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On Irregular Fuzzy Soft Graphs

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Abstract- **In this paper, irregular fuzzy soft graph , totally irregular fuzzy soft graphs ,neighbourly irregular fuzzy soft graphs, neighborly total irregular fuzzy soft graphs, highly irregular fuzzy soft graphs and highly total irregular fuzzy graphs are introduced. A condition under which neighborly irregular and highly irregular fuzzy graphs are equivalent is provided. Some results on neighbourly irregular fuzzy graphs are established. Some properties of irregular fuzzy soft graphs studied.**

Keywords - **irregular fuzzy soft graph , totally irregular fuzzy soft graphs ,neighborly irregular fuzzy soft graphs, neighbourly total irregular fuzzy soft graphs, highly irregular fuzzy soft graphs and highly total irregular fuzzy graphs**

I. INTRODUCTION

In 1736, Euler first introduced the concept of graph theory. In the history of mathematics, the solution given by Euler of the well-known Konigsberg bridge problem is considered to be the first theorem of graph theory. The graph theory is a very useful tool for solving combinatorial problems in different areas such as operations research, optimization, topology, geometry, number theory, algebra and computer science. Fuzzy set theory, introduced by Zadeh in 1965 is a mathematical tool for handling uncertainties like vagueness, ambiguity and imprecision in linguistic variables [12]. Research on theory of fuzzy sets has been witnessing an exponential growth; both within mathematics and in its application. Fuzzy set theory has emerged as a potential area of interdisciplinary research and fuzzy graph theory is of recent interest.

The first definition of fuzzy graph was introduced by Haufmann in 1973, based on Zadeh's fuzzy relations in 1971. In 1975, Rosenfeld introduced the concept of fuzzy graphs [9]. Nagoor Gani and Latha[26] introduced irregular fuzzy graphs.The fuzzy relations between fuzzy sets were also considered by Rosenfeld and he developed the structure of fuzzy graphs using fuzzy relations, obtaining analogs of several graph theoretical concepts. During the same time Yeh and Bang have also introduced various connectedness concepts in fuzzy graph [11]. Now, fuzzy graphs have been witnessing a tremendous growth and finds application in many branches of engineering and technology.

A. NagoorGani and K. Radha introduced the concept of regular fuzzy graphs in 2008 [5]. In 1999, D.Molodtsov[12] introduced the notion of soft set theory to solve imprecise problems in economics, engineering and environment. He has shown several applications of this theory in solving many practical problems. There are many theories like theory of probability, theory of fuzzy sets, theory of intuitionist fuzzy sets, theory of rough sets, etc. which can be considered as mathematical tools to deal with uncertainties. But all these theories have their own inherent difficulties. The theory of probabilities can deal only with possibilities. The most appropriate theory to deal with uncertainties is the theory of fuzzy sets, developed by Zadeh [9] in 1965. But it has an inherent difficulty to set the membership function in each particular r cases.

Also the theory of intuitionist fuzzy set is more generalized concept than the theory of fuzzy set, but also there have same difficulties. The soft set theory is free from above difficulties. In 2001, P.K.Maji, A.R.Roy,R.Biswas [20, 21] initiated the concept of fuzzy soft sets which is a combination of fuzzy set and soft set. In fact, the notion of fuzzy soft set is more generalized than that of fuzzy set and soft set. Muhammad Akram and Saira Nawaz [25] introduced more concepts on fuzzy soft graphs.

II. PRELIMINARIES

Definition 1: A graph G is called regular if every vertex is adjacent only to vertices having the same degree.

Definition 2.: A graph G is called irregular, if there is a vertex which is adjacent only to vertices with distinct degrees.

Definition 3: A connected graph G is said to be highly irregular if every vertex of G is adjacent only to vertices with distinct degrees.

Definition 4: A connected graph G is said to be neighbourly irregular if no two adjacent vertices of G have the same degree.

Definition 5: A fuzzy graph G is a pair of functions $G:(\sigma,\mu)$ where σ is a fuzzy Subset of a non empty set V and μ is a symmetric fuzzy relation on σ . The underlying crisp graph of $G:(\sigma,\mu)$ is denoted by $G^*(V,E)$ where $E \subseteq V\times V$. A fuzzy graph G is complete if $\mu(uv) = \sigma(u)$

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$\wedge\sigma(v)$ for all u, $v\in V$ where uv denotes the edge between u and v.

Definition 6: A fuzzy graph H : (t, u) is called a partial fuzzy sub graph of G : (s, μ) if $t(u) \le s(u)$ for every u and $u(u, v) \le \mu(u, v)$ for every u and v . In particular we call a partial fuzzy sub graph H : (t, u) a fuzzy sub graph of G : (s, μ) if t (u) = s(u) for every u in t * and u (u, v) = μ(u, v) for every arc (u, v) in u*.

Definition 7: Let U be a nonempty finite set of objects called Universe and let E be a nonempty set called parameters. An ordered pair (F,E) is said to be a Soft set over U, where F is a mapping from E into the set of all subsets of the set U. That is

F: E → P (U). The set of all Soft sets over U is denoted by S (U)

Definition 8: Let (F, A) be a soft set over V. Then (F, A) is said to be a Soft graph of G if the sub graph induced by F(x) in G, F%(x) is a connected sub graph of G for all x belongs to A. The set of all soft graph of G is denoted by SG(G).

Definition 9: Let V be a non empty set of vertices , E be the set of parameters and $A\subseteq E$. Also let

1.$\rho : A \rightarrow F(V)$ (collection of all fuzzy subsets in V)

$e \mapsto \rho(e) = \rho e$.(say) and

$\rho e : V\rightarrow [0,1]$

$xi \mapsto \rho e (xi)$

(A, ρ) is a fuzzy soft vertex.

2.$\mu : A \rightarrow F(V \times V)$ (collection of all fuzzy subsets in E)

$e \mapsto \mu(e) = \mu e$.(say) and

$\mu e : V \times V \rightarrow [0,1]$

$(xi , xj) \mapsto \mu e (xi , xj)$

(A, μ) is a fuzzy soft edge.

Then ((A, ρ),(A,μ)) is called fuzzy soft graph if and only if $\mu e (xi , xj) \le \rho e (xi) \wedge \rho e (xj)$ for all e belongs to A.

Which is also equivalent to the definition that,

A fuzzy soft graph GA,V = (G*, F, K ,A) is a 4- tuple such that,

- G* = (V ,E) is a simple graph
- A is tha set of parameters
- (F,A) is a fuzzy soft set over V
- (F(e), K(e)) is a fuzzy soft set over E
- (F(e),K(e)) is a fuzzy subgraph of G* for all e belongs to A

i.e) $K(e) (xy) \le \min \{ F(e) (x) ,K(e) (y) \}$ for all $e\in A$ $x,y \in V$.

the fuzzy graph (F(e) ,K(e)) is denoted by HA,V (e).

Definition 2.10: Let G = (σ,μ) be a fuzzy graph. Then G is irregular, if there is a vertex which is adjacent to vertices with distinct degrees.

Definition 11: Let G = (σ,μ) be a connected fuzzy graph. G is said to be a neighbourly irregular fuzzy graph if every two adjacent vertices of G have distinct degree.

Definition 12: Let G = (σ,μ) be a fuzzy graph. Then G is totally irregular, if there is a vertex which is adjacent to vertices with distinct total degrees.

Definition 13: If every two adjacent vertices of a fuzzy graph G = (σ,μ) have distinct total degree, then G is said to be a neighbourly total irregular fuzzy graph.

Definition 14: Let G = (σ,μ) be a connected fuzzy graph. G is said to be a highly irregular fuzzy graph if every vertex of G is adjacent to vertices with distinct degrees.

Definition 15: Let G* = (V ,E) be a crisp graph and GA,V be a fuzzy soft graph of G* .Then GA,V is said to be a regular fuzzy soft graph if HA,V(e) is a regular fuzzy graph for all $e \in A$. If HA,V(e)is a regular fuzzy graph of degree r for all $e\in A$; then GA,Vis a r-regular fuzzy soft graph.

Definition 16 : Let G* = (V ,E) be a crisp graph and GA,V be a fuzzy soft graph of G* .Then GA,V is said to be a totally regular fuzzy soft graph if HA,V(e) is a totally regular fuzzy graph for all $e \in A$. If HA,V(e)is a totally regular fuzzy graph of degree r for all $e\in A$. Then GA,V is a r- totally regular fuzzy soft graph.

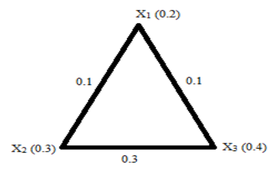
III..IRREGULAR ,NEIGHBOURLY IRREGULAR, HIGHLY IRREGULAR FUZZY SOFT GRAPHS

Definition 1

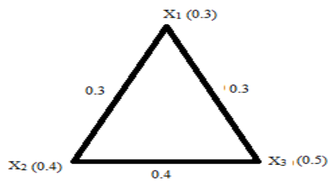
A fuzzy soft graph GA,V = (G*, F, K ,A) is said to be irregular if HA,V (e)= (F(e) ,K(e)) is a irregular fuzzy graph for some e belongs to A .

Example 1

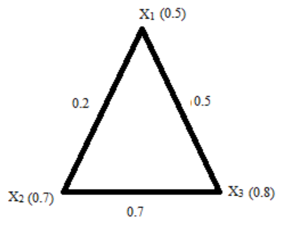
F(e1) = { X1 | 0.2 , X2 | 0.3 , X3 | 0.4 }
F(e2) = { X1 | 0.3 , X2 | 0.4 , X3 | 0.5 }
F(e3) = { X1 | 0.5 , X2 | 0.7 , X3 | 0.8 }
and
K(e1) = { X1 X2 | 0.1 , X1 X3 | 0.1 , X2X3 | 0.3 }
K(e2) = { X1 X2 | 0.3 , X1 X3 | 0.3 , X2X3 | 0.4 }
K(e3) = { X1 X2 | 0.2 , X1 X3 | 0.5 , X2X3 | 0.7}



HA,V (e1)



HA,V (e2)



HA,V (e3)

Which is an example for irregular fuzzy soft graph?

Definition 2 A fuzzy soft graph GA,V = (G*, F, K ,A) is said to be neighbourly irregular fuzzy soft graph if HA,V (e)= (F(e) ,K(e)) is a neighbourly irregular fuzzy graph for some e belongs to A .

Example 2

F(e1) = { X1 | 0.2 , X2 | 0.1 , X3 | 0.4, X4 | 0.2 }
F(e2) = { X1 | 0.3 , X2 | 0.2 , X3 | 0.3, X4 | 0.3 }
F(e3) = { X1 | 0.5 , X2 | 0.3 , X3 | 0.5, X4 | 0.5 }
F(e4) = { X1 | 0.8 , X2 | 0.8 , X3 | 0.8, X4 | 0.8 }

and

K(e1) ={ X1 X2 | 0.1 , X2 X4 | 0.1 , X3X4 | 0.2, X1X3 | 0.2 }
K(e2) = { X1 X2 | 0.2 , X2 X4 | 0.2 , X3X4 | 0.3, X1X3 | 0.3 }
K(e3) = { X1 X2 | 0.3 , X2 X4 | 0.3 , X3X4 | 0.5, X1X3 | 0.5 }
K(e4) = { X1 X2 | 0.3 , X2 X4 | 0.3 , X3X4 | 0.7, X1X3 | 0.7 }

Here no two adjacent vertices has same degree and hence it is an example of neighborly irregular fuzzy soft graph.

Definition 3 A fuzzy soft graph GA,V = (G*, F, K ,A) is said to be highly irregular fuzzy soft graph if HA,V (e)= (F(e) ,K(e)) is a highly irregular fuzzy graph for some e belongs to A .

Example 3

F(e1) = { X1 | 0.2 , X2 | 0.3 , X3 | 0.4 }
F(e2) = { X1 | 0.3 , X2 | 0.4 , X3 | 0.5 }
F(e3) = { X1 | 0.5 , X2 | 0.7 , X3 | 0.8 }

and

K(e1) = { X1 X2 | 0.1 , X1 X3 | 0.2 , X2X3 | 0.3 }
K(e2) = { X1 X2 | 0.3 , X1 X3 | 0.5 , X2X3 | 0.4 }
K(e3) = { X1 X2 | 0.2 , X1 X3 | 0.5 , X2X3 | 0.7 }

Definition 4- A fuzzy soft graph GA,V = (G*, F, K ,A) is said to be totally irregular fuzzy soft graph if HA,V (e)= (F(e) ,K(e)) is a totally irregular fuzzy graph for some e belongs to A .

Consider the example 1.

Definition 5 -A fuzzy soft graph GA,V = (G*, F, K ,A) is said to be neighbourly irregular fuzzy soft graph if HA,V (e)= (F(e) ,K(e)) is a neighbourly total irregular fuzzy graph for some e belongs to A .

Consider the example 2.

Definition 6 - A fuzzy soft graph GA,V = (G*, F, K ,A) is said to be highly irregular fuzzy soft graph if HA,V (e)= (F(e) ,K(e)) is a highly total irregular fuzzy graph for some e belongs to A .

Consider the example 3.

Theorem 1

Let GA,Vbe a fuzzy soft graph. If GA,V is neighbourly irregular fuzzy soft graph and F is a constant function in every HA,V(ei) for all ei belongs to A , then GA,V is a neighbourly total irregular fuzzy soft graph.

Proof:

Let GA,V is neighbourly irregular fuzzy soft graph.

⇒Every HA,V (e)is neighbourly irregular fuzzy graph for some e ∈ A

Let u and v be two adjacent vertices of HA,V (e).

⇒ dHA,V (u)= k1 and dHA,V(v)= k2

⇒ k1 $\neq$ k2

Also,

Assume that F is a constant function in every HA,V(ei) for all ei belongs to A

⇒F(e) (u) = F(e) (v) = c ,a constant ,for all c∈[0, 1]

Now,

tdHA,V (u) = dHA,V (u) + F(u) = k1+c and

tdHA,V (v) = dHA,V (v) + F(v) = k2+c

⇒tdHA,V (u) $\neq$ tdHA,V (v)

⇒ For any two adjacent vertices u and v in HA,V (u) with distinct degrees , its total degrees are also distinct.

⇒ HA,V (e)is a neighbourly total irregular fuzzy graph for some e ∈ A

⇒ GA,V is a neighbourly total irregular fuzzy soft graph.

Theorem 2

Let GA,Vbe a fuzzy soft graph. If GA,V is neighbourly total irregular fuzzy soft graph and F is a constant function in every HA,V(ei) for all ei belongs to A , then GA,V is a neighbourly irregular fuzzy soft graph.

Proof:

Let GA,V is neighbourly total irregular fuzzy soft graph.

⇒Every HA,V (e)is neighbourly total irregular fuzzy graph for some e ∈ A

Let u and v be two adjacent vertices of HA,V (e).

⇒ tdHA,V (u)= k1 and tdHA,V(v)= k2

⇒ k1 $\neq$ k2

Also,

Assume that F is a constant function in every HA,V(ei) for all ei belongs to A

⇒F(e) (u) = F(e) (v) = c , a constant,for all c∈[0, 1]

Now,

tdHA,V (u) = dHA,V (u) + F(u)

⇒k1 = dHA,V (u) + c

⇒dHA,V (u) = k1- c

and

tdHA,V (v) = dHA,V (v) + F(v)

⇒k2 = dHA,V (u) + c

⇒dHA,V (u) = k2- c

⇒dHA,V (u) $\neq$ dHA,V (v)

⇒ For any two adjacent vertices u and v in HA,V (u) with distinct total degrees , its degrees are also distinct.

⇒ HA,V (e)is a neighbourly irregular fuzzy graph for some e ∈ A

⇒ GA,V is a neighbourly irregular fuzzy soft graph.

Theorem 3

Let GA,Vbe a fuzzy soft graph. Then GA,V is both highly irregular and neighbourly irregular fuzzy soft graph iff all the degrees of all vertices of are HA,V (e) distinct for some e ∈ A.

Proof:

Let GA,Vbe a fuzzy soft graph with n vertices u1 , u2 ,……., un. .

Assume that GA,V is both highly irregular fuzzy soft graph and neighborly irregular fuzzy soft graph.
⇒ HA,V (e) is both highly irregular fuzzy graph and neighborly irregular fuzzy graph for some e ∈ A.
Let the adjacent vertices of u1 be u2 , u3……., un with degrees k2 , k3,……., kn. respectively.
Since HA,V (e) is highly irregular,
k2 ≠ k3 ≠ ………≠ kn.
Since HA,V (e) is neighbourly irregular,
dHA,V (u1) ≠ k2 ≠ k3 ≠ ………≠ kn
⇒ Degrees of all the vertices of HA,V (e) are all distinct for some e ∈ A.
Conversely ,
Suppose the degrees of all the vertices of HA,V (e) are all distinct for some e ∈ A. ⇒ Every two adjacent vertices have distinct degree and every vertices adjacent to vertices having distinct degree. ⇒ GA,V is both highly irregular fuzzy soft graph and neighbourly irregular fuzzy soft graph.

IV. SOME PROPERTIES OF IRREGULAR FUZZY SOFT GRAPHS

Proposition 1 A highly irregular fuzzy soft graph need not be a neighbourly irregular fuzzy soft graph.

Example 1

F(e1) = { X1 | 0.1 , X2 | 0.1 , X3 | 0.2, X4 | 0.2 }
F(e2) = { X1 | 0.3 , X2 | 0.2 , X3 | 0.2, X4 | 0.2 }
F(e3) = { X1 | 0.4 , X2 | 0.5 , X3 | 0.4, X4 | 0.5 }
F(e4) = { X1 | 0.2 , X2 | 0.1 , X3 | 0.2, X4 | 0.1 }
and
K(e1) ={ X1 X2 | 0.1 , X2 X4 | 0.1 , X3X4 | 0.2, X1X3 | 0.1 }
K(e2) = { X1 X2 | 0.3 , X2 X4 | 0.2 , X3X4 | 0.2, X1X3 | 0.2 }
K(e3) = { X1 X2 | 0.4 , X2 X4 | 0.4 , X3X4 | 0.4, X1X3 | 0.5 } K(e4) = { X1 X2 | 0.1 , X2 X4 | 0.1 , X3X4 | 0.1, X1X3 | 0.2 }

Here in every HA,V (e) , every vertex is adjacent to the vertices having distinct degrees and hence highly irregular fuzzy soft graph. But the adjacent vertices X1 and X2 has same degree in HA,V (e1) and HA,V (e2) and the adjacent vertices X1 and X3 has same degree in HA,V (e3) and HA,V (e4). and hence it is not neighbourly irregular fuzzy soft graph. Hence it is not neighbourly irregular fuzzy soft graph.

Proposition 2 A neighbourly irregular fuzzy soft graph need not be highly irregular. Consider the Example 2.It is an example of neighbourly irregular fuzzy soft graph. But the vertex X2 is adjacent with the vertices X1 and X4 which has the same degree in HA,V (e) for all e∈ A . Hence it is not highly irregular fuzzy soft graph.

Proposition 3 A neighbourly irregular fuzzy soft graph need not be neighbourly total irregular fuzzy soft graph.

Example 5

F(e1) = { X1 | 0.2 , X2 | 0.3 , X3 | 0.3, X4 | 0.4 }
F(e2) = { X1 | 0.5 , X2 | 0.4 , X3 | 0.4, X4 | 0.3 }
F(e3) = { X1 | 0.5 , X2 | 0.7 , X3 | 0.7, X4 | 0.9 }
F(e4) = { X1 | 0.4 , X2 | 0.3 , X3 | 0.5, X4 | 0.4 }
and
K(e1) ={ X1 X2 | 0.2 , X2 X4 | 0.1 , X3X4 | 0.1, X1X3 | 0.2}
K(e2) = { X1 X2 | 0.2 , X2 X4 | 0.3 , X3X4 | 0.3, X1X3 | 0.2 }
K(e3) = { X1 X2 | 0.5 , X2 X4 | 0.3 , X3X4 | 0.3, X1X3 | 0.5 }
K(ee) = { X1 X2 | 0.3 , X2 X4 | 0.3 , X3X4 | 0.2, X1X3 | 0.2 }

It is an example of neighbourly irregular fuzzy soft graph. But every HA,V (e) is not neighbourly total irregular fuzzy graph and hence it is not neighbourly total irregular fuzzy soft graph.

Proposition 4A neighbourly total irregular fuzzy soft graph need not be a neighbourly irregular fuzzy soft graph.

Example 2

F(e1) = { X1 | 0.2 , X2 | 0.1 , X3 | 0.4, X4 | 0.2 }
F(e2) = { X1 | 0.3 , X2 | 0.2 , X3 | 0.4, X4 | 0.3 }
F(e3) = { X1 | 0.5 , X2 | 0.3 , X3 | 0.7, X4 | 0.7 }
F(e4) = { X1 | 0.9 , X2 | 0.8 , X3 | 0.8, X4 | 0.9 }
and
K(e1) ={ X1 X2 | 0.1 , X2 X4 | 0.1 , X3X4 | 0.1, X1X3 | 0.2}
K(e2) = { X1 X2 | 0.2 , X2 X4 | 0.2 , X3X4 | 0.2, X1X3 | 0.3}
K(e3) = { X1 X2 | 0.3 , X2 X4 | 0.3 , X3X4 | 0.3, X1X3 | 0.5} K(e4) = { X1 X2 | 0.3 , X2 X4 | 0.7 , X3X4 | 0.7, X1X3 | 0.7}

Proposition 5

Let GA,Vbe a fuzzy soft graph. Then GA,V is both neighbourly irregular and neighbourly total irregular fuzzy soft graph then F need not be a constant function.
Consider tha Example 2.
It is both neighbourly irregular and neighbourly total irregular fuzzy soft graphs.
But F is not a constant function.

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