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Regular Single Valued Neutrosophic Hypergraphs

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Abstract. In this paper we define the regular and totally regular single Valued neutrosophic hypergraphs, and discuss the order and size along with properties of regular and totally regular single valued neutrosophic hypergraphs,we extended work on completeness of single valued neutrosophic hypergraphs.

Keywords: Single valued neutrosophic hypergraphs, regular single valued neutrosophic hypergraphs and totally regular single valued neutrosophic hypergraphs.

1 Introduction

The notion of neutrosophic sets (NSs) was proposed by Smarandache [39, 8] as a generalization of the fuzzy sets [14], intuitionistic fuzzy sets [12], interval valued fuzzy set [11] and interval-valued intuitionistic fuzzy sets [13] theories. The neutrosophic set is a powerful mathematical tool for dealing with incomplete, indeterminate and inconsistent information in real world. The neutrosophic sets are characterized by a truth-membership function (*t*), an indeterminacy-membership function (*i*) and a falsity membership function (*f*) independently, which are within the real standard or nonstandard unit interval $]^-0 , 1^+[$. Smarandache [39] introduced the concept of the single-valued neutrosophic set (SVNS), mentioned in [40], a subclass of the neutrosophic sets. The same authors [10] introduced the concept of the interval valued neutrosophic set (IVNS), which is more precise and flexible than the single valued neutrosophic set. The IVNS is a generalization of the single valued neutrosophic set, in which the three membership functions are independent and their value belong to the unit interval [0, 1]. More works on single valued neutrosophic sets, interval valued neutrosophic sets and their applications can be found on *http://fs.gallup.unm.edu/NSS/* [38].

Hypergraph is a graph in which an edge can connect more than two vertices, hypergraphs can be applied to analyse architecture structures and to represent system partitions, Mordesen J.N and P.S Nasir gave the definitions for fuzzy hypergraphs. Parvathy.R and M. G. Karunambigai's paper introduced the concepts of Intuitionistic fuzzy hypergraphs and analyse its components, Nagoor Gani.A and Sajith Begum.S defined degree, order and size in intuitionistic fuzzy graphs and extend the properties. Nagoor Gani.A and Latha.R introduced irregular fuzzy graphs and discussed some of its properties.

Regular intuitionistic fuzzy hypergraphs and totally regular intuitionistic fuzzy hypergraphs are introduced by I. Pradeepa and S. Vimala [38] in this paper we will extend regularity and totally regularity on single valued neutrosophic hypergraphs.

2 Preliminaries

Definition 2.1 Let X be a space of points (objects) with generic elements in X denoted by x. A single valued neutrosophic set A (SVNS A) is characterized by truth membership function $T_A(x)$, indeterminacy membership function $I_A(x)$ and a falsity membership function $F_A(x)$. For each point x ∈ X , $T_A(x)$, $I_A(x)$, $F_A(x)$ ∈ [0 , 1].

Definition 2.2 Let A be a SVNS on X then support of A is denoted and defined by,

$Supp(A) = \{ x : x \in X , T_A(x) > 0 , I_A (x) > 0 , F_A (x) > 0 \}$

Definition 2.3 A hypergraph is an ordered pair H = (X , E) where,

(1) $X = \{ x_1 , x_2, \ldots , x_n\}$ a finite set of vertices.

(2) $E = \{ E_1, E_2 , \ldots, E_m\}$ a family of subsets of X.

(3) E_j for $j = 1,2,3,\ldots,m$ and $\cup_j(E_j) = X$.

The set X is called set of vertices and E is the set of edges(or hyperedges).

In a hypergraph two or more vertices x_1, $x_2, \ldots, x_n$ are said to be adjacent if there exist an edge E_j which contains those vertices. In a hypergraph two edges E_i and E_j –for i and j not equals) is said to be adjacent if their intersection is not empty. The size of a hypergraph depends on the cardinality of its hyperedges. We define the size of H as the sum of the cardinalities of its hyperedges. A regular hyper graph is one in which every vertex is contained in k edges for some constant k. In a complete hypergraph the edge set consists of the power set $P(X)$, where X is the set of vertices other than singleton set and empty sets. A hyper graph H is said to be k-uniform if the number of vertices in each hyper edge is k.

Definition 2.4 A single valued neutrosophic hypergraph is an ordered pair H = (X , E) where,

(1) $X = \{ x_1, x_2, \ldots, x_n \}$ a finite set of vertices.

(2) $E = \{ E_1, E_2, \ldots, E_m \}$ a family of SVNSs of X.

(3) $E_j \neq O = (0, 0, 0)$ for $j = 1,2,3,\ldots,m$ and $\bigcup_j Supp(E_j) = X$.

The set X is called set of vertices and E is the set of SVN-edges(or SVN-hyperedges).

Proposition 2.5 Single valued neutrosophic hypergraph is the generalization of fuzzy hypergraphs and intuitionistic fuzzy hypergraphs.

3 Regular and Totally regular SVNHGs

Defination 3.1 The open neighborhood of a vertex x in single valued neutrosophic hypergraphs (SVNHGs) is the set of adjacent vertices of x , excluding that vertex and is denoted by N(x).

Defination 3.2 The closed neighborhood of a vertex x in single valued neutrosophic hypergraphs (SVNHGs) is the set of adjacent vertices of x , including that vertex and is denoted by N[x].

Example 3.3 Consider a single valued neutrosophic hypergraphs H = (X , E) where, *X = { a,b,c,d,e }* and *E = { P,Q,R,S }* dfined by

P = { (a, .1, .2, .3) , (b, .4, .5, .6) }

Q = { (c, .1, .2, .3) , (d, .4, .5, .6) , (e, .7, .8, .9) }

R = { (b, .1, .2, .3) , (c, .4, .5, .6) }

S = { (a, .1, .2, .3) , (d, .4, .5, .6) }

Then the open neighborhood of a vertex a is b and d, and closed neighborhood of a vertex b is b, a and c.

Definition 3.4 Let H = (X , E) be a SVNHG , the open neighborhood degree of a vertex x is denoted and defined by

$$deg(x) = (deg_T(x), deg_I(x), deg_F(x))$$

where,

$$deg_T(x) = \sum_{x \in X} T_E(x)$$

$$deg_I(x) = \sum_{x \in X} I_E(x)$$

$$deg_F(x) = \sum_{x \in X} F_E(x)$$

Example 3.5 Consider a single valued neutrosophic hypergraphs H = (X , E) where, *X = { a,b,c,d,e }* and *E = { P,Q,R,S }* defined by

P = { (a, .1, .2, .3) , (b, .4, .5, .6) }

Q = { (c, .1, .2, .3) , (d, .4, .5, .6) , (e, .7, .8, .9) }

R = { (b, .1, .2, .3) , (c, .4, .5, .6) }

S = { (a, .1, .2, .3) , (d, .4, .5, .6) }

Then the open neighborhood of a vertex a is b and d, and therefor open neighbourhood degree degree of a vertex a is (.8 , 1, 1.2).

Definition 3.6 Let H=(X , E) be a SVNHG , the closed neighborhood degree of a vertex x is denoted and defined by

$$deg[x] = (deg_T[x], deg_I[x], deg_F[x])$$

where,

$$deg_T[x] = deg_T(x) + T_E(x)$$

$$deg_I[x] = deg_I(x) + I_E(x)$$

$$deg_F[x] = deg_F(x) + F_E(x)$$

Example 3.7 Consider a single valued neutrosophic hypergraphs H = (X , E) where, *X = { a,b,c,d,e }* and *E={ P,Q,R,S }* defined by

P = { (a, .1, .2, .3) , (b, .4, .5, .6) }

Q = { (c, .1, .2, .3) , (d, .4, .5, .6) , (e, .7, .8, .9) }

R = { (b, .1, .2, .3) , (c, .4, .5, .6) }

S = { (a, .1, .2, .3) , (d, .4, .5, .6) }

The closed neighbourhood of a vertex b is b, a and c, hence the closed neighbourhood degree of a vetex a is (.9 , .1.2 , 1.5).

Definition 3.8 Let H = (X , E) be a SVNHG , then H is said to be n-regular SVNHG if all the vertices have the same open neighbourhood degree n = (n_1 , n_2 , n_3)

Definition 3.9 Let H = (X , E) be a SVNHG , then H is said to be m-totally regular SVNHG if all the vertices have the same closed neighbourhood degree m = (m_1 , m_2 , m_3)

Proposition 3.10 A regular SVNHG is the generalization of regular fuzzy hypergraphs and regular intuitionistic fuzzy hypergraphs.

Proposition 3.11 A totally regular SVNHG is the generalization of totally regular fuzzy hypergraphs and totally regular intuitionistic fuzzy hypergraphs.

Example 3.12 Consider a single valued neutrosophic hypergraphs H = (X , E) where, *X = { a, b, c, d }* and

E = { P, Q, R, S } defined by

P = { (a, .8, .2, .3), (b, .8, .2, .3) }

Q = { (b, .8, .2, .3), (c, .8, .2, .3) }

R = { (c, .8, .2, .3), (d, .8, .2, .3) }

S = { (d, .8, .2, .3), (a, .8, .2, .3) }

Here the open neighbourhood degree of every vertex is (1.6, .4, .6) hence H is regular SVNHG and closed neighbourhood degree of every vertex is (2.4, .6, .9) Hence H is both regular and totally regular SVNHG.

Theorem 3.13 Let H = (X, E) be a SVNHG which is both regular and totally regular SVNHG then E is constant.

Proof: Suppose H is n-regular and m-totally regular SVNHG. Then ,

$$deg(x) = n = (n_1, n_2, n_3)$$

$$deg[x] = m = (m_1, m_2, m_3)$$

for all x ∈ E_i . consider , deg[x] = m hence by definition, deg(x) + E_i(x) = m this implies E_i(x) = m – n for all x in E_i . hence E is constant.

Remark 3.14 The converse of above theorem need not to be true in general.

Example 3.15 Consider a single valued neutrosophic hypergraphs H = (X , E) where, *X = { a, b, c, d }* and

E = { P, Q, R, S } defined by

P = { (a, .8, .2, .3) , (b, .8, .2, .3) }

Q = { (b, .8, .2, .3) , (d, .8, .2, .3) }

R = { (c, .8, .2, .3) , (d, .8, .2, .3) }

S = { (d, .8, .2, .3) , (d, .8, .2, .3) }

Here E is constant but deg(a) = (1.6, .4, .6) and deg(d) = (2.4, .6, .9) i.e deg(a) and deg(d) are not equals hence H is not regular SVNHG. Next deg[a] = (2.4, .6, .9) and deg[d] = (3.2, .8, 1.2) hence deg[a] and deg[d] are not equals hence H is not totally regular SVNHG , we conclude that H is neither regular and nor totally regular SVNHG.

Theorem 3.16 Let H = (X, E) be a SVNHG then E is costant on X if and only if following are equivalent,

(1) H is regular SVNHG.

(2) H is totally regular SVNHG.

Proof : Suppose H = (X , E) be a SVNHG and E is constant in H, i.e ,

$$E_i(x) = c = (c_1, c_2, c_3)$$

For all x ∈ E_i . Suppose H is n-regular SVNHG, then

$$deg(x) = n = (n_1, n_2, n_3)$$

for all x ∈ E_i . consider

$$deg[x] = deg(x) + E_i(x) = n + c$$

for all x ∈ E_i , hence H is totally regular SVNHG.

Next suppose that H is m-totally regular SVNHG , then

$$deg[x] = m = (m_1, m_2, m_3)$$

for all x ∈ E_i , i.e,

$$deg(x) + E_i(x) = m$$

for all x ∈ E_i , this implies that

$$deg(x) = m – c$$

for all x ∈ E_i , thus H is regular SVNHG, thus (1) and (2) are equivalent.

Conversely : Assume that (1) and (2) are equivalent, i.e H is regular SVNHG if and onl if H is totally regular SVNHG.

Suppose contrary E is not constant , i.e , E_i(x) and E_i(y) not equals for some x and y in X. Let H = (X , E) be n-regular SVNHG , then

$$deg(x) = n = (n_1, n_2, n_3)$$

for all x ∈ E_i , consider ,

deg[x] = deg(x) + E_i*(x) = n +* E_i*(x)*

deg[y] = deg(y) + E_i*((y) = n +* E_i*(y)*

since E_i(x) and E_i(y) are not equals for some x and y in X , hence deg[x] and deg[y] are not equals, thus H is not totally regular SVNHG , which is contradiction to our assumption.

Next let H be totally regular SVNHG, then deg[x] = deg[y] i.e ,

deg(x) + E_i *(x) = deg(y) +* E_i *(y)*

deg(x) – deg(y) = E_i*(y) –* E_i*(x)*

since RHS of above equation is nonzero, hence LHS of above equation is also nonzero, thus deg(x) and deg(y) are not equals , so H is not regular SVNHG, which is again contradict to our assumption , thus our supposition was wrong , hence E must be constant , this completes the proof.

Definition 3.17 Let H= (X , E) be a regular SVNHG, then the order of SVNHG H is denoted and defined by

O(H) = (p, q, r) , where

$$p = \sum_{x \in X} T_{E_i}(x)$$

$$q = \sum_{x \in X} I_{E_i}(x)$$

$$r = \sum_{x \in X} F_{E_i}(x)$$

For every x ∈ X and size of regular SVNHG is denoted and defined by

$$S(H) = \sum_{i=1}^{n} (S_{E_i})$$

Where S(E_i) = (a , b , c) which is defined by

$$a = \sum_{x \in E_i} T_{E_i}(x)$$

$$b = \sum_{x \in E_i} I_{E_i}(x)$$

$$c = \sum_{x \in E_i} F_{E_i}(x)$$

Example 3.18 Consider a single valued neutrosophic hypergraphs H = (X , E) where, *X = { a, b, c, d }* and

E = { P, Q, R, S } defined by

P = { (a, .8, .2, .3), (b, .8, .2, .3) }

Q = { (b, .8, .2, .3), (c, .8, .2, .3) }

R = { (c, .8, .2, .3), (d, .8, .2, .3) }

S = { (d, .8, .2, .3), (a, .8, .2, .3) }

Here order and size of H are given (3.2, .8, 1.2) and (6.4, 1.6, 2.4) respectively.

Proposition 3.19 The size of n-regular SVNHG H = (H , E) is nk/2 where |X|= k.

Proposition 3.20 If H = (X, E) be m-totally regular SVNHG then *2S(H) + O(H) = mk* , where |X|= k.

Corollary 3.21 Let H = (X,E) be a n-regular and m-totally regular SVNHG then *O(H) = k(m - n)*, where |X|= k.

Proposition 3.22 The dual of n-regular and m-totally regular SVNHG H= (X, E) is again a n-regular and m-totally regular SVNHG.

Definition 3.23 A single valued neutrosophic hypergraph (SVNHG) is said to be complete SVNHG if for every x in X , *N(x) = { x : x in X-{x} }* that is N(x) contains all remaining vertices of X except x.

Example 3.24 Consider a single valued neutrosophic hypergraphs H = (X , E) where, *X = { a, b, c, d }* and

E = { P, Q, R } defined by

P = { (a, .4, .6, .3), (c, .8, .2, .3) }

Q = { (a, .8, .8, .3), (b, .8, .2, .1), (d, .8, .2, .1) }

R = { (c, .4, .9, .9), (d, .7, .2, .1), (b, .4, .2, .1) }

Here N(a) = {b, c, d} , N(b) = {a, c, d}, N(c) = {a, b, d}, N(d) = {a, b, c} hence H is complete SVNHG.

Remark 3.25 In a complete SVNHG H = (X , E) the cardinality of N(x) is same for every vertex .

Theorem 3.26 Every complete SVNHG H = (X , E) is both regular and totally regular if E is constant in H.

Proof : Let H = (X , E) be complete SVNHG, suppose E is constant in H, so

E_i*(x) = c = (*c_1 *,* c_1*,* c_3*)*

For all x ∈ E_i , since SVNHG is complete, then by definition for every vertex x in X , *N(x) = { x : x in X-{x} }* , open neighbourhood degree of every vertex is same. i.e,

deg(x) = n = (n_1 *,*n_2*,* n_3 *)*

for all x ∈ E_i , Hence complete SVNHG is regular SVNHG.

Also

$$deg[x] = deg(x) + E_i(x) = n + c$$

for all x ∈ E_i . Hence H is totally regular SVNHG.

Remark 3.27 Every complete SVNHG is totally regular even if E is not constant.

Definition 3.28 A SVNHG is said to be k-uniform if all the hyperedges have same cardinality.

Example 3.29 Consider a single valued neutrosophic hypergraphs H = (X , E) where, *X = {a, b, c, d}* and

E = { P, Q, R } defined by

P = { (a, .8, .2, .3), (b, .7, .5, .3) }

Q = { (b, .8, .1, .8), (c, .8, .4, .2) }

R = { (c, .8, .1, .4), (d, .8, .9, .5) }

4 Conclusion

Theoretical concepts of graphs and hypergraphs are highely utilized by computer science applications. Single valued neutrosophic hypergraphs are more flexible than fuzzy hypergraphs and intuitionistic fuzzy hypergraphs. The concepts of single valued neutrosophic hypergraphs can be applied in various areas of engineering and computer science. In this paper we defined the regular and totally regular single valued neutrosophic hypergraphs. We plan to extend our research work to regular and totally regular on Bipolar single valued neutrosophic hypergraphs, regular and totally regular on interval valued neutrosophic hypergraphs, regular and totally regular on Bipolar single valued neutrosophic hypergraphs, irregular and totally irregular on single valued neutrosophic hypergraphs, irregular and totally irregular on bipolar single valued neutrosophic hypergraphs, irregular and totally irregular on interval valued neutrosophic hypergraphs.

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