demonstration shown in Section 4. Section 5 provides conclusions followed by the references.

2. Plithogenic set

In this section, some basic notation related to current paper is given below:

Definition 1: Neutrosophic Set [5]: The neutrosophic set consist three independent functions called as truth, indeterminacy and false, (T, I, F) to represent the uncertainty in attributes. The range of these three independent functions varies between 0 and 1 and mutually exclusive under the conditions $0 \leq T + I + F \leq 3$. The Neutrosophic value 0 represents the universal false cases and 3 represents the universal truth cases i.e. $N = \{\langle x : T, I, F \rangle : x \in \xi\}$. It means this set contains triplet having a true, a false and indeterminacy membership values which can be characterized independently, T_N, F_N , I_N, independently in [0, 1] can be abbreviate as follows:

$N = \{<k; T_N(k), I_N(k), F_N(k)>: k \in \xi; T_N(k), I_N(k), F_N(k) \in \xi]^{-}0, 1^{+}[\}$ ……(1)

Whereas $0^{-} \leq T_N(k) + I_N(k) + F_N(k) \leq 3^{+}$. ……….…………….....(2)

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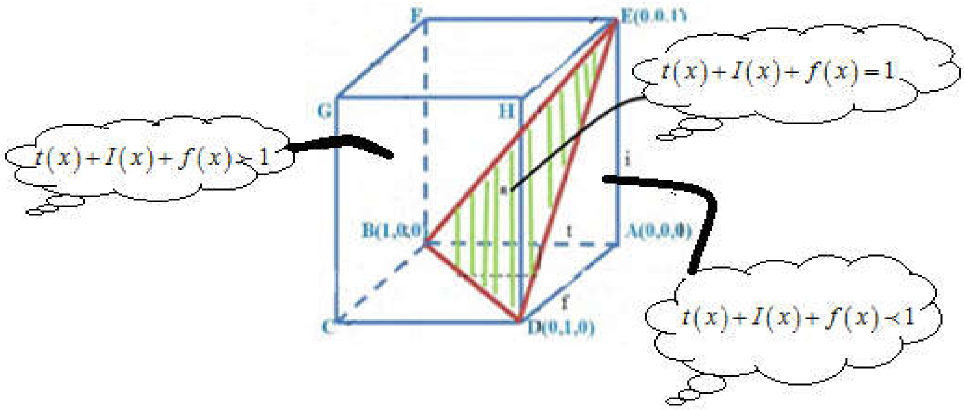

Figure 1. The graphical visualization of neutrosophic environment

Example 1: Let us suppose that, an expert provides his/her opinion about a player (x_1) that the player (x_1) may get gold in the given Olympic having 60 percent possibility otherwise he/she will get Silver with 20 percent possibility. In case the player (x_1) will not get gold or silver then there is a high possibility i.e. 70 percent to get Bronze in the given Olympic. This type of three-valued data can be represented precisely using the properties of single-valued Neutrosophic set as (0.6, 0.2, 0.7). The problem arises when the contradiction arises among two experts for the player (x_1) due to his/her consistency and fitness. To deal with it the properties of Plithogenic set is introduced as given below in Definition 2.

Definition 2. Plithogenic Set [8]: This set contains five parts to represents the multi-valued attributes of the given data sets. Let us suppose, ξ be a universe of discourse, P be a subset of this universe of discourse, "a" a multi-valued attribute, V is the range of the multi-valued attribute, "d" be the known (fuzzy, intuitionistic fuzzy, or neutrosophic) degree of appurtenance with regard to some generic of element x's attribute value to the set P, and c is the (fuzzy, intuitionistic fuzzy, neutrosophic) degree of contradiction (dissimilarity) among the attribute values as (<A, Neutral A, Anti A>; <B, Neutral B, Anti B>; <C, Neutral C, Anti C>). It can be represented as a set (P, a, V, d, c) which named as a Plithogenic Set (**P**). The Plithogenic set is a set **P** (P, a, V, d, c) in which each element $x \in P$ is characterized by all attribute's (a) values in $V = \{v_1, v_2, \ldots, v_n\}$, for $n \geq 1$ for the degree of appurtenance (d). The contradiction degree function (c) distinct the Plithogenic set from all of the above set. It represents the between the attribute values in form of fuzzy t-norm and fuzzy t-conorm as:

(i) $c: V \times V \rightarrow [0, 1]$ represents the contradiction degree function among v_1 and v_2.

It used be noted as $c(v_1, v_2)$, and satisfies the following axioms:

(ii) $c(v_1, v_1) = 0$ *i.e.* the contradiction among v_1 and v_2 is zero.

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(iii) $c(v_1, v_2) = c(v_2, v_1)$, the contradiction among v_1 and v_2 or v_2 and v_1 used to be

considered as per the commutativity properties. In this paper author focuses on single-valued fuzzy membership to handle the Plithogenic set.

Example 2: Let us suppose, two experts (y_1) and (y_2) given an opinion towards the player (x_1) for the given Olympic as follows: The expert (y_1) agreed that there is 60 percent possibility that the player (x_1) may get gold whereas the expert (y_2) agreed that he/she is suitbale 70 percent to get gold medal without any contradiction. The expert (y_1) agreed that, in case the player (x_1) will not get gold then he/she can get Bronze with 20 percent possibility whereas the expert (y_2) agreed on 40 percent which created 33 percent contradiction. In last the expert (y_1) agreed that in case the player (x_1) will not get gold or silver then there is high possibility to get Bronze with 70 percent whereas the expert (y_2) agreed on 60 percent which created 67 percent contraction on this medal. The valid reason given by the expert (y_1) for his fopinion on the player (x_1) due to his/her 80 percent consistency whereas the expert (y_2) agreed on it 60 percent without any contradiction. Another reason given by the expert (y_1) that, the player (x_1) can win medal due to his/her 50 fitness whereas expert (y_2) agreed 40 percent on this which created 50 percent contradiction. This type of multi-valued data with Plithogenic attributes can be written using the properties of single-valued Plithogenic set as shown in Table 1 and Table 2.

Table 1: The expert (y_1) opinion towards the player (x_1) to get medal in the given olympic

Contradiction degree	0	0.33	0.67		0	0.5
Multi-attributes	Gold	Silver	Bronze		Consistent	Fitness
Fuzzy degree	0.6	0.2	0.7		0.8	0.5

Table 2: The expert (y_2) opinion towards the player (x_1) to get medal in the given olympic

Contradiction degree	0	0.33	0.67		0	0.5
Multi-attributes	Gold	Silver	Bronze		Consistent	Fitness
Fuzzy degree	0.7	0.4	0.6		0.6	0.4

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In this way the properties of single-valued Plithogenic set provides a way to represent the contradiction among two experts for further processing. It can be observed that, the numerical representation of data with single-valued plithoegnic set does not provide precise information for miulit-decision tasks. Same time it is complex to write and understand. To deal with this issue, current paper try to introduce the single-valued Plithogenic graph and its applications in the next section.

3. Proposed method for Single-valued Plithogenic Graph Visualization

In this section, a method is proposed for graphical structure visualization of data with single-valued Plithogenic attributes as given below:

Step 1. Let us consider any data set having single-valued Plithogenic attributes as (*P*, *a*, *V*, *d*, *c*), where *P* is a single-valued Plihogenic set, *a* is the set of attribute values, *V is* the attribute range, *d* is the degree of appurtenance and *c* is the degree of contradiction. The degree of appurtenance and the degree of contradiction of the attribute values are determined with respect to a dominant attribute value

Step 2. The given data set as (*P*, *a*, *V*, *d*, *c*) can be represented as single-valued Plithogenic context as shown in Table 3.

Table 3: A single-valued Plihogenic context

Contradiction degree	c_1	c_2	c_3	…	c_{n-1}	c_n
Multi-attributes	a_1	a_2	a_3	…	a_{n-1}	a_n
Single-valued fuzzy degree for expert 1	$d_{11}(a_1)$	$d_{12}(a_2)$	$d_{13}(a_2)$		$d_{1n-1}(a_{n-1})$	$d_{1n}(a_n)$
Single-valued fuzzy degree for expert 2	$d_{21}(a_1)$	$d_{22}(a_2)$	$d_{23}(a_2)$		$d_{2n-1}(a_{n-1})$	$d_{2n}(a_n)$

Step 3. The computation of relations for the complete Plithogenic graph and its edges can be computed using the intersection as shown in Table 4. It can be computed as given below:

$$d_{p_1}(a_p,v_p)\wedge d_{p_2}(a_p,v_p)=(1-c_p)\times(d_{p_1}(a_p,v_p)\wedge_f d_{p_2}(a_p,v_p))+c_p(d_{p_1}(a_p,v_p)\vee_f d_{p_2}(a_p,v_p))$$

Otherwise the relation can be as follows:

$$d_{p_1}(a_p,v_p)\wedge d_{p_2}(a_p,v_p)\geq(1-c_p)\times(d_{p_1}(a_p,v_p)\wedge_f d_{p_2}(a_p,v_p))+c_p(d_{p_1}(a_p,v_p)\vee_f d_{p_2}(a_p,v_p))$$

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onsider the performance as Plithogenic graph G=$(V_p, E_p, a_p, d_p, c_p)$ where (Vp) represents the vertex of Plithogenic attributes, (Ep) represents the edges for the Plithogenic attributes, (a_p) represents the multi-valued i.e. one or more attributes of distinct values.

The degree of appurtenance (dp) says that at what level the given multi-valued attributes belongs to the set whereas (c_p) represents the contradiction degrees.

Table 4: The computation of intersection among single-valued Plihogenic conext

Contradiction degree	c_1	c_2	c_3	…	c_{n-1}	c_n
Multi-attributes	a_1	a_2	a_3	…	a_{n-1}	a_n
Single-valued fuzzy degree for expert 1 (y_1)	$d_{11}(a_1)$	$d_{12}(a_2)$	$d_{13}(a_2)$		$d_{1n-1}(a_{n-1})$	$d_{1n}(a_n)$
Single-valued fuzzy degree for expert 2(y_2)	$d_{21}(a_1)$	$d_{22}(a_2)$	$d_{23}(a_2)$		$d_{2n-1}(a_{n-1})$	$d_{2n}(a_n)$
$y_1 \wedge y_2$	$d_{p_{11}} \wedge d_{p_{21}}$	$d_{p_{12}} \wedge d_{p_{22}}$	$d_{p_{13}} \wedge d_{p_{23}}$		$d_{p_{1n-1}} \wedge d_{p_{2n-1}}$	$d_{p_{1n}} \wedge d_{p_{2n}}$

Step 4. The maximum or upper boundary of relationship among the Plithogenic vertex can be computed suing the union as shown in Table 5. It can be computed as given below:

$$d_{p_1}(a_p, v_p) \vee d_{p_2}(a_p, v_p) = (1 - c_p) \times (d_{p_1}(a_p, v_p) \vee_f d_{p_2}(a_p, v_p)) + c_p (d_{p_1}(a_p, v_p) \wedge_f d_{p_2}(a_p, v_p))$$

Table 5: The computation of union among single-valued Plihogenic conext

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Contradiction degree	c_1	c_2	c_3	…	c_{n-1}	c_n
Multi-attributes	a_1	a_2	a_3	…	a_{n-1}	a_n
Single-valued fuzzy degree for expert 1 (y_1)	$d_{11}(a_1)$	$d_{12}(a_2)$	$d_{13}(a_2)$		$d_{1n-1}(a_{n-1})$	$d_{1n}(a_n)$
Single-valued fuzzy degree for expert 2(y_2)	$d_{21}(a_1)$	$d_{22}(a_2)$	$d_{23}(a_2)$		$d_{2n-1}(a_{n-1})$	$d_{2n}(a_n)$
$y_1 \vee y_2$	$d_{p_{11}} \vee d_{p_{21}}$	$d_{p_{12}} \vee d_{p_{22}}$	$d_{p_{13}} \vee d_{p_{23}}$		$d_{p_{1n-1}} \vee d_{p_{2n-1}}$	$d_{p_{1n}} \vee d_{p_{2n}}$

Step 5. Now each of the attributes considered as vertexes of a single-valued Plithoegnic graph as (V, E, P) where V is set of vertex, E is set of edges, and P is Single-valued Plithoegnic relationship among them. It means vertex represented as $\frac{(a_p, d_p, c_p)}{V_p}$ where (a_p) represents one or more attributes which defines the Plithogenic vertex (Vp).

The degree of appurtenance (dp) represents the belongingness of multi-valued attributes in the defined Plithogenic vertex. The contradiction degrees is represented as (c_p). In similar way the edges represented as $\frac{(a_{pq}, d_{pq}, c_{pq})}{E_{pq}(V_p V_q)}$ shown in Figure 2.

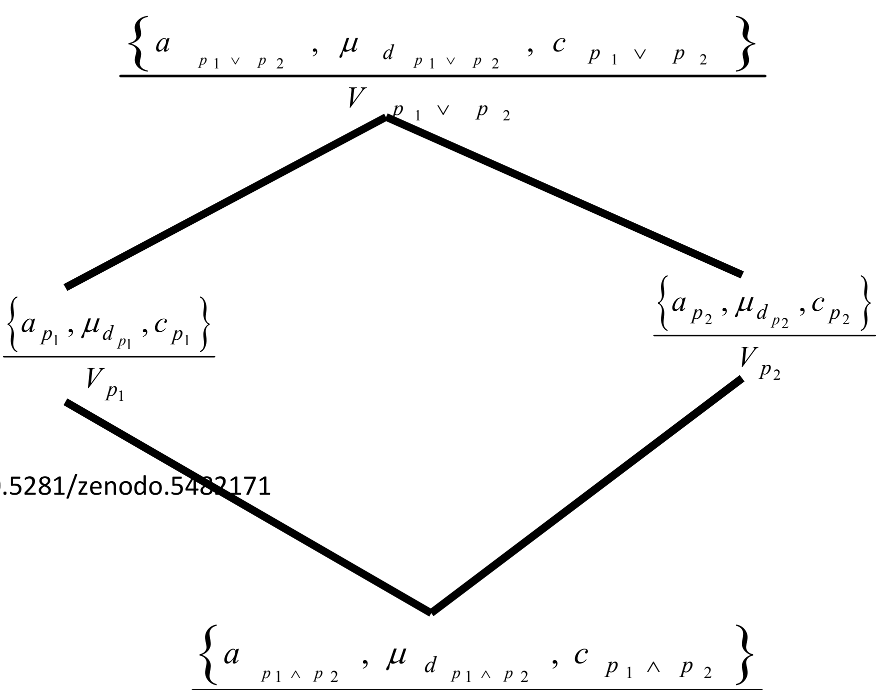

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Figure 2: A generalized visualization of Single-valued Plithoegnic graph

Step 6. The contradiction among v_1 and v_2 or v_2 and v_1 used to be follow the commutativity properties $c(v_1, v_2) = c(v_2, v_1)$. Hence the Plithogenic set based Edges (E_{pq}) and (E_{qp}) represents same edge. The contradiction degrees $c(v_1, v_1) = 0$ due to which the edges can be edges can be represented as $(E_{pq} \subseteq V_p \times V_q - V_p \times V_p - V_q \times V_q)$.

Step 7. The biasness among experts opinion can be computed using the complement of single-valued Plithogenic set as: $(d_p(a_p, v_p))' = (1 - c_p) \times d_p(a_p, v_p)$ where *dp* represents degree of appurtenance, c_p represents contradiction degrees for the multi-valued attributes a_p.

Step 8. The knowledge can be discovered from the single-valued Plithogenic graph shown in Figure 2 based on its infimum and supremum.

Time complexity: Let us suppose, there are *n*-plithogenic attribute in the given data set to visualize having *m*-number of multi-attributes. In this case, the time complexity taken in drawing the graph can be taken to draw the graph can be O(*n.m*) and its degree computation for the edges can take maximum O($m.n^2$) or ($n.m^2$).

In the next section the proposed method is demonstrated with an illustrative example for better understanding of single-valued Plithogenic graph and its applications.

4. Illustration

This paper focused on handling data with single-valued Plithogenic attribute for knowledge processing tasks. Recently, some of the researchers paid attention towards this direction [8-11]. This paper focused on introducing graphical structure visualization of single-valued Plithoegnic attributes. To achieve this goal, a method is proposed in Section 3. This section try to demonstrate the proposed method as given below:

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Example 3: Let us consider the Example 3 discussed in Section 2. The problem arises with Table 1 and Table 2 to find some decision and visualization them in the graph. It can be achieved using the proposed method in Section 3 as given below:

Step 1. Let us consider the data with Plithogenic attribute shown in Table 1 and Table 2.

Step 2. Try to represent them in a single-valued Plithogenic context as shown in Table 6.

Table 6: A single-valued Plihogenic context representation of Table 1 and Table 2

Contradiction degree	0	0.33	0.67		0	0.5
Multi-attributes	Gold	Silver	Bronze		Consistent	Fitness
Expert(y_1) opinion about player(x_1) based on single-valued fuzzy membership	0.6	0.2	0.7		0.8	0.5
Expert(y_1) opinion about player(x_1) based on single-valued fuzzy membership	0.7	0.4	0.6		0.6	0.4

Step 3. Compute the intersection among expert opinion using the algebra of single-valued Plithogenic Set as follows:

$$d_{p_1}(a_p,v_p)\wedge d_{p_2}(a_p,v_p)=(1-c_p)\times(d_{p_1}(a_p,v_p)\wedge_f d_{p_2}(a_p,v_p))+c_p(d_{p_1}(a_p,v_p)\vee_f d_{p_2}(a_p,v_p))$$

where *dp* represents degree of appurtenance, c_p represents contradiction degrees for the multi-valued attributes a_p. Others are fuzzy t-norms to define the intersection. It is shown in Table 7.

Table 7: The computation of experts opinion and its intersection shown in Table 6

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Contradiction degree	0	0.33	0.67		0	0.5
Multi-attributes	Gold	Silver	Bronze		Consistent	Fitness
Expert(y_1) opinion about player(x_1) based on single-valued fuzzy membership	0.6	0.2	0.7		0.8	0.5
Expert(y_1) opinion about player(x_1) based on single-valued fuzzy membership	0.7	0.4	0.6		0.6	0.4
$y_1 \wedge_x y_1$	0.42	0.23	0.73		0.48	0.45

Step 5. Compute the Union among expert opinion using the algebra of single-valued Plithogenic Set as follows:

$$d_{p_1}(a_p, v_p) \vee d_{p_2}(a_p, v_p) = (1 - c_p) \times (d_{p_1}(a_p, v_p) \vee_f d_{p_2}(a_p, v_p)) + c_p(d_{p_1}(a_p, v_p) \wedge_f d_{p_2}(a_p, v_p))$$

where dp represents degree of appurtenance, c_p represents contradiction degrees for the multi-valued attributes a_p. It is shown in Table 8.

Table 8: Union of Table 1 and 2 using Plithogenic operator

Contradiction degree	0	0.33	0.67		0	0.5
Multi-attributes	Gold	Silver	Bronze		Consistent	Fitness
Expert(y_1) opinion about player(x_1) based on single-valued fuzzy membership	0.6	0.2	0.7		0.8	0.5
Expert(y_1) opinion about player(x_1) based on single-valued fuzzy membership	0.7	0.4	0.6		0.6	0.4
$y_1 \vee_x y_1$	0.88	0.37	0.57		0.92	0.45

Step 6. In similar way compute for the edges and try to merge them in a single-valued Plithogenic context as shown in Table 9. In similar way any data set with single-valued Plithogenic attributes can be converted into context

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for knowledge processing tasks. Now the problem is to visualize the Table 9 as compact representation for multi-decision process. It can be visualized using the vertex and edges of a defined single-valued Plithogenic graph.

Table 9: A single-valued Plithogenic context representation of Table 7 and Table 8

Contradiction degree	0	0.33	0.67		0	0.5
Multi-attributes	Gold	Silver	Bronze		Consistent	Fitness
Expert(y_1) opinion about player(x_1) based on single-valued fuzzy membership	0.6	0.2	0.7		0.8	0.5
Expert(y_1) opinion about player(x_1) based on single-valued fuzzy membership	0.7	0.4	0.6		0.6	0.4
$y_1 \wedge_x y_1$	0.42	0.23	0.73		0.48	0.45
$y_1 \vee_x y_1$	0.88	0.37	0.57		0.92	0.45

Step 7. Figure 3 represents the single-valued Plithogenic graph visualization of context shown in Table 9.

Step 8: The knowledge discovered from Figure 3 are as follows:

(i) Both of the experts agreed that the player(x_1) has minimum 42 percent possibility to get gold whereas maximum 72 percent possibility to get Bronze with 66 percent contradiction due to his/her consistency and fitness with 50 percent contradiction.

(ii) Both of the experts agreed that the player(x_1) has maximum 88 percent possibility to get gold whereas minimum 57 percent possibility to get Bronze due to his/her consistency and fitness.

(iii) The last the Figure 3 provides a compact representation of single-valued Plithogenic data set shown in Table 9 for knowledge processing tasks. It is one of the significant outcome of the proposed method when compared to any recent study in this field.

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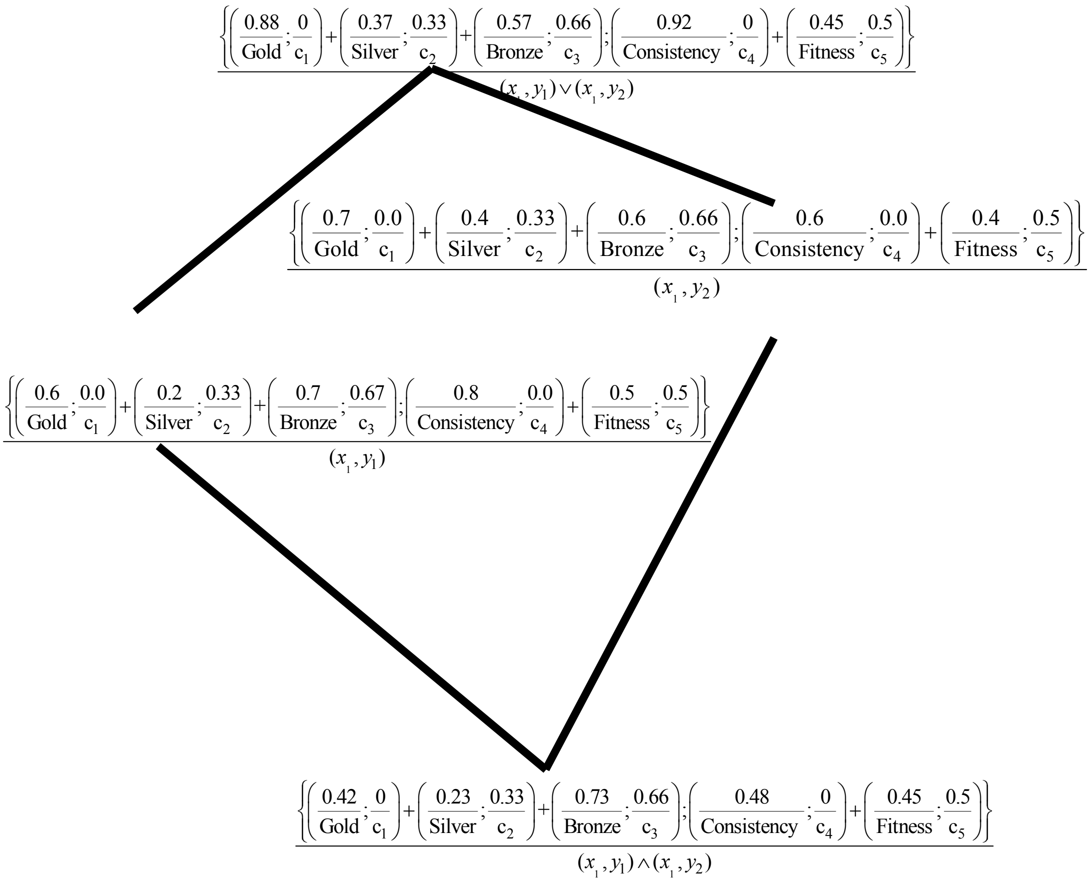

Figure 3. The Plithogenic graph visualization of context shown in Table 9.

The above obtained information will be much helpful for the player(x_1) to concentrate on his/her consistency and weak point of the player with whom he/she has to play for silver medal match. It will help to improve their performance more precisely on the particular attribute to win gold or Bronze.

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Table 10. A comparison of the proposed method with recently available approaches on Plithogenic set

	Plithogenic set [8]	Plithogenic context [10]	Plithogenic Set applications [15]	The proposed method in this paper
Plithogenic attributes	Yes	Yes	Yes	Yes
Multi-valued data	Yes	Yes	Yes	Yes
Decision making	Yes	Yes	Yes	Yes
Graphical visualization	No	No	No	Yes
Union and Intersection	Yes	Yes	Yes	Yes
Infimum and Supremum	No	No	No	Yes
Time complexity	Not given	Not given	Not given	O($m.n^2$) or ($n.m^2$)

In future the author work will focus on introducing new mathematics [18] for handling changes in Plithogenic set [19] and its applications in various fields [20].

5. Conclusions

This paper fopcused on handling data with single-valued Plithogenic attributes. To deal with it the current paper introduced a method for precise representation of single-valued Plithogenic context and its graphical visualization based on its infimum and supremum. It is one of the significant outcome of the proposed method which distinct it from any of the availoable approaches as shown in Table 10. In near future, the author will focus on introducing other algebra for single-valued Plithogenic set and its uses for knowledge discovery and representations tasks.

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